MN Wheat On-Farm Research Network 2021 Report

ON-FARM RESEARCH NETWORK
MINNESOTA WHEAT

MINNESOTA WHEAT
RESEARCH & PROMOTION COUNCIL

DEPARTMENT OF AGRICULTURE

AFREC
Agricultural Fertilizer Research & Education Council

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Seeding Rate

Objective

Determine the optimum seeding rates for various hard red spring wheat varieties currently grown in MN.

Years of Study

2016-2021

Treatments

In 2021, seeding rates were 0.75, 1.25, and 1.75 million live seeds per acre tested on the varieties WB 9590, SY Valda, MN-Torgy, and MN-Washburn.

In 2016-2019, seeding rates were tested at 1.0, 1.5, and 2.0 mil live seeds per acre on various varieties.

Methods

- Trials included three replications of the three seeding rates at eight locations in 2020.
- Varieties used in 2021 were WB 9590, SY Valda, MN-Torgy, and MN-Washburn. Previous years also studied Bolles, Lang-MN, Linkert, and Shelly. A total of 50 locations from 2016-2021 are included in the combined analysis.
- Plots were established and harvested with producer equipment. One plot is typically one to two passes of the planter wide by the full length of the field.
- At harvest, one combine pass from each plot is weighed in a weigh wagon or a grain cart at harvest and the grain is sampled to test moisture content, test weight, and protein content.
- The established stand and the number of spikes per acre were counted during the growing season to calculate in-season stand loss and tillering capacity of each variety.
- All statistical analyses were conducted at the 90% confidence level.

Table 1. Field information for the 2021 seeding rate locations.

	WB9590		MN-Torgy			MN-Washburn		SY Valda	
	RLF	Stephen	Sabin	Fosston	McIntosh	Hallock	Roseau	Beltrami	Hendrum
Planting Date	23-Apr	26-Apr	2-Apr	1-May	28-Apr	24-Apr	5-May	1-May	6-Apr
Harvest Date	2-Aug	2-Aug	30-Jul	9-Aug	10-Aug	8-Aug	18-Aug	3-Aug	4-Aug
N (lbs N/ac)	139	148	180	155	155	160	135	120	115
SOM (%)	5.2	2.9	5.3	--	4.6	4	--	3.9	4.7
Soil type	sandy loam	sandy loam	clay loam	sandy loam	loam	silty clay	clay loam	loam	clay loam
Previous crop	soybean	soybean	sugarbeet	soybean	edibles	sunflower	soybean	soybean	soybean
Total rain*	2.5"	9.8"	9.1"	4.5"	4.2"	6.7"	4.6"	3.5"	6.3"

*Total rain estimated between planting and harvest using Iteris ClearAg Weather data

Table 2. Yield, protein, test weight, and harvest moisture for the 2021 seeding rate locations.

	WB9590		MN-Torgy			MN-Washburn		SY Valda	
Seeding rate	RLF	Stephen	Sabin	Fosston	McIntosh	Hallock	Roseau	Beltrami	Hendrum
(live seeds/ac)					*Yield (bu/acre)*				
0.75 mil	41.8 a	76.7 -	64.8 -	71.9 -	77.8 -	65.8 -	74.1 -	52.9 -	75.0 -
1.25 mil	36.8 b	75.8 -	67.2 -	74.2 -	77.1 -	68.8 -	70.5 -	56.5 -	83.4 -
1.75 mil	36.4 b	78.4 -	70.7 -	76.5 -	76.2 -	70.7 -	76.0 -	54.7 -	76.2 -
LSD 90% CL	1.7	NS	NS	NS	NS	NS	NS	NS	NS
CV (%)	2.6	2.2	6.6	2.7	3.6	3.4	3.9	3.1	5.4

Seeding rate	RLF	Stephen	Sabin	Fosston	McIntosh	Hallock	Roseau	Beltrami	Hendrum
(live seeds/ac)					*Protein (%)*				
0.75 mil	16.9 a	14.9 a	15.5 -	14.4 a	14.5 -	11.9 a	13.1 -	14.6 b	13.3 -
1.25 mil	16.4 b	14.5 b	15.9 -	14.1 b	14.6 -	11.4 b	12.7 -	14.9 a	12.5 -
1.75 mil	16.9 a	14.2 b	15.5 -	14.0 b	14.6 -	11.3 c	12.5 -	14.7 b	12.7 -
LSD 90% CL	0.3	0.3	NS	0.2	NS	0.1	NS	0.1	NS
CV (%)	1.0	1.2	4.1	0.7	1.1	0.4	3.1	0.55	2.69

Seeding rate	RLF	Stephen	Sabin	Fosston	McIntosh	Hallock	Roseau	Beltrami	Hendrum
(live seeds/ac)					*Test weight (lbs/bu)*				
0.75 mil	62.4 -	59.6 b	61.9 b	62.2 -	62.7 -	61.8 -	62.3 -	63.1 -	63.3 b
1.25 mil	62.3 -	60.1 b	62.4 a	62.3 -	62.8 -	62.1 -	62.7 -	63.9 -	63.5 ab
1.75 mil	62.4 -	60.9 a	62.5 a	62.3 -	62.8 -	62.3 -	62.5 -	64.0 -	63.7 a
LSD 90% CL	NS	0.6	0.3	NS	NS	NS	NS	NS	0.3
CV (%)	0.7	0.6	0.2	0.7	0.5	0.4	0.4	0.81	0.26

Seeding rate	RLF	Stephen	Sabin	Fosston	McIntosh	Hallock	Roseau	Beltrami	Hendrum
(live seeds/ac)					*Harvest Moisture (%)*				
0.75 mil	10.1 b	11.2 a	12.5 -	12.6 -	12.1 -	14.7 -	10.9 -	12.6 a	13.0 a
1.25 mil	10.3 a	10.2 b	12.7 -	12.4 -	12.0 -	14.6 -	11.1 -	11.8 b	12.5 b
1.75 mil	10.1 b	10.5 b	12.7 -	12.4 -	11.9 -	14.4 -	10.9 -	11.6 b	12.5 b
LSD 90% CL	0.1	0.4	NS	NS	NS	NS	NS	0.5	0.2
CV (%)	0.8	2.4	1.4	1.7	2.0	1.0	1.0	2.3	0.7

* Lowercase letters (a, b, c) indicate a treatment is significantly different from other treatments with a different letter at the same location at the 90% confidence level.

- 2021 was dry, however most locations still yielded reasonably well – likely due to subsoil moisture
- Red Lake Falls showed the greatest yield as the lowest seeding rate. This site received <2.5" of rain during the season and was on somewhat sandy ground, so the reduced plant-to-plant competition may have led to a higher yield at the 0.75 mil seeds/acre treatment

Table 3. Yield, protein, test weight, and harvest moisture for the 2021 seeding rate locations combined by variety.

	WB9590	MN-Torgy	MN-Washburn	SY Valda
Seeding rate	2 Locations	3 Locations	2 Locations	2 Locations
(live seeds/ac)		---------- *Yield (bu/acre)* ----------		
0.75 mil	59.3 -	71.5 -	69.9 -	63.9 -
1.25 mil	56.3 -	72.8 -	69.7 -	69.9 -
1.75 mil	57.4 -	74.5 -	73.3 -	65.4 -
LSD 90% CL	NS	NS	NS	NS
CV (%)	7.5	4.7	5.7	5.5
(live seeds/ac)		---------- *Protein (%)* ----------		
0.75 mil	15.9 -	14.8 -	62.0 b	14.0 -
1.25 mil	15.5 -	14.9 -	62.4 a	13.7 -
1.75 mil	15.6 -	14.7 -	62.4 a	13.7 -
LSD 90% CL	NS	NS	0.5	NS
CV (%)	2.9	2.6	2.3	4.5
(live seeds/ac)		---------- *Test weight (lbs/bu)* ----------		
0.75 mil	62.3 -	62.3 -	62.0 b	63.2 b
1.25 mil	62.5 -	62.5 -	62.4 a	63.7 a
1.75 mil	62.5 -	62.5 -	62.4 a	63.9 a
LSD 90% CL	NS	NS	0.4	0.6
CV (%)	0.5	0.5	0.4	0.6
(live seeds/ac)		---------- *Harvest Moisture* ----------		
0.75 mil	10.7 -	12.4 -	12.8 -	12.8 a
1.25 mil	10.3 -	12.3 -	12.8 -	12.1 b
1.75 mil	10.3 -	12.3 -	12.6 -	12.0 b
LSD 90% CL	NS	NS	NS	0.5
CV (%)	7.2	2.2	1.6	2.3

* Lowercase letters (a, b, c) indicate a treatment is significantly different from other treatments with a different letter at the same location at the 90% confidence level.

- 2021 was a drought year. Many of the locations still performed reasonably well, except for one site of WB9590 in Red Lake Falls which received <2.5" of rain during the season.
- Yield among the three treatments varied by up to 4 bu/acre, however there were no statistical differences as the 90% confidence level for any of the varieties combined from 2020-21. It is notable that the yield for the 0.75 mil treatment was within 4 bu of the 1.75 mil seeding rate, even under water stress conditions
- In 2021 the drought resulted in very little weed pressure during the season. This very likely benefited the lowest seeding rate this year. The thin stand at the 0.75 mil plants per acre rate is slow to canopy and may see increased weed pressure in years with normal precipitation.

Table 4. Established stand, stand loss, and tillering for the 2021 seeding rate locations combined by variety.

	WB9590		MN-Torgy		MN-Washburn		SY Valda	
Seeding rate	2 Locations		3 Locations		2 Locations		2 Locations	
(live seeds/ac)	---------- *Established Stand (mil per acre)* ----------							
0.75 mil	0.73	c	0.74	c	0.59	c	0.52	c
1.25 mil	1.07	b	1.17	b	1.04	b	0.95	b
1.75 mil	1.66	a	1.64	a	1.35	a	1.24	a
Seeding rate	---------- *Total heads (mil per acre)* ----------							
0.75 mil	2.18	-	2.08	-	1.90	-	2.09	-
1.25 mil	2.18	-	2.11	-	2.05	-	2.27	-
1.75 mil	2.39	-	2.30	-	2.25	-	2.09	-
Seeding rate	---------- *Stems per plant* ----------							
0.75 mil	3.0	a	2.8	a	3.4	-	4.4	-
1.25 mil	2.1	b	1.8	b	2.0	-	2.5	-
1.75 mil	1.5	c	1.4	c	1.7	-	1.8	-
Seeding rate	---------- *Stand loss* ----------							
0.75 mil	3.3%	a	1.7%	a	21.8%	-	30.0%	a
1.25 mil	14.5%	b	6.1%	b	16.7%	-	24.2%	b
1.75 mil	5.5%	a	6.3%	b	23.0%	-	29.3%	a

* Lowercase letters (a, b, c) indicate a treatment is significantly different from other treatments with a different letter at the same location at the 90% confidence level.

- Despite the drought, the lowest seeding rate was still able to tiller enough to all but keep up with the higher seeding rates in the total number of heads per acre
- At several locations, it was observed that the 0.75 mil seeding rate stayed noticeably greener for longer into the season than the other two seeding rates. This could be from reduced plant-plant competition for water at the lower seeding rate.

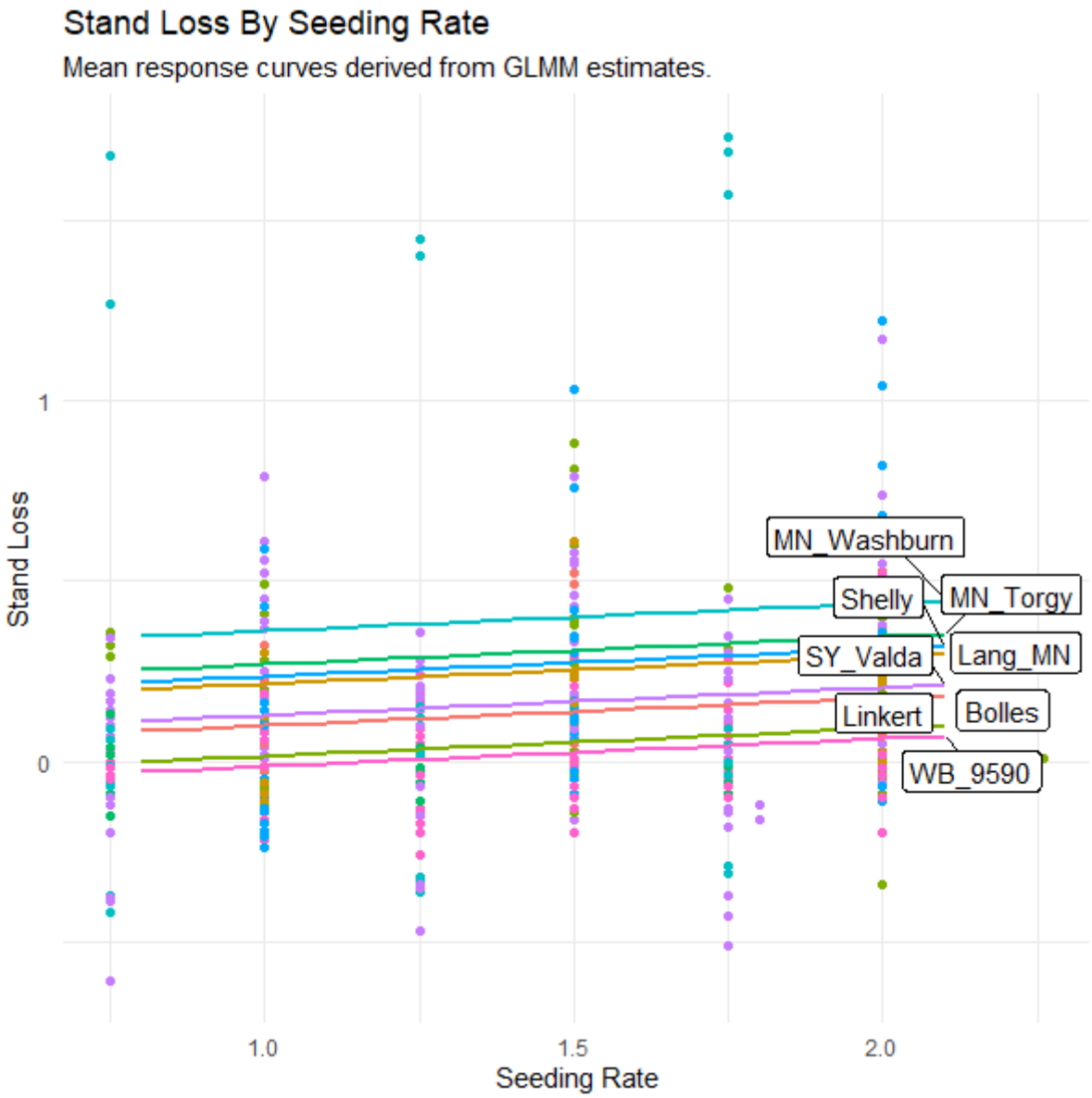


Figure 1. Influence of seeding rate on in-season stand loss using the combined location data from 2016-2021. The number of locations for each variety included in the analysis: Bolles = 4, Linkert = 10, Shelly = 5, Lang-MN = 3, WB9590 = 9, SY Valda = 12, MN-Washburn = 4, MN-Torgy = 3.

- Estimates indicate on average, an increase of 100,000 seeds results in 7,800 fewer plants.

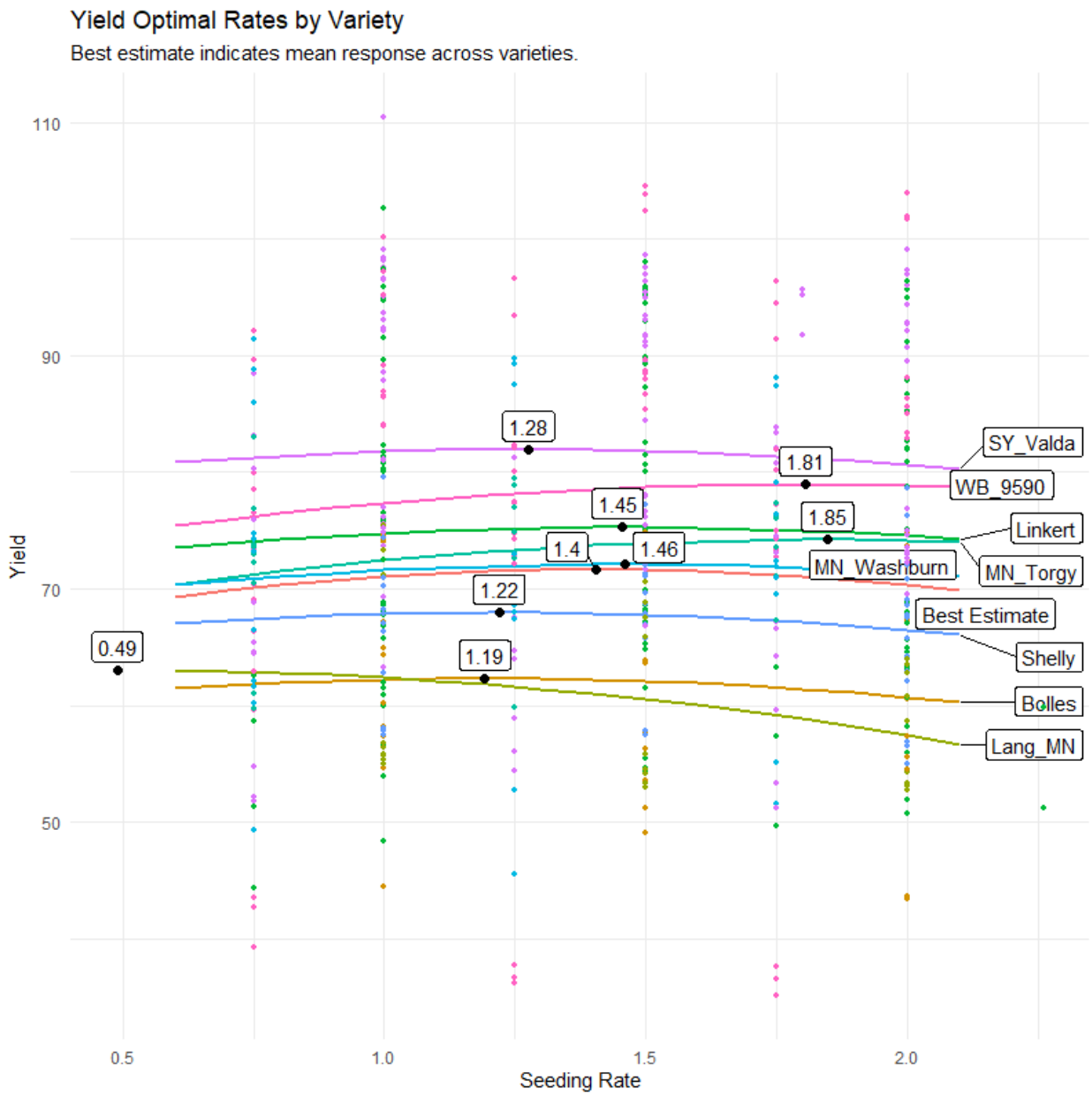


Figure 2. Optimal seeding rate to maximize yield for each variety, using the combined location data from 2016-2021. The number of locations for each variety included in the analysis: Bolles = 4, Linkert = 10, Shelly = 5, Lang-MN = 3, WB9590 = 9, SY Valda = 12, MN-Washburn = 4, MN-Torgy = 3. Results for varieties with many locations of data will be more reliable than varieties that have only a few locations tested.

- The Best Estimate is the mean response across all varieties and indicates the most significant result.

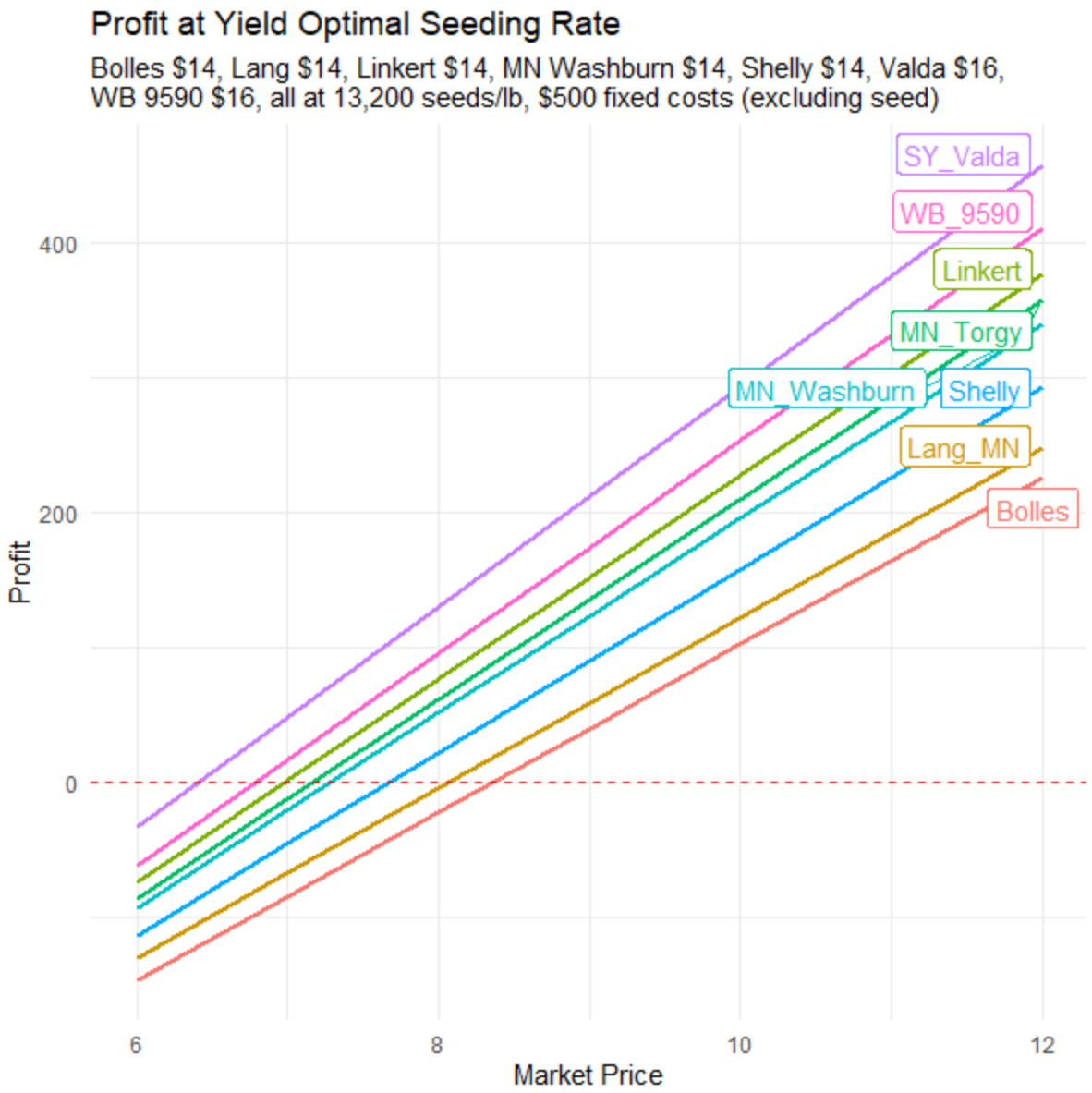
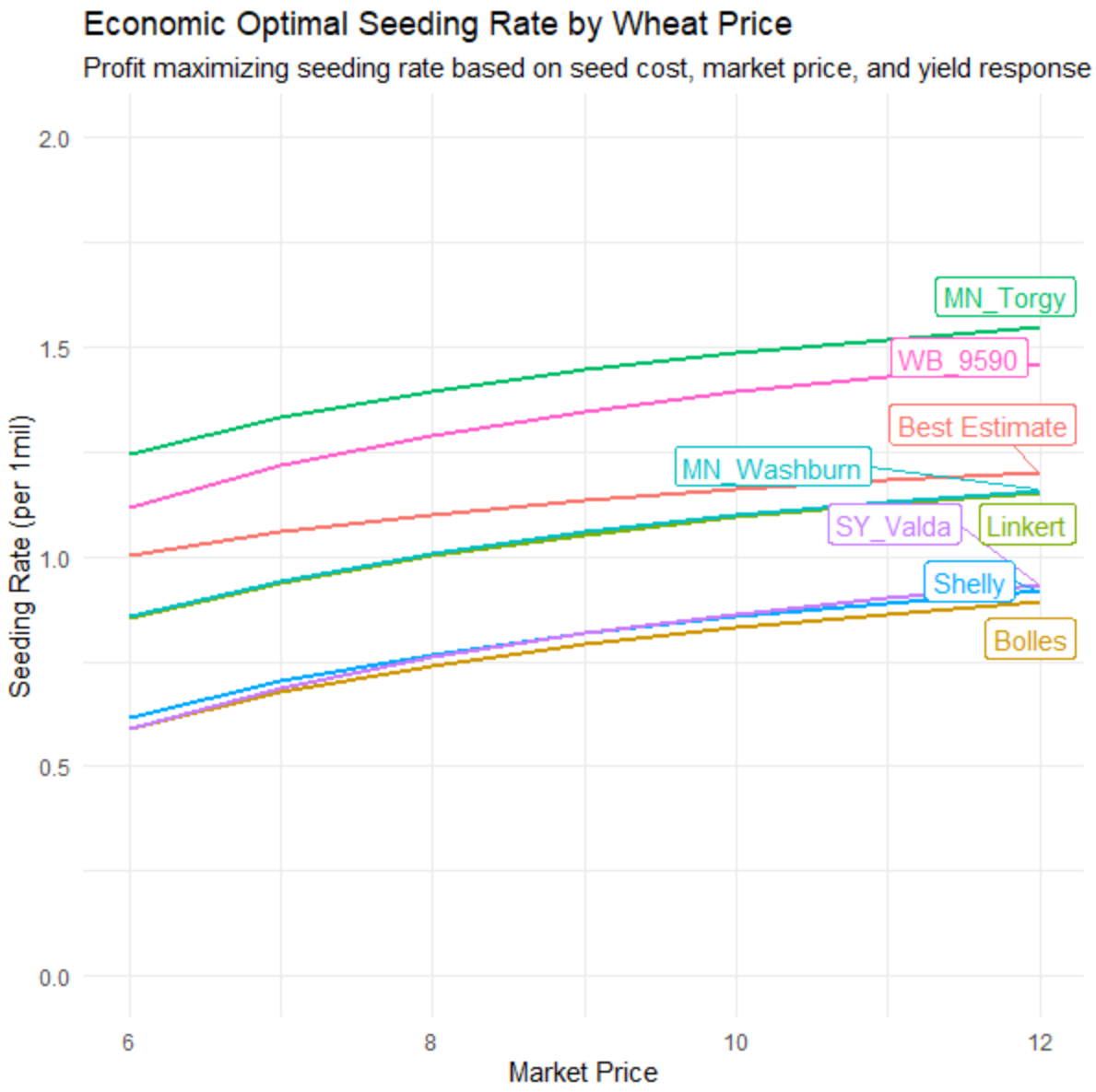


Figure 3. Profit varying by market price for each variety at the individual yield optimal seeding rates from the previous figure. The number of locations for each variety included in the analysis: Bolles = 4, Linkert = 10, Shelly = 5, Lang-MN = 3, WB9590 = 9, SY Valda = 12, MN-Washburn = 4, MN-Torgy = 3. Results for varieties with many locations of data will be more reliable than varieties that have only a few locations tested.

- These results assume a fixed cost for all expenses across all varieties with variability only in seed expense.
- Points of intersection with the dashed red line ($0) indicate break-even points.



- The Best Estimate is the mean response across all varieties and indicates the most significant result.

Flag Leaf Fungicide

Objective

Determine the effect of adding fungicide application at the flag leaf growth stage on yield and protein.

Years of Study

2018-2021

Treatments

See Table 4 below

Methods

- Treated plots included an additional fungicide application at the flag leaf growth stage, in addition to the control applications at the 4-5 leaf and flowering growth stages. Treatment details are outlined below in Table 2.
- Treatments were replicated four times at four locations in 2021. A total of 21 locations from 2018-2021 are summarized in the analyses below.
- Varieties used in 2021 were WB 9479 and SY Valda
- Plots were established and harvested with producer equipment. One plot is typically one to two passes of the application equipment wide by the full length of the field.
- At harvest, one combine pass from each plot is weighed in a weigh wagon or a grain cart at harvest and the grain is sampled to test moisture content, test weight, and protein content.
- All statistical analyses were conducted at the 90% confidence level

Table 5. Treatments for the flag leaf fungicide trial.

Growth Stage	Treatment	Control
4-5 leaf	propiconazole 2 oz/acre	propiconazole 2 oz/acre
Flag leaf	Priaxor 2 oz/acre fluxapyroxad+pyraclostrobin	None
Early flowering	Prosaro 6.5 oz/acre (prothioconazole+tebuconazole)	Prosaro 6.5 oz/acre (prothioconazole+tebuconazole)

Table 6. Field information for the 2021 flag leaf fungicide locations.

	WB479	SY Valda	SY Valda	SY Valda
	Crookston	Hallock	Hendrum	Beltrami
Planting Date	27-Apr	7-Apr	6-Apr	1-May
Harvest Date	30-Jul	2-Aug	4-Aug	3-Aug
First fungicide	8-Jun	7-Jun	115	120
Flag leaf fungicide	12-Jun	14-Jun	4.7	3.9
Scab fungicide	20-Jun	24-Jun	clay loam	loam
Previous crop	soybean	sunflower	soybean	soybean
Total rain*	4.3"	7.1"	6.3"	3.5"

*Total rain estimated between planting and harvest using Iteris ClearAg Weather data

Table 7. Yield, protein, test weight, and harvest moisture for the 2021 flag leaf fungicide locations.

	WB9479	---------- SY Valda ----------			
Treatment	Crookston	Hallock	Hendrum	Beltrami	Combined
		---------- *Yield (bu/acre)* ----------			
Control	59.1 a	66.4 -	72.7 -	59.1 -	66.1 -
Flag-leaf Fung	57.3 b	70.9 -	71.9 -	57.9 -	66.9 -
LSD 90% CL	1.7	NS	NS	NS	NS
CV (%)	1.7	5.8	3.7	3.1	6.9
		---------- *Protein (%)* ----------			
Control	15.1 -	12.3 -	13.2 a	14.7 -	13.4 -
Flag-leaf Fung	15.2 -	12.2 -	12.9 b	14.8 -	13.3 -
LSD 90% CL	NS	NS	0.1	NS	NS
CV (%)	1.7	1.0	0.7	0.5	1.62
		---------- *Test weight (lbs/bu)* ----------			
Control	64.2 -	63.6 -	63.3 -	64.2 -	63.7 -
Flag-leaf Fung	63.8 -	63.6 -	63.4 -	64.3 -	63.8 -
LSD 90% CL	NS	NS	NS	NS	NS
CV (%)	0.8	0.1	0.3	0.4	0.3
		---------- *Harvest Moisture* ----------			
Control	12.3 -	10.5 -	12.6 -	12.0 -	11.7 -
Flag-leaf Fung	12.7 -	11.1 -	12.7 -	11.9 -	11.9 -
LSD 90% CL	NS	NS	NS	NS	NS
CV (%)	3.7	4.1	0.9	1.4	4.0

* Lowercase letters (a, b, c) indicate a treatment is significantly different from other treatments with a different letter at the same location at the 90% confidence level.

- At the Crookston location, the flag leaf fungicide treatment decreased yield by 1.8 bu. It is unsure what might have caused this effect.

Last Year's data

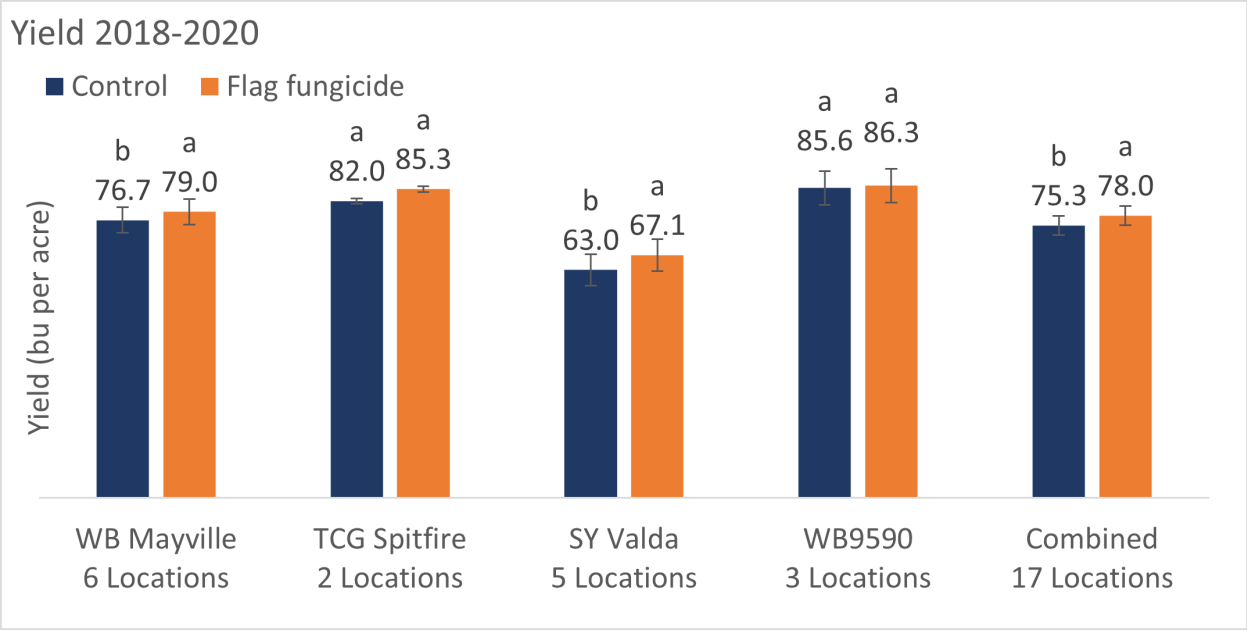


Figure 5. Yield combined across locations from 2018-2020. Differing letters indicate differences among treatments at the 90% confidence level.

- When combining locations by variety, the flag-leaf fungicide application significantly increased yield for WB-Mayville, SY Valda, and when combined across all varieties.

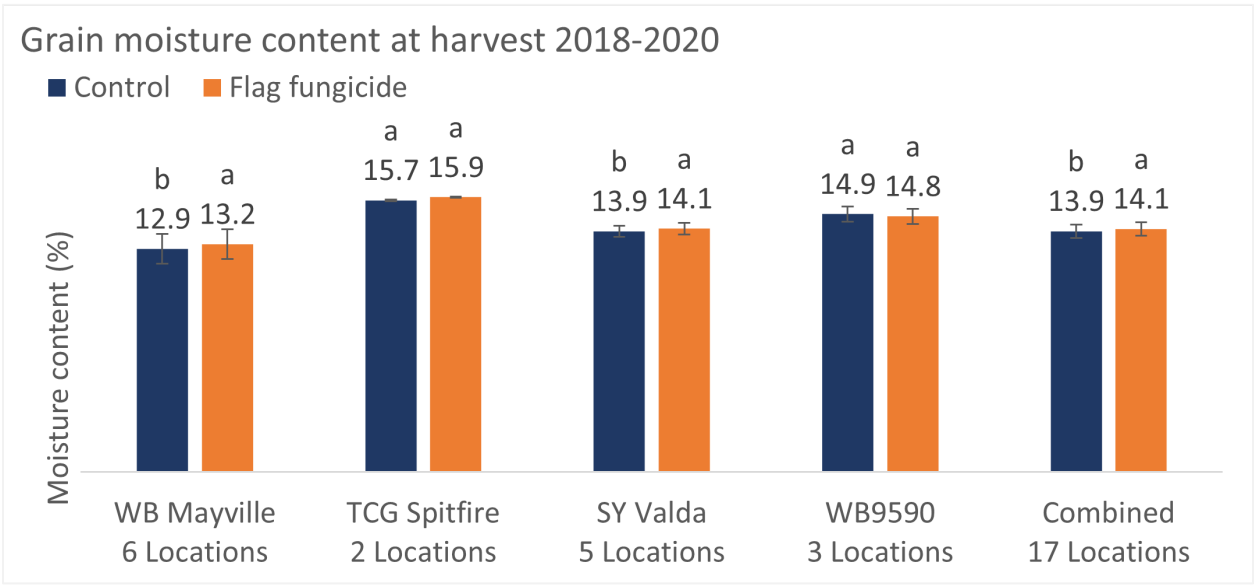


Figure 6. Grain moisture content at harvest combined across locations from 2018-2020. Differing letters indicate differences among treatments at the 90% confidence level.

- Grain moisture at harvest was 0.3-0.4% higher for the flag leaf fungicide treatment compared to the control for WB-Mayville, SY Valda, and when combined across all varieties.

- An increase in grain yield was also associated with a slight increase in grain moisture at harvest.

Table 8. Partial profit analysis of flag leaf fungicide application for individual varieties and combined locations from 2018-2020 (prior years).

Variety	SY Valda	TCG Spitfire	WB9590	WB Mayville	Combined
			---------- *(bu/acre)* ----------		
Control	63	82	87.6	76.7	75.3
Flag Fungicide	67.1	85.3	89.4	79	78
Yield difference	4.1	NS	NS	2.3	2.7
Application Cost[1]	$14.50	$14.50	$14.50	$14.50	$14.50
Net Revenue (ac)[2,3]	$6.00	$ (14.50)	$ (14.50)	$ (3.00)	$ (1.00)

1 Application cost based on $6.50/acre Priaxor + $8.00/acre application cost

2 Revenue based on cash price of $5.00/bu wheat

3 Net Revenue = Yield difference*Cash price – Application cost

Key Take-Aways

- In drought years it is not economically advisable to apply fungicides if there is no disease pressure or forecasted conditions conducive to disease development
- In normal years, when using an application cost of $14.50/acre and a market price of $5.00/bu wheat, only SY Valda appeared to have an average positive return on investment for the flag leaf fungicide application.
- A positive return on investment for individual producers will depend on the magnitude of yield response within a field, the producer's individual cost of application, and the grain market price.

N-Stabilizers

Objective

To determine if yield and protein can be increased by including N-stabilizers with fall and spring applied anhydrous ammonia.

Years of Study

2019-2021

Treatments

Anhydrous ammonia

- Control – Producer rate NH3
- Treatment 2 – Producer rate NH3 + Centuro at 5 gal/ton

Methods

- Treatments were replicated four times at two locations in 2021.
- Plots were established and harvested with producer equipment. One plot is typically one to two passes of the application equipment wide by the full length of the field.
- Soil was sampled at the 0-6" depth using a custom fabricated tool to sample a 6 in deep x 12 in wide slice of soil to sample across the entire width of the anhydrous band.
- Soil samples were sent to AgVise for analysis.
- At harvest, one combine pass from each plot was weighed in a weigh wagon, and grain was sampled from the auger while unloading to test moisture content, test weight, and protein.
- All statistical analyses were conducted at the 90% confidence level.

Table 9. Field information for Argyle and Dorothy sites in 2020-2021.

	Argyle	Dorothy
Fall residual N	45 lbs	50 lbs
SOM%	6%	4.4%
N rate	140 lbs N	130 lbs N
Anhydrous spacing	12"	12"
Date applied	10/13/2020	10/12/2020
Planted	4/1/2021	4/27/2021
Harvested	8/1/2021	7/31/2021
Variety	WB9590	WB9479
Previous crop	Soybean	Soybean
Total rainfall	9.3"	3.5"

*Total rain estimated between planting and harvest dates using Iteris ClearAg Weather data

** Dorothy location was severely affected by drought stress

Table 10. 2021 Soil nitrogen prior to wheat planting, 2, and 4 weeks after planting following fall 2020 anhydrous ammonia application.

	Argyle		Dorothy	
	NO3	NH4	NO3	NH4
	------ Pre-plant N lb/acre -----			
Control	97.5 -	48.5 -	100.8 -	19.3 -
Centuro	81.5 -	54.5 -	100.3 -	11.3 -
LSD 90% CL	32.6	25.9	25.8	15.1
CV%	21.9	30.2	15.4	59.5
	------ 2 WAP N lb/acre -----			
Control	190.0 -	47.3 -	151.0 -	3.8 -
Centuro	172.5 -	62.5 -	146.3 -	5.0 -
LSD 90% CL	44.4	30.9	35.8	1.5
CV%	14.7	33.9	14.5	20.3
	------ 4 WAP N lb/acre -----			
Control	202.5 -	129.3 -	155.0 -	54.0 -
Centuro	180.0 -	114.0 -	142.5 -	37.5 -
LSD 90% CL	45.5	96.0	22.3	36.5
CV%	14.3	47.4	9.0	47.9

* Fall anhydrous was applied on 10-13-20 at Argyle and 10-12-20 at Dorothy

** Lowercase letters (a, b) indicate a treatment is significantly different from other treatments with a different letter at the same location at the 90% confidence level.

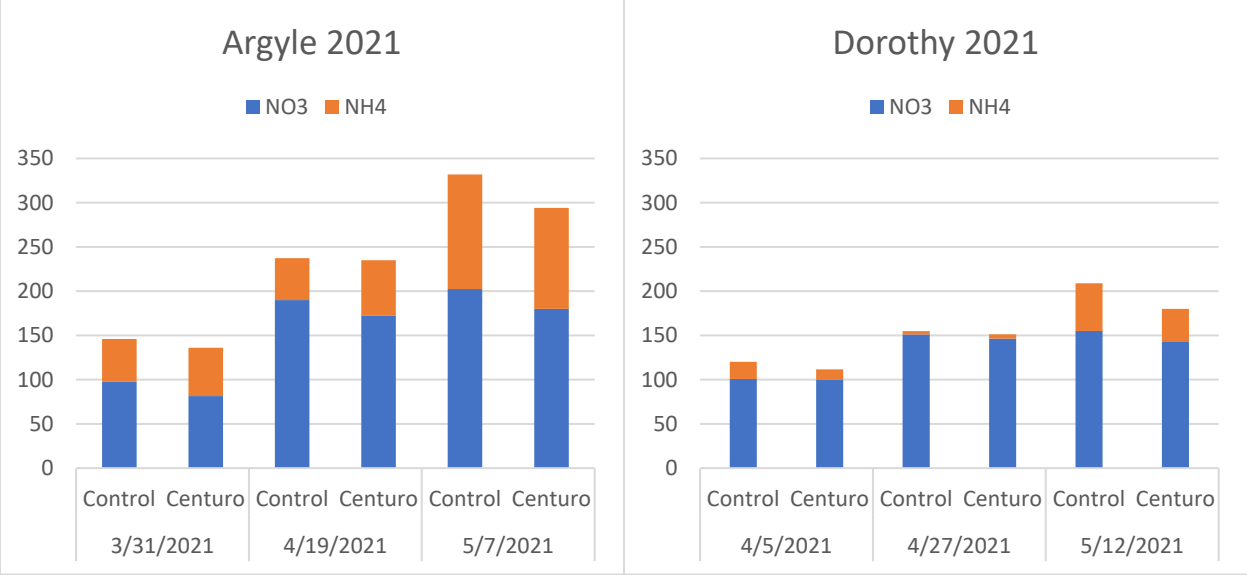


Figure 7. Nitrate-N and ammonium-N at roughly 0, 2, and 4 weeks after wheat planting at Argyle and Dorothy, MN, in 2021.

Table 11. Wheat yield and quality at Argyle and Dorothy, MN, in 2021.

Argyle	Treatment	Yield (bu/ac)	Protein (%)	Moisture (%)	TW (lbs/bu)
	Control	74.0 -	14.3 -	13.0 -	63.2 -
	Treated	72.3 -	14.4 -	12.4 -	63.8 -
	LSD 90% CL	NS	NS	NS	NS
	CV (%)	2.4	0.6	3.1	0.6
Dorothy	Treatment	Yield (bu/ac)	Protein (%)	Moisture (%)	TW (lbs/bu)
	Control	41.7 -	17.7 -	12.0 -	60.3 -
	Treated	40.3 -	17.8 -	12.0 -	60.5 -
	LSD 90% CL	NS	NS	NS	NS
	CV (%)	6.1	1.1	1.2	0.4
	* Dorothy severely affected by drought; results are unreliable				

Key Take-Aways

- Argyle received > 8 in of rain during one large rain event on May 19th after the final soil sampling date, making the total season rainfall for this location closer to 13". Leaching was likely not an issue as much of the water ran off. If any N losses from denitrification did occur, it did not show in the yield data for this experiment.
- The wheat at Dorothy suffered from extreme drought conditions, and any treatment effects have been confounded by severe water stress and dry soil and are not reliable.

Long-term Elevated P and K Fertility

Objective
To compare the effects of elevated P and K fertility over four years of a wheat-soybean rotation.

Years of Study
2019-2021

Treatments
Control - Farmer practice (FP) rate of P and K fertility
Treatment - FP rate of P and K, + 50 units P + 50 units K

Methods
The large on-farm large trials were conducted in conjunction with small-plot research conducted at the U of MN Magnusson Research Farm near Roseau, MN. The small plot treatment rates included 0, 20, 40, 60, 80 and 100 units of P and K and combination of P and K in both wheat and soybeans. The total number of treatments will be 15 plus an untreated for a total of 16 in wheat and soybeans. The results from the small plot P&K trial can be used to help interpret findings in the large-plot on-farm trials as we continue with this project.

- Five large on-farm research experiments, one soybean and four wheat locations, were harvested near Baudette, Elbow Lake, Roseau, and Ross in 2021.
- Fertilizer was applied by the producer's co-op, and plots were harvested by the producer. Individual plots were replicated four to five times and the treatments were one to two passes of the application equipment by the full length of the field.
- At harvest, one combine pass from each plot was weighed in a weigh wagon or a grain cart at harvest and the grain was sampled to test moisture content, test weight, and protein content.

Table 12. Agronomic Information for the Five Large-plot On-Farm Sites in 2021

	Roseau-1	Roseau-2	Roseau-3	Baudette	Elbow Lake
Crop	Wheat	Wheat	Wheat	Wheat	Soybean
Variety	MN-Washburn	Linkert	MN-Washburn	MN-Washburn	LGS0701XF
Planting Date	4/28/2021	4/30/2021	4/27/2021	5/7/2021	5/6/2021
Harvest Date	7/30/2021	7/31/2021	8/9/2021	8/14/2021	9/18/2021
Organic Matter	5.7	3.9	4.4	2.89	4.7
Soil Type	Loam	Sandy Loam	Clay Loam	Clay Loam	Clay Loam
2020 - P ppm	6.5	6	20	17.8	
2020 - K ppm	113	111	379	120.1	
Total rainfall				6.1"	8.1"

*Total rain estimated between planting and harvest using Iteris ClearAg Weather data; Baudette measured with in-field rain gauge after each rain event by cooperator

Large-plot Results

Table 13. Yield, protein, test weight, and harvest moisture for the 2021 large plot wheat locations.

	Roseau-1	Roseau-2	Roseau-3	Baudette	Combined
Treatment			*Yield (bu/acre)*		
Control	41.7 b	48.4 -	64.4 -	78.0 -	57.7 -
Extra 50 u P + K	47.0 a	49.6 -	63.1 -	78.9 -	59.4 -
LSD 90% CL	0.3	6.0	7.0	11.2	3.6
CV (%)	0.3	7.4	4.6	8.6	7.1
			Protein (%)		
Control	14.2 b	--	16.8 -	11.8 -	14 -
Extra 50 u P + K	14.4 a	--	17 -	11.7 -	14 -
LSD 90% CL	0.1	NS	--	NS	--
CV (%)	1.0	6.0	--	0.9	--
			Test Weight (lb/bu)		
Control	63 -	61 -	60 -	62.5 -	61.6 -
Extra 50 u P + K	63 -	61 -	60 -	62.5 -	61.6 -
LSD 90% CL	NS	NS	NS	NS	NS
CV (%)	--	--	--	0.4	--

* Lowercase letters (a, b) indicate a treatment is significantly different from other treatments with a different letter at the same location at the 90% confidence level.

Table 14. Soybean yield and quality at Elbow Lake in 2021.

Treatment	Yield (bu/ac)	Protein (%)	Oil (%)	Moisture (%)	TW (lbs/bu)
Control	46.0 -	35.2 a	18.4 -	10.7 b	56.3 a
Treated	47.7 -	34.5 b	16.1 -	10.9 a	54.4 b
LSD 90% CL	NS	0.4	NS	0.1	1.8
CV (%)	3.3	0.6	20.7	0.4	1.9
Base rate fertility: 130-100-50-10S					

* Lowercase letters (a, b) indicate a treatment is significantly different from other treatments with a different letter at the same location at the 90% confidence level.

Large Plot Results

- At the (0.05%) confidence level, there was a 5.5 bu/ac yield advantage from the Plus 50 compared to the farmer practice at the Roseau-1 location. The soil P at this location was 6.5 (low). In 2021, one of four wheat sites (33%) gave a positive response to additional P&K.
- The combined analysis did not show significant differences between treatments at the (0.10) confidence level.
- This trial will be conducted again in 2022. Several more years of research in various environments at additional locations are needed before any conclusions can be drawn from this elevated P&K fertility trial.

Small plot results

Table 15. Initial 2019 Background Soil Test Values for Small Plots Prior to Fertilizer Treatments

0-6" sample	Site 1	Site 2
	2021 wheat plots	2021 soybean plots
OM %	2.8	2.8
PH - 8.2	8.2	7.8
P (Olsen) ppm	6 ppm	23 ppm
K ppm	154 ppm	166 ppm
S ppm	14 lbs/ac	34 lbs/ac
Soluble salts (mmho/cm)	0.23	0.4

Wheat Small Plot Summary (Table 16)

- Soil test values after harvest (untreated) in 2021 for P = 3.7 ppm and K = 120 ppm
- Yields ranged from 60 to 84.8 bu/ac
- All P rates applied alone or in combination with K gave higher wheat yields (0.05% confidence level) than the untreated
- Wheat yields in bu/ac averaged over all P rates = 78 , all K rates = 61.5 and the combination of P&K = 81.2 bu/ac compared to the untreated of 60 bu/ac
- Wheat yields from all K treatments applied alone gave similar yields at the untreated
- Test weight ranged from 61.1 to 62.3 #/bu with no treatment difference
- Wheat protein ranged from 16.6 to 17.1% with no treatment differences
- P applied alone or in combination with K increased soil test levels of P
- P soil test increased from 5.5 ppm at 0-20-0 to 16.8 ppm at 0-100-0
- Soil test levels for P tended to increase as the rate of increased from 20 to 100
- K soil test levels tended to increase only with the highest applied rates of K
- All rates of P increased the levels of P in wheat tissue vs untreated
- K rates of 60, 80 and 100 increased K tissue test levels vs untreated

Soybean Small Plot Summary (Table 17)

- Soil test values after harvest (untreated) in 2021 for P = 12.5 ppm and K = 110 ppm
- Yields ranged from 46 to 54.1 bu/ac
- Yields generally similar from all treatments compared to the untreated
- Yields in bu/ac averaged over all P rates = 47.2 , all K rates = 50.4 and the combination of P&K = 48.4 bu/ac compared to the untreated of 46 bu/ac
- No treatment difference in test weight, protein and oil vs untreated
- P applied alone or in combination generally increased soil test levels for P
- P soil test levels increased with rate
- K soil test levels tended to or increased with all K rates
- No treatment effect in P tissue test levels vs untreated
- Applied K generally increased K tissue levels in the plants

Table 16. Spring Wheat - Soybean Fertility Rotation Trial U of MN, Magnusson Research Farm Roseau, MN

Wheat-2021					Soil Test Results[4]		Tissue Test Results[5]	
Trt.	Added[1] P & K	Yield[2]	Test		P	K	P	K
		Bu/Acre	Wt./Bu	Protein[3]	ppm	ppm	%	%
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	0.05	0.3
LSD @10%level		5.8	0.5	0.6	3.1	10.0	0.04	0.2
CV(%)		6.7	0.6	3.0	28.0	6.0	9.0	7.0

Experimental Design: RCB with 4 reps

Linkert wheat seeded at 120 lbs/ac on 5/06/21

Plots harvested on 07/31/21

Added[1] P&K - P source 0-46-0, and K source 0-0-60

Yield[2] - Yields correct to 12% moisture

Protein[3] - Dry matter basis

Soil test results[4] - Soil samples taken after harvest on 08/17/21

Background soil test spring of 2019 - OM-2.8%; pH 8.2; P (Olsen) 6 ppm; K 154 ppm

Soil type - Borup silt loam

Tissue samples[5] - Wheat late tillering on 06/14/21

Plot size= 6' x 15' Harvest area= 5' x 12'

160 pounds of nitrogen applied and incorporated prior to planting

Table 17. Soybean - Spring Wheat Fertility Rotation Trial U of MN, Magnusson Research Farm Roseau, MN

Soybean-2021						Soil Test Results[4]		Tissue Test Results[5]	
Trt.	Added[1] P & K	Yield[2]	Test			P	K	P	K
		Bu/Acre	Wt./Bu	Protein[3]	Oil[3]	ppm	ppm	%	%
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

Experimental Design: RCB with 4 reps

Soybean variety - AG005x1 seeded at 1.4 units/ac; 172,000 PLS/ac on 05/13/21

Plots harvested on 09/13/21

Added[1] P&K - P source 0-46-0 and K source 0-0-60

Yield[2] - Yields correct to 13% moisture

Protein and oil[3] - Dry matter basis

Soil test results[4] - Soil samples taken after harvest on 09/14/21

Soil type - Zippel very fine sandy loam

Background soil test taken spring of 2019: OM 2.8%; pH 7.8; P (Olsen) 23 ppm: K 166 ppm

Tissue samples[5] - Soybeans sampled at early flowering on 07/05/21

Plot size= 6' x 15' Harvest area= 5' x 12'

Green-seeding Soybean into Rye Cover Crop

Objective
Determine if planting soybean into a rye cover crop established in the previous fall can reduce the effects of IDC in soybean and observe any differences the cover crop makes.

Years of Study
2019-2021

Treatments
Control – No fall cereal rye cover crop
Treatment – Cereal rye cover crop following wheat harvest, soybeans planted into living rye in the spring

Methods
- Treatment were replicated six times at on location in Roseau, MN in the 2020-21 season.
- Plots were established and harvested with producer equipment. One plot is typically one to two passes of the application equipment wide by the full length of the field.
- Rye biomass and soil nitrate was measured at soybean planting and prior to chemical termination in late June
- Soil moisture and temperature, soybean stand, height, and IDC score, and weed pressure were measured at 0, 2, and 4 weeks after soybean planting
- At harvest, one combine pass from each plot was weighed in a weigh wagon or a grain cart and the grain was sampled to test moisture content and grain quality.
- All statistical analyses were conducted at the 90% confidence level

Table 18. Equipment and field details for the rye cover crop trial at Roseau, MN.

Fall 2020		Spring 2020	
Tillage	1 pass chisel	Tillage	1 pass Salford vertical tillage
Planter	JD 1890 Single Disc	Variety	H008E1
Rye seeding rate	30 lbs/ac	Planting date	5/24/2020
Rye planting date	9/10/2020	Planter	JD 1890 Single Disc
Fertility	11-52-60 blend	Row spacing	7.5 in
SSURGO soil type	fine sandy loam	Rye termination date	6/1/2021
		Termination tank mix	
		Total rain	9.7"

*Total rain estimated between planting and harvest using Iteris ClearAg Weather data

Table 19. Soil NO3-N affected by cover crop at Roseau, MN in 2020-2021.

	10-13-20 Pre-Hard Frost			5-10-21 Pre-Soybean Planting			5-23-21 Rye Termination		
Treatment	0-6 in	6-24 in	0-24 in	0-6 in	6-24 in	0-24 in	0-6 in	6-24 in	0-24 in
	--lbs per ac--			--lbs per ac--			--lbs per ac--		
Control	25.2 -	21.0 -	46.2 -	31.2 a	33.6 -	64.8 a	33.8 a	34.8 a	68.6 a
Rye	28.7 -	19.5 -	48.2 -	23.8 b	27.6 -	51.4 b	11.2 b	18.6 b	29.8 b
LSD 90% CL	NS	NS	NS	5.7	NS	9.4	3.8	5.2	7.5
CV (%)	18.6	11.0	9.1	15.5	15.5	11.9	12.5	14.4	11.3

* Lowercase letters (a, b) indicate a treatment is significantly different from other treatments with a different letter at the same location at the 90% confidence level.

- The rye cover crop treatment had 13.4 lbs less NO3-N in the top 24 in of soil at soybean planting
- By the time the rye was terminated, the cover crop plots had 38.8 less lbs of NO3-N available compared to the no-cover crop control.
- The gradual increase in available N may be partially due to the addition of some N in the fall fertilizer application, and increasing N mineralization in the spring as the soil warmed
- Iron deficiency chlorosis was not an issue in this field during the experiment, although these data suggest that a rye cover crop could be used to take-up soil NO3 when excess NO3 or leaching is a concern
- In N-limiting situations, a rye cover crop can reduce the amount of N available to the main crop
- Total N uptake will depend on time of cover crop termination and density of cover crop stand

Table 20. Soil moisture and temperature at 0, 2, 4, and 6 weeks after planting (WAP) at Roseau, MN, 2021.

Treatment	Pre-plant	2 WAP	4 WAP	6 WAP
	---------- Soil moisture % v/v ----------			
Control	0.27 -	0.76 -	0.24 -	0.24 -
Rye	0.28 -	0.29 -	0.25 -	0.26 -
LSD 90% CL	NS	NS	NS	NS
CV%	11.5	157.9	7.8	5.6
	---------- Soil temperature F ----------			
Control	54 -	49.8 b	72.7 b	67.3 b
Rye	53.6 -	50.4 a	73.2 a	67.8 a
LSD 90% CL	0.2	0.2	0.2	0.2
CV%	1.95	1.7	0.84	0.89

*Soil moisture probe measured surface soil moisture at the 2” depth in the soybean row
**Soil temperature probe measured at the 4” soil depth in the soybean row

- Soil moisture was not different between the cover crop and control plots at any of the timings, however field observations indicated that the soybeans seeded into rye were affected by increased water stress from the rye. Two possible reasons for this could be 1) the soil moisture stress occurred below 2 inches in the cover crop treatments, or 2) the hand-held soil moisture meter or sampling procedure may not have accurately quantified moisture differences.
- Soil temperature varied by less than 1 degree between treatments; statistically significant differences between temperature means would not be considered agronomically significant.

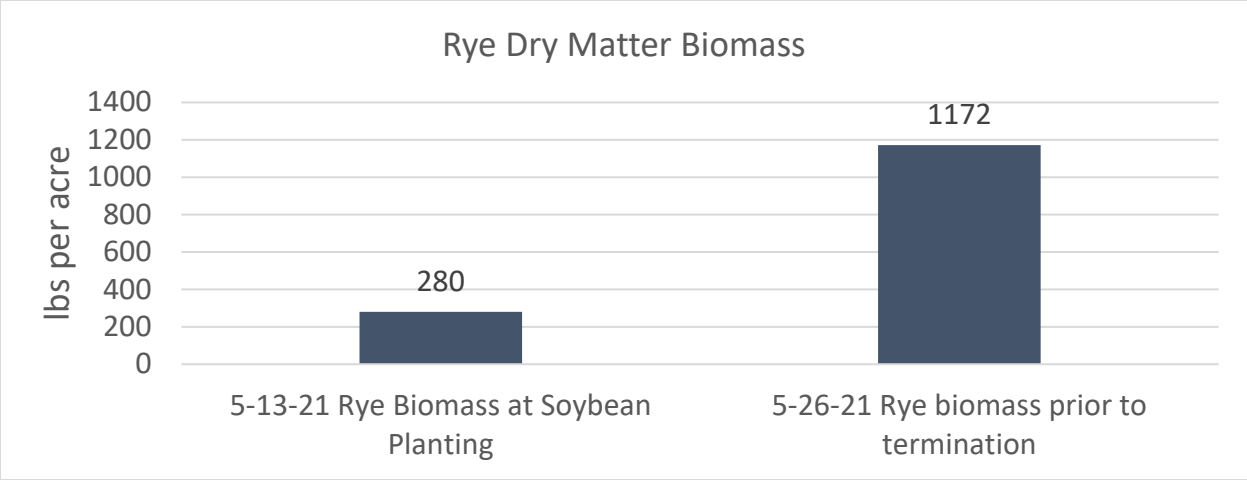


Figure 8. Rye biomass (lbs/acre) at soybean planting and prior to termination in 2021.

- Rye was at the mid-tillering stage when soybeans were planted
- Rye was at the late boot/early heading stage by the time it was terminated on June 1st with the first regular soybean herbicide pas

Table 21. Soybean height and vegetative growth stage at 4, and 6 weeks after planting (WAP) at Roseau, MN, 2021.

Treatment	4 WAP	6 WAP
	-- Height (in) --	
Control	2.4 b	6.0 a
Rye	2.7 a	4.8 b
LSD 90% CL	0.4	0.3
CV%	12.5	4.0
	-- Growth Stage --	
Control	1.2 a	4.4 a
Rye	0.9 b	2.9 b
LSD 90% CL	0.1	0.2
CV%	10.5	4.1

* Vegetative growth stage measured as the number of fully developed trifoliate leaves

Table 22. Weed pressure at 0, 2, and 6 weeks after planting at Roseau, MN, 2021.

Treatment	Pre-plant	2 WAP	6 WAP
	-- weeds per sq. yard --		
Control	6.3 a	1.7 -	1.3 a
Rye	20. b	3.1 -	0.1 b
LSD 90% CL	1.6	NS	1.0
CV%	32	164	131

* Herbicides sprayed at 3 WAP

- Weeds were higher at soybean planting in the rye plot vs the control, however there were fewer weeds in the rye treatment following herbicide application at 3 WAP
- The high CVs (>10%) mean that there is a very high amount of variability in the data, and the results should be viewed cautiously

- The rye cover crop stunted soybean height and delayed early growth, which continued throughout the season. It was suspected that the stunting was caused by increased competition for soil moisture.

Table 23. Soybean yield and quality data from Roseau, MN, 2021.

Treatment	Yield (bu/ac)	Protein (%)	Oil (%)	Moisture (%)	TW (lbs/bu)
Control	37.6 a	32.2 a	19.5 b	11.0 b	58.8 -
Rye	31.6 b	31.7 b	19.9 a	11.5 a	58.6 -
LSD 90% CL	1.5	0.3	0.3	0.4	NS
CV (%)	3.8	0.8	1.2	3.3	0.6

* Lowercase letters (a, b) indicate a treatment is significantly different from other treatments with a different letter at the same location at the 90% confidence level.

- The rye cover crop reduced yield by 6.0 bushels compared to the control
- Based on field observations, the rye likely reduced yield by using up available soil moisture, which stunted the soybean growth and also caused a temporary K deficiency several weeks after planting (See Figure 9).

Figure 9. Potassium deficiency in rye cover crop treatments. Drought conditions early in the growing season were compounded in the cover crop treatments from the competition between the cereal rye and the soybeans for the remaining available soil moisture.

Key Take-aways

- A rye cover crop will use available soil moisture and soil nitrogen in both the spring and fall. The amount of water or nitrogen taken up depends on the density of the rye stand and how soon the rye is terminated in the spring.
- In dry year, the rye competed with the soybeans and reduced yield when left to grow until boot stage.
- Rye should be terminated near the time of soybean planting to avoid a possible yield penalty

ON-FARM RESEARCH NETWORK LEADERSHIP TEAM

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Minnesota Wheat's On-Farm Research Network (OFRN) conducts producer-funded, producer-driven research that investigates producer-selected research topics in a large plot environment.

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