Nitrogen Management: Balancing Production, Profitability, and Water Quality

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Agvise Soil Fertility Seminar

January 7, 8 and 9, 2020

Granite Falls, MN; Watertown, SD & Grand Forks, ND

University of Minnesota
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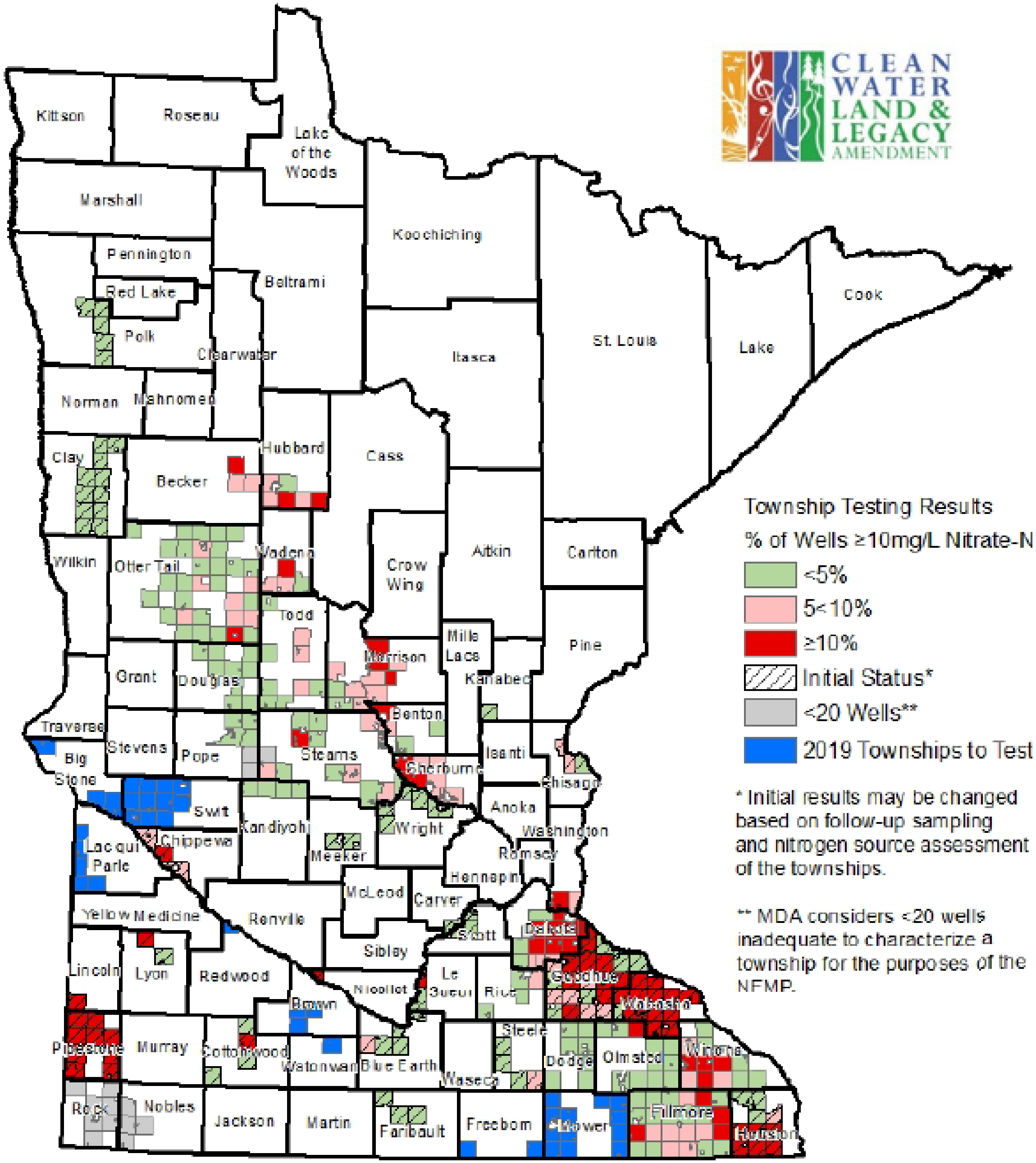
available at: www.mda.state.mn.us/townshiptesting.

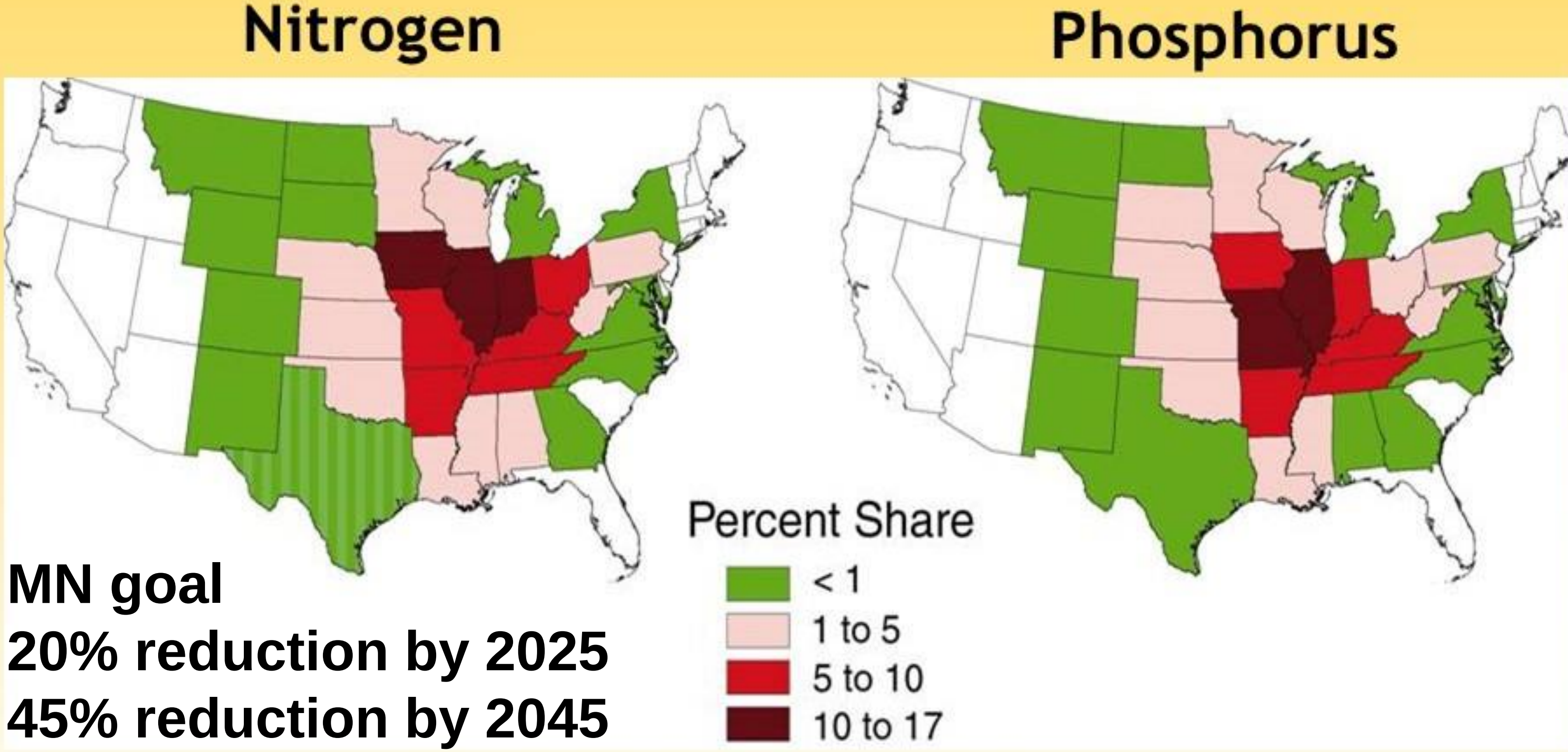
Groundwater protection via well monitoring for nitrate.

Groundwater Protection Rule limits fall N application in sensitive areas.



Combined Final and Initial Testing Results Updated June 2019

Nutrient delivery to the Gulf of Mexico
State shares of the total nutrient flux



MN goal
20% reduction by 2025
45% reduction by 2045

Alexander et al, 2008 *Environ. Sci. Techn.*

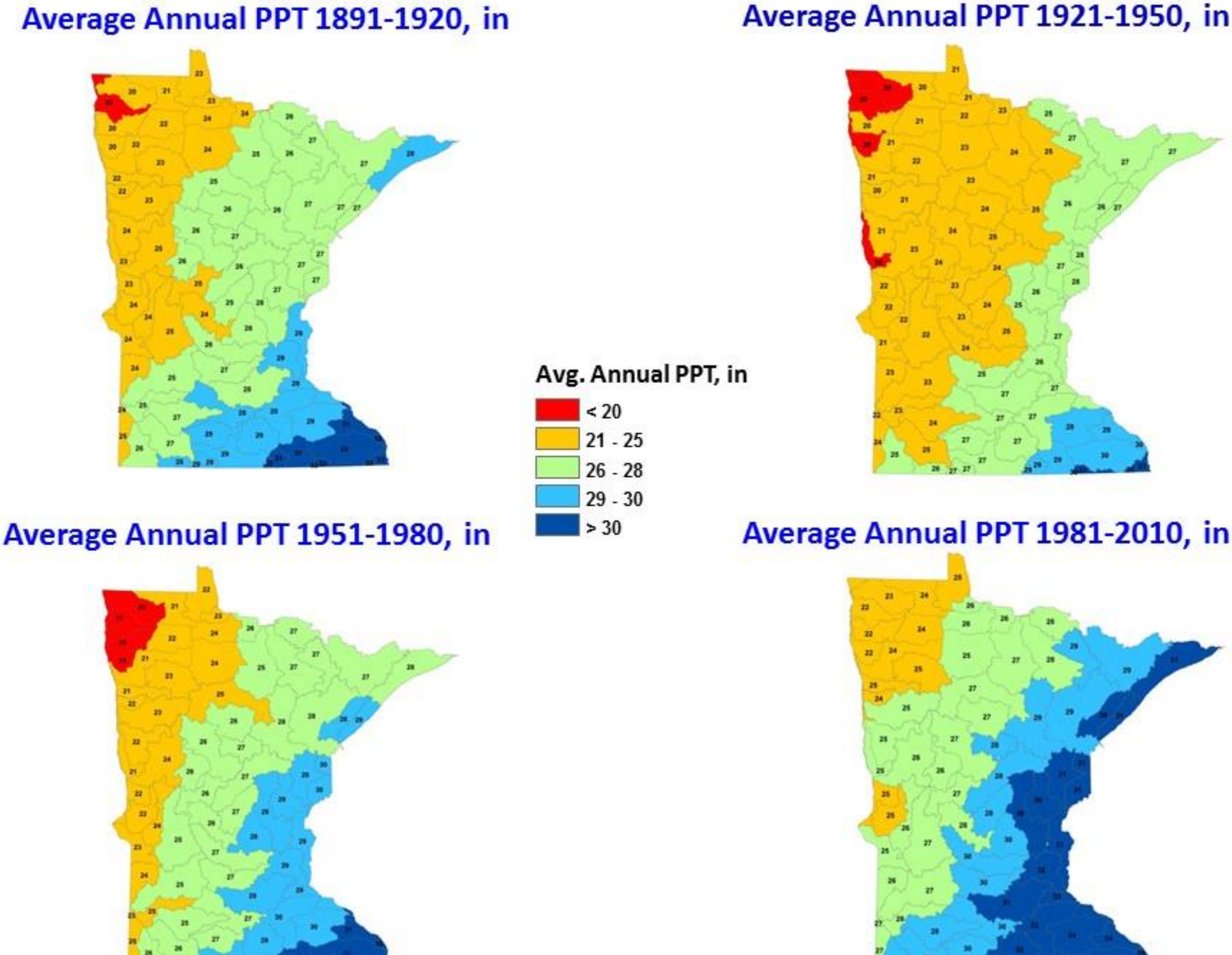
Nutrient Reduction Goals for Lake Winnipeg

Nitrogen goal
13% reduction
from 2003
condition

Phosphorus
10% reduction

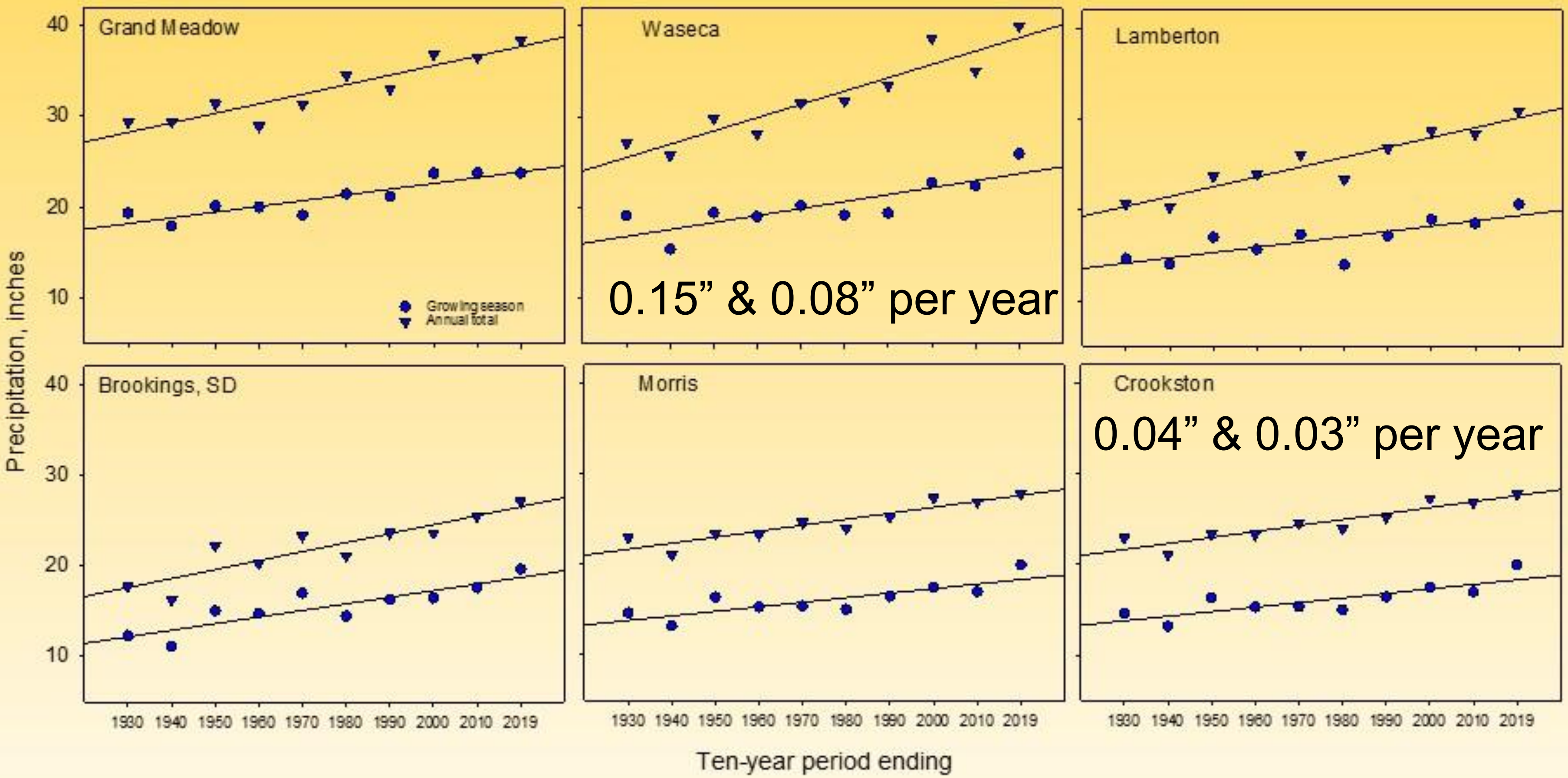
Figure 1. Major drainage basins in Minnesota.

Source: https://www.pca.state.mn.us/sites/default/files/wq-s1-80a.pdf



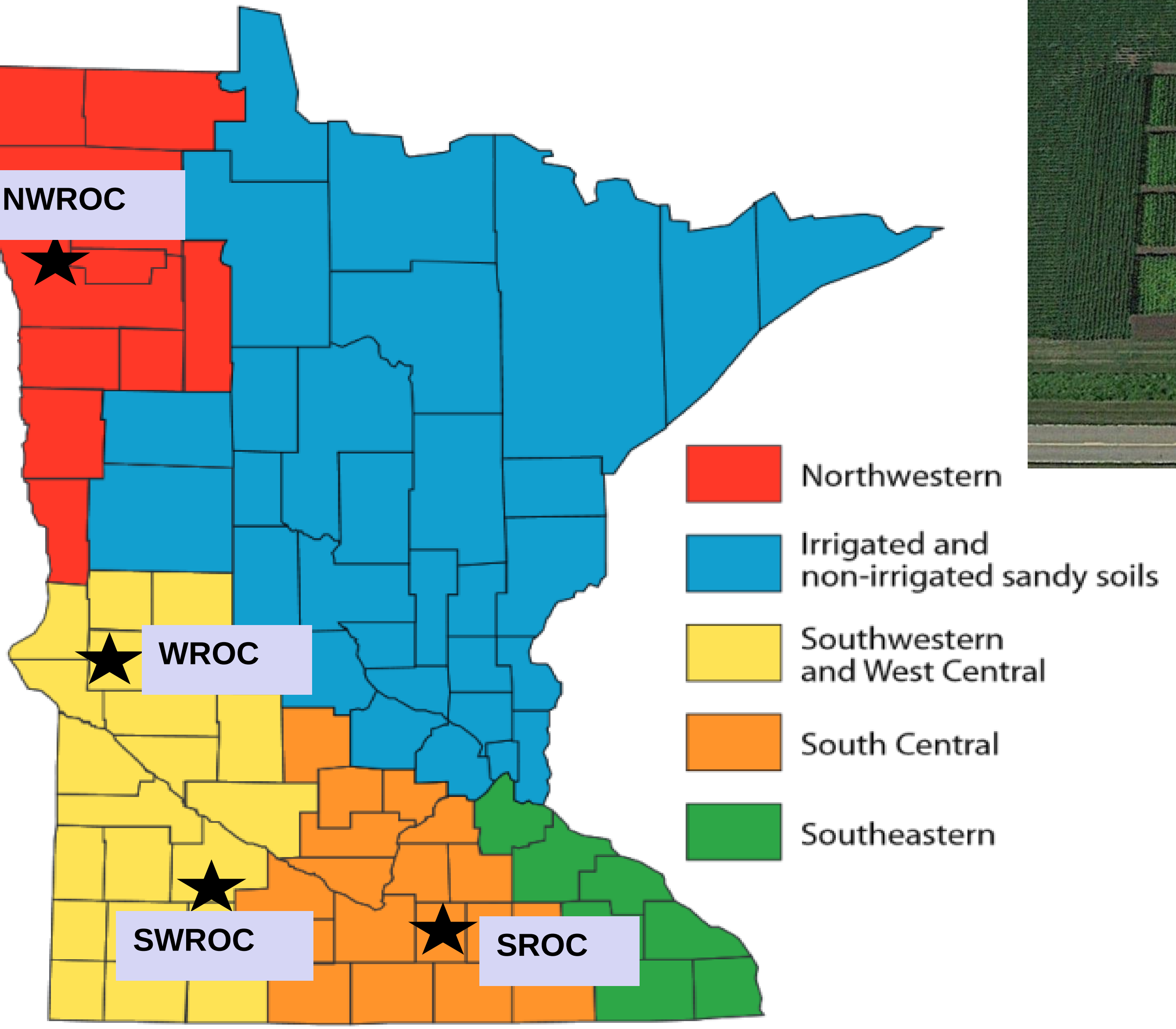
Source: MN-SCO

Trends in Total and Growing Season Precipitation by Decade from 1930 – 2019.



Source: MN climatology working group

Re-evaluate Minnesota Nitrogen BMPs



Management practices that affect N loss and/or crop yield:

1. Cropping system is HUGE
2. Rate of N application
3. N Source & time of application
4. Inhibitors and EEF's
5. Cover crops

Effect of CROPPING SYSTEM on drainage volume, NO_3-N concentration, and N loss in subsurface tile drainage during a 4-yr period (1990-93) in MN.

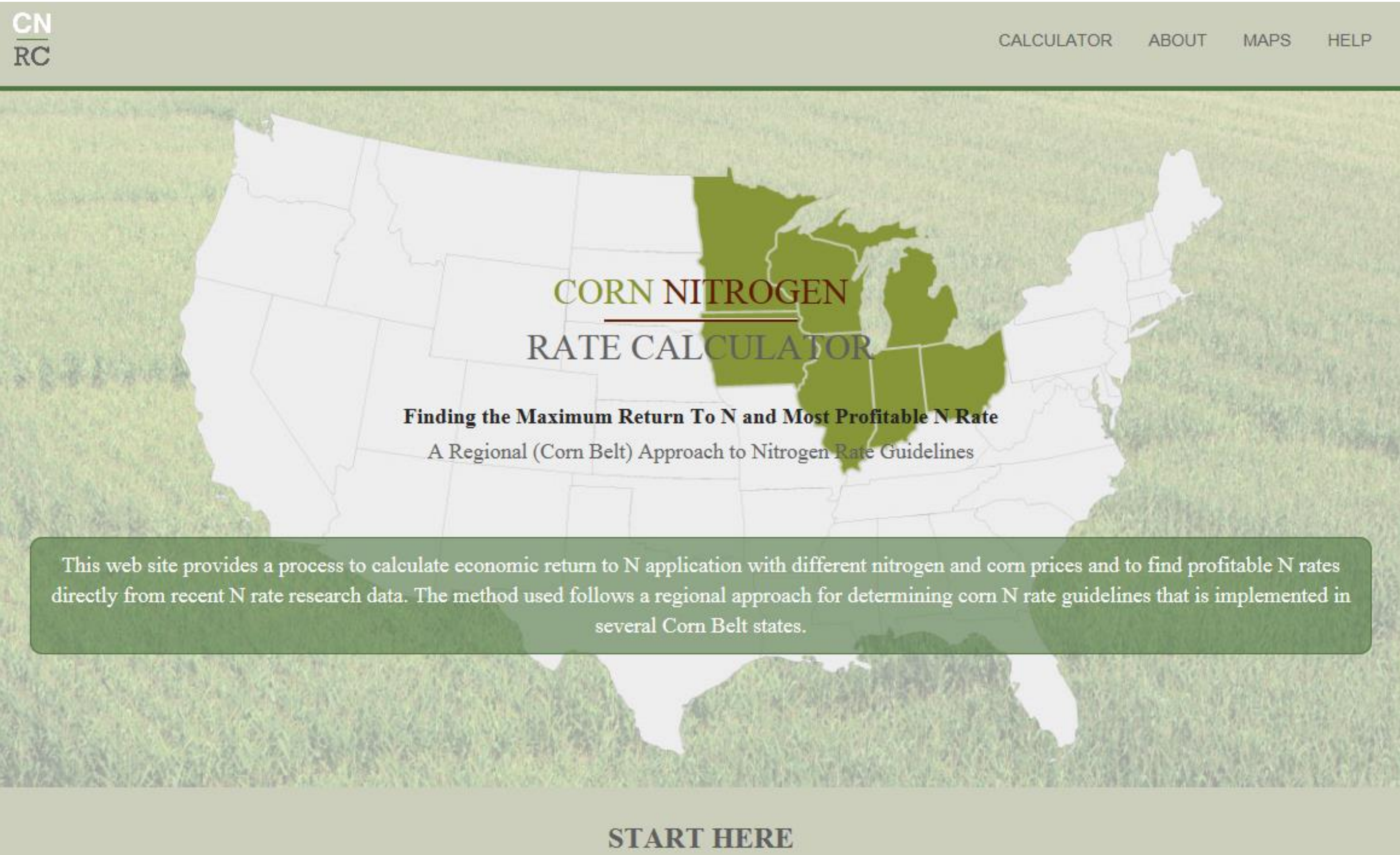
Cropping System	Total discharge	Nitrate-N	
		Conc.	Loss
	Inches	ppm	lb/ac
Continuous corn	30.4	28	194
Corn – soybean	35.5	23	182
Soybean – corn	35.4	22	180
Alfalfa	16.4	1.6	6
CRP	25.2	0.7	4

Randall et al., 1997

Nitrogen Rate

Vetsch, 2020

http://cnrc.agron.iastate.edu/



Rates and Charts

Options

CHART SIZE

- ○ Small
- ◉ Medium
- ○ Large

DISPLAY CHARTS

- ☑ Return to N
- ☐ % of Max Yield
- ☐ EONR Frequency
- ☐ EONR vs. Yield

HELP

Definitions

Calculated Values

RECALCULATE

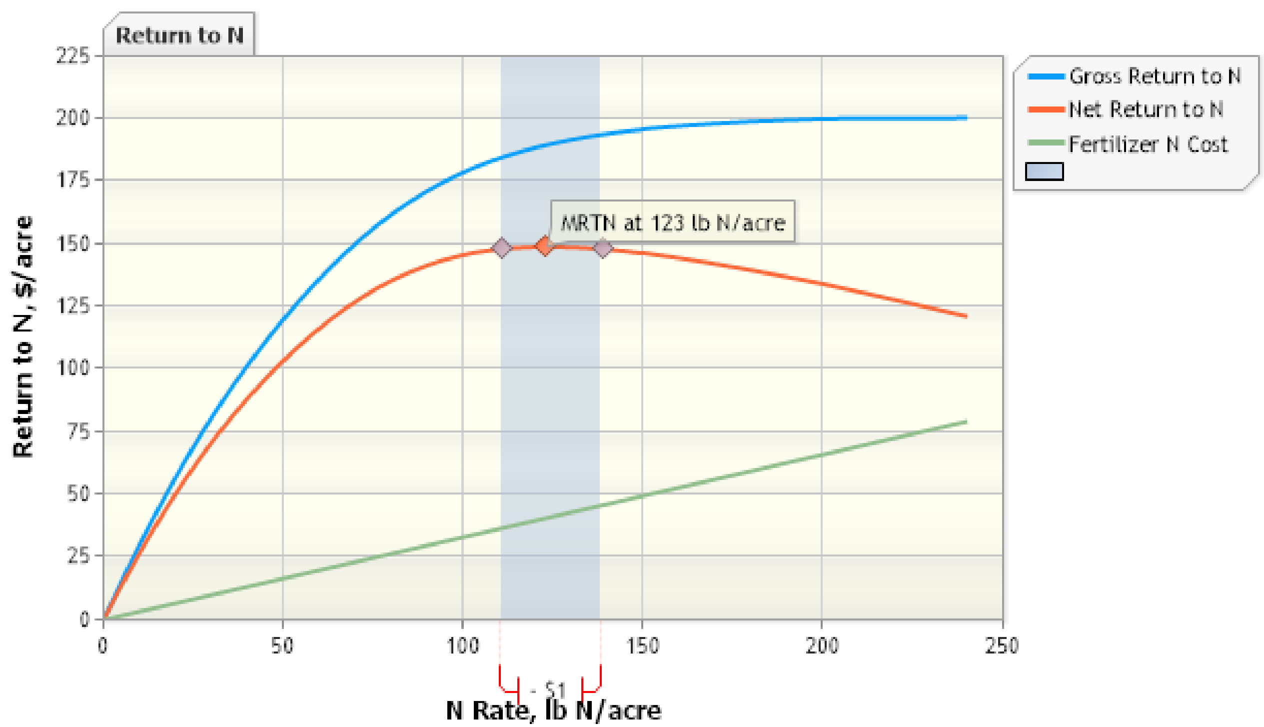
RETURN TO INPUT

State: Minnesota

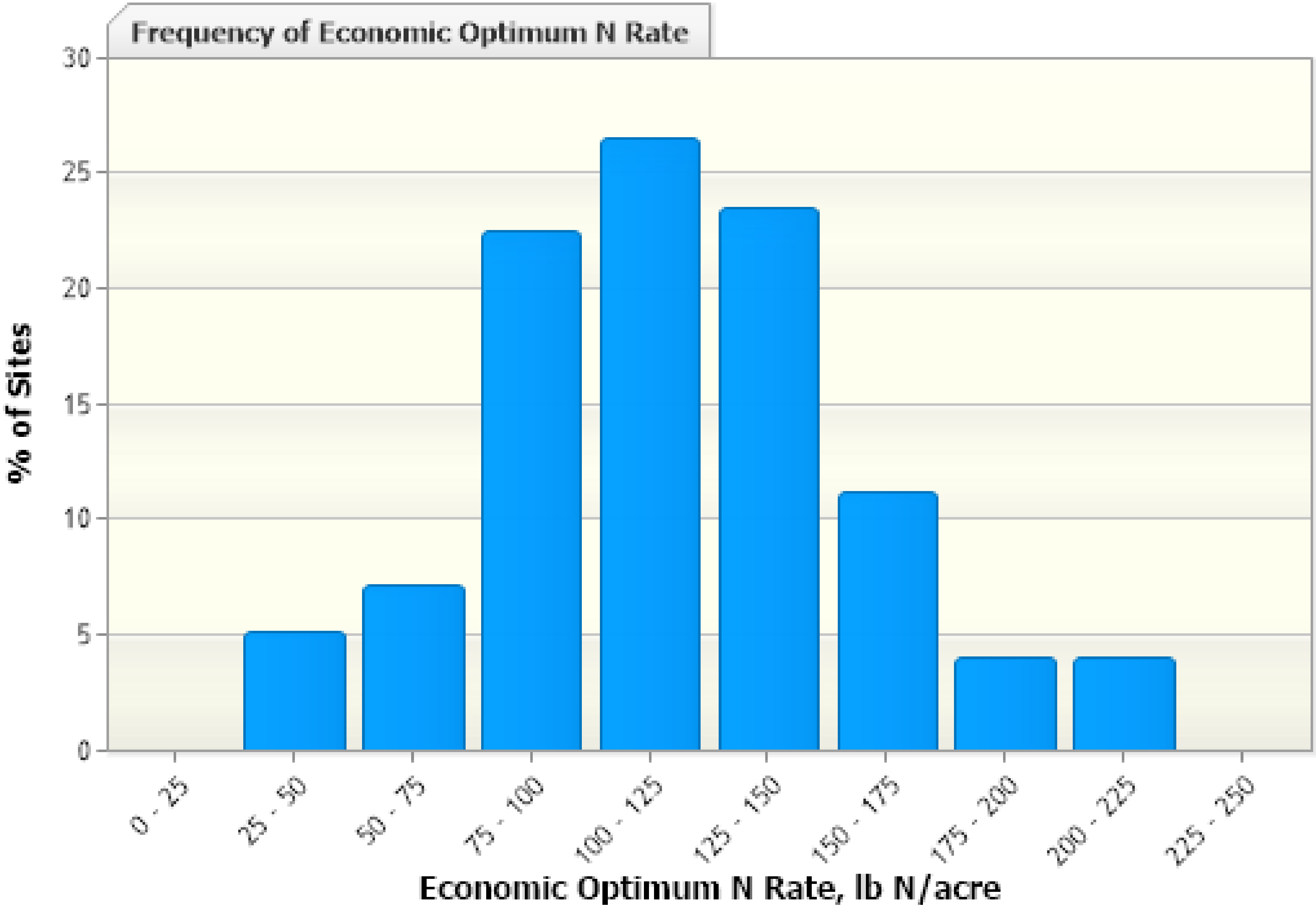
Number of sites: 98

Rotation: Corn Following Soybean

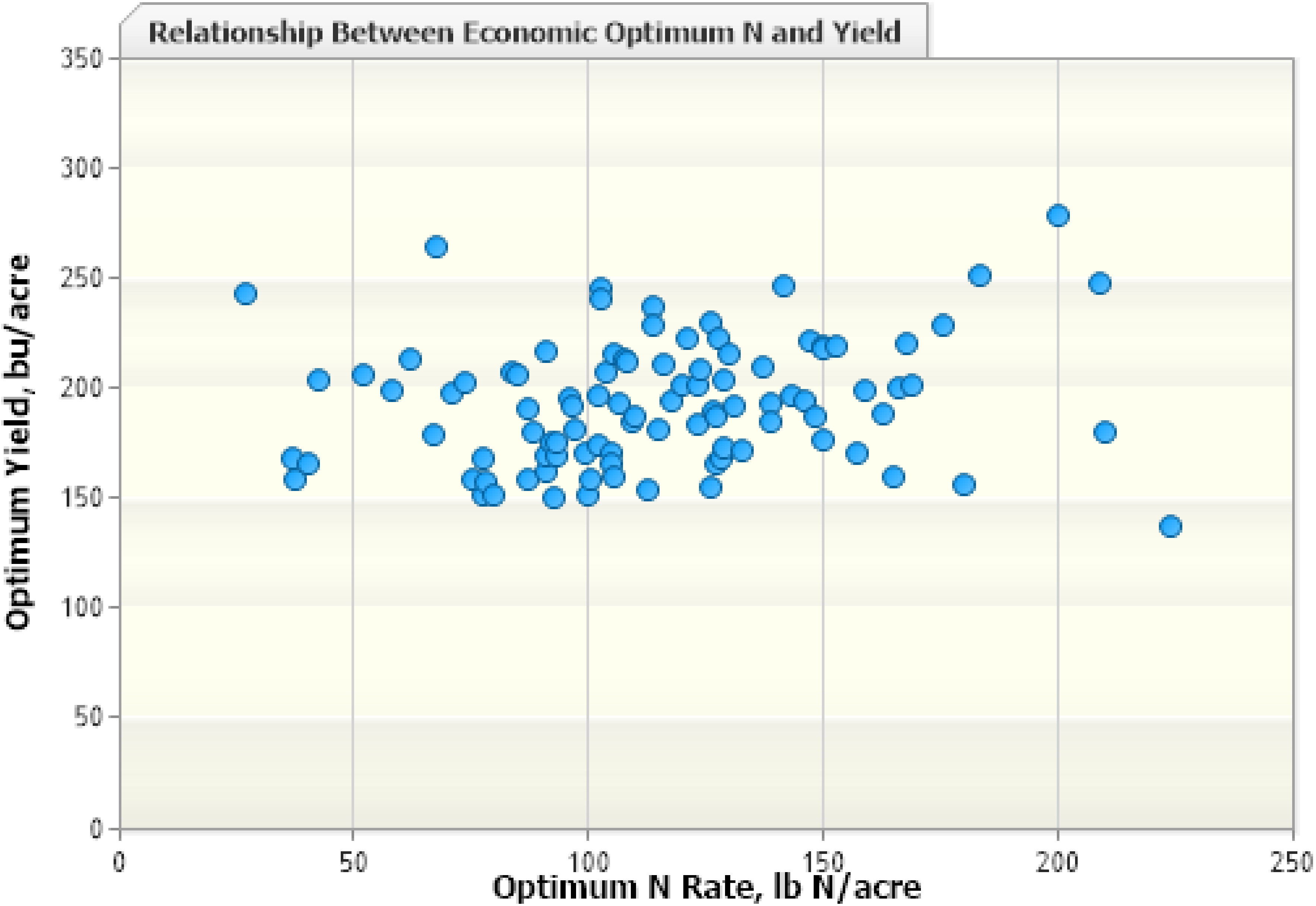
Nitrogen Price ($/lb):	0.33
Corn Price ($/bu):	3.30
Price Ratio:	0.10
MRTN Rate (lb N/acre):	123
Profitable N Rate Range (lb N/acre):	110 - 138
Net Return to N at MRTN Rate ($/acre):	$148.92
Percent of Maximum Yield at MRTN Rate:	98%
Anhydrous Ammonia (82% N) at MRTN Rate (lb product/acre):	150
Anhydrous Ammonia (82% N) Cost at MRTN Rate ($/acre):	$40.59



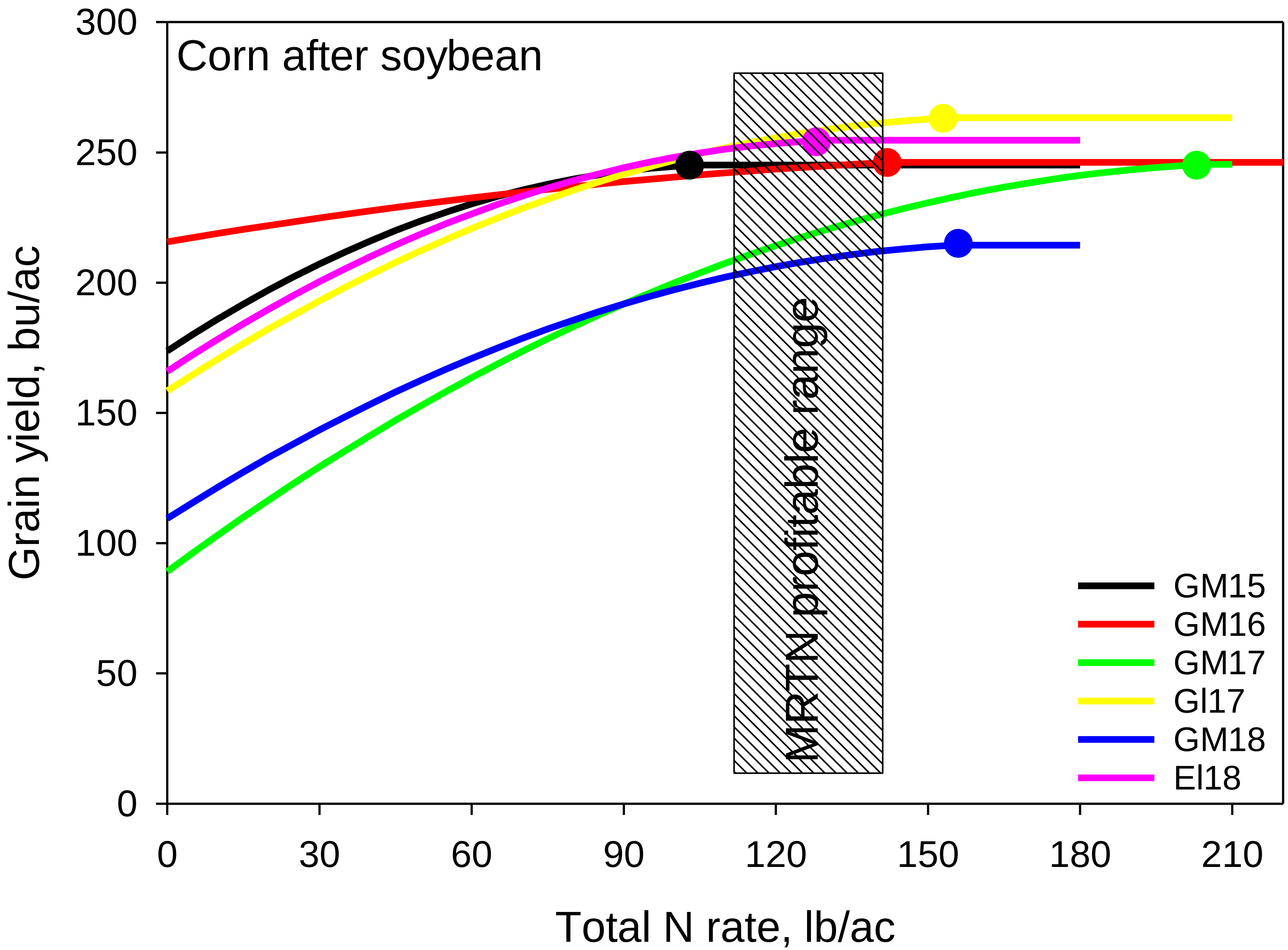
Frequency distribution of economic optimum N rate



Yield vs economic optimum N rate relationship



N rate response of corn in southeast MN.



Vetsch, 2020

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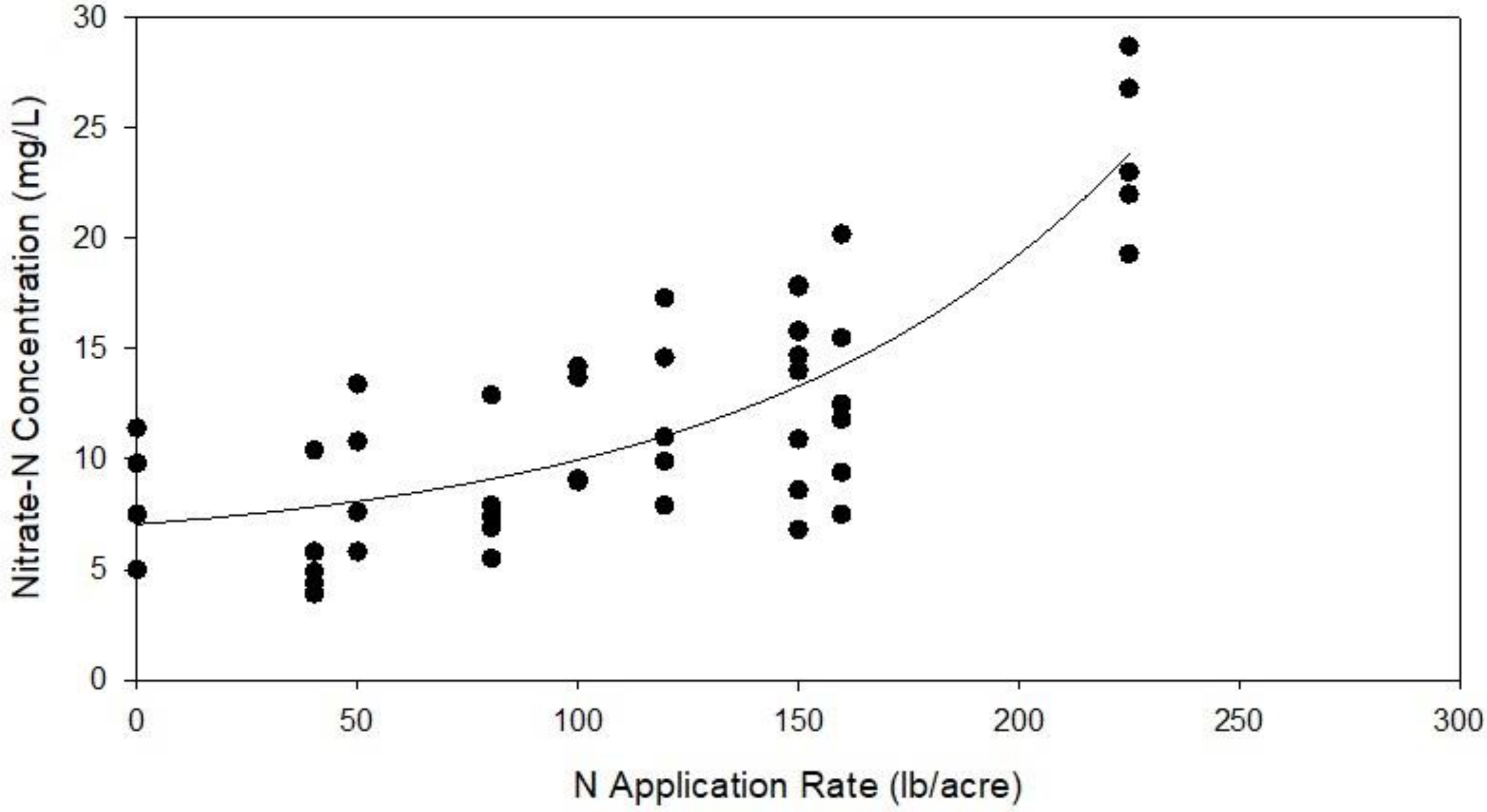
Effect of N rate on corn yield at Waseca, 2000–2003 average (Vetsch et al., 2019).

Anhydrous Ammonia Treatment			Corn
Time	N Rate	N-Serve	Yield
	lb/ac		bu/ac
Fall	80	Yes	143c
Fall	120	Yes	167b
Fall	160	Yes	172ab
Fall	120	No	165b
Spring	120	No	180a
Spring	120	Yes	180a
Control	0	No	110d

Effect of N rate on nitrate-N concentration in tile drainage water at Waseca (Vetsch et al., 2019).

Anhydrous Treatment			Nitrate-N Concentration			
Time	N Rate	N-Serve	2000	2001	2002	2003
	lb/ac		------------- mg L^{-1} -------------			
Fall	80	Yes	18.8c	15.1b	10.3b	10.9c
Fall	120	Yes	22.6b	16.0b	11.2b	12.7ab
Fall	160	Yes	28.9a	22.5a	14.8a	13.7a
Fall	120	No	21.6b	16.6b	16.9a	11.8b

N-Rate versus Nitrate Concentration slide courtesy of M. Helmers



Nitrogen Source and Time of Application

Objectives

- Effect of N sources and Time of application on corn yield

N source	N time	CC lb N ac^{-1}	CSb or CWh lb N ac^{-1}
Anhydrous Ammonia (AA)‡	Fall vs Spring	120	120
Urea (U)†		120	80/120
Urea + Instinct II (U+I)†		120	80
Environmental Smart N (ESN)±		120	80

‡ Injected (Inj)

† Broadcasted and incorporated (BI) or subsurface banded (SSB)

± Broadcasted and incorporated (BI)

Fernández et al. 2019

N Sources

Comparison	Time	Occurrence	Percent %	Yield Diff bu ac^{-1}
ESN > Urea BI	Fall	4/15	27	42
	Spring	5/15	33	34
ESN > AA	Fall	0/6; 2/6*	0; 33	; -39
	Spring	2/6	33	29
AA > Urea BI	Fall	17/24	71	50
(combined across w & w/o inhibitor)	Spring	9/24; 1/24*	38; 4	47; -29
AA > Urea SSB	Fall	6/16	38	58
(combined across w & w/o inhibitor)	Spring	5/16; 2/16*	31; 13	33; -49

*Reverse response. All other comparisons were non-significant

Fernández et al. 2019

Effect of time of AA application and N-Serve on corn yields after soybean from 1987-2001 at Waseca.

	Time of N Application		
Parameter	Fall	Fall+N-Serve	Spring
15-Yr Avg. Yield (bu/A)	144	153	156
15-Yr Avg. FW NO_3-N Conc. (mg/L)	14.1	12.2	12.0
15-Yr N recovery in grain (%)	38	46	47
*7-Yr Avg. Yield (bu/A)**	*131*	*146*	*158*

* Seven years when statistically significant differences occurred.

Adapted from
Randall et al., 2003
Randall and Vetsch, 2005

1987–2001 Summary

- At Waseca, adding a nitrification inhibitor (N-Serve) to fall-applied anhydrous increased corn yield and NUE, while reducing nitrate concentration in tile drainage.
  - **Benefit of inhibitor less likely under drier moisture regimes and high pH soils (western MN, N & S Dakota).**
- **Spring application of anhydrous averaged 12 bu/ac greater yield than fall in 7 of 15 years (wet springs).**

Effect of time of N application and N-Serve on corn yields at Waseca.

Timing / N Source	N-Serve w/AA	2016	2017
		-------- bu/ac --------	
Fall AA	No	198c	201d
Fall AA	YES	198c	200d
Spring AA	No	224ab	218bc
Spring AA	YES	231ab	222bc
Split Fall AA+V6 Urea	YES	222b	212c
Split Spr. AA+V6 Urea	No	224ab	218bc

Split was 70% as AA and 30% as V6 urea.

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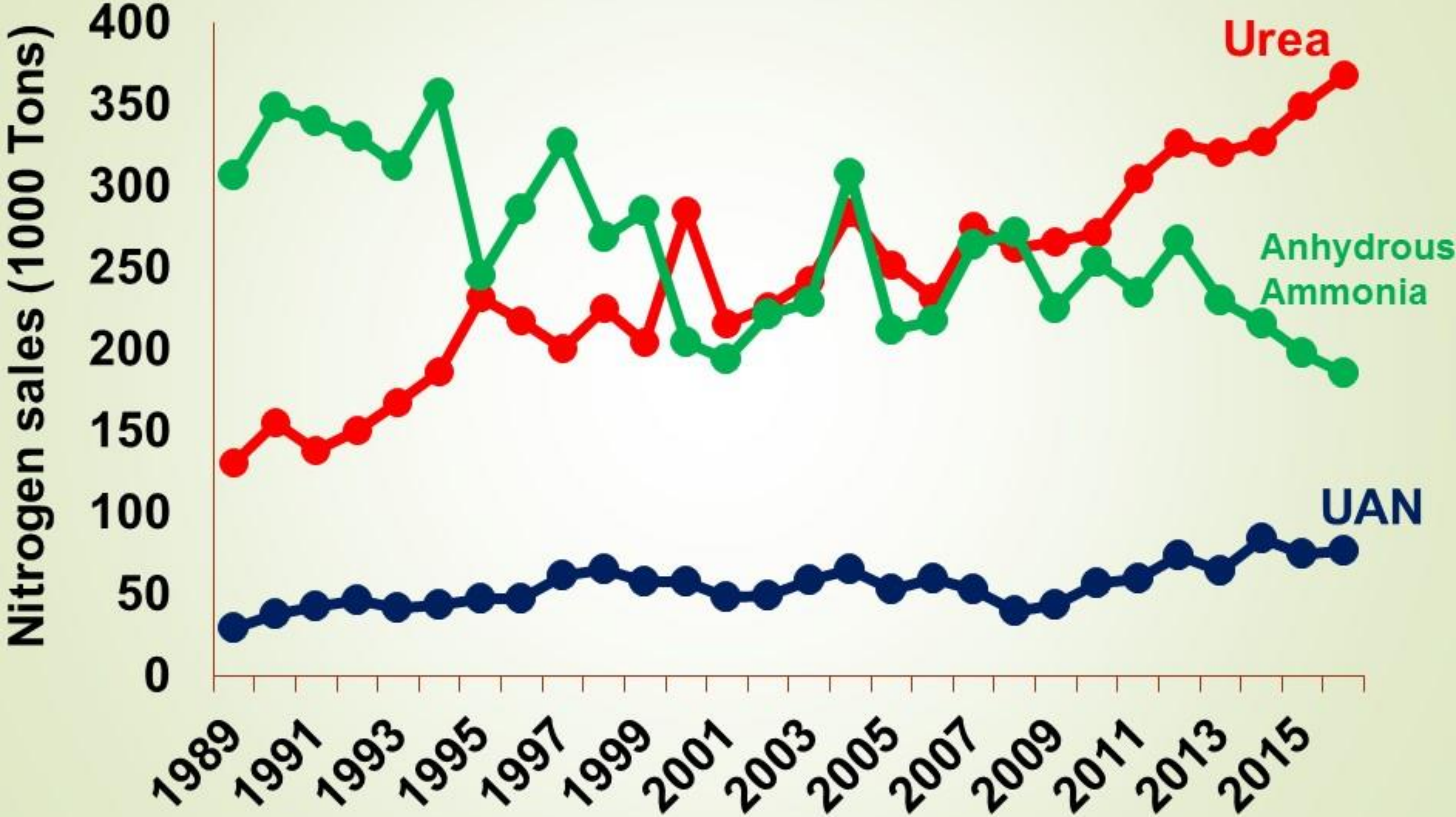
Minnesota Nitrogen Sales



Source: Minnesota Department of Agriculture, 2019

Objectives

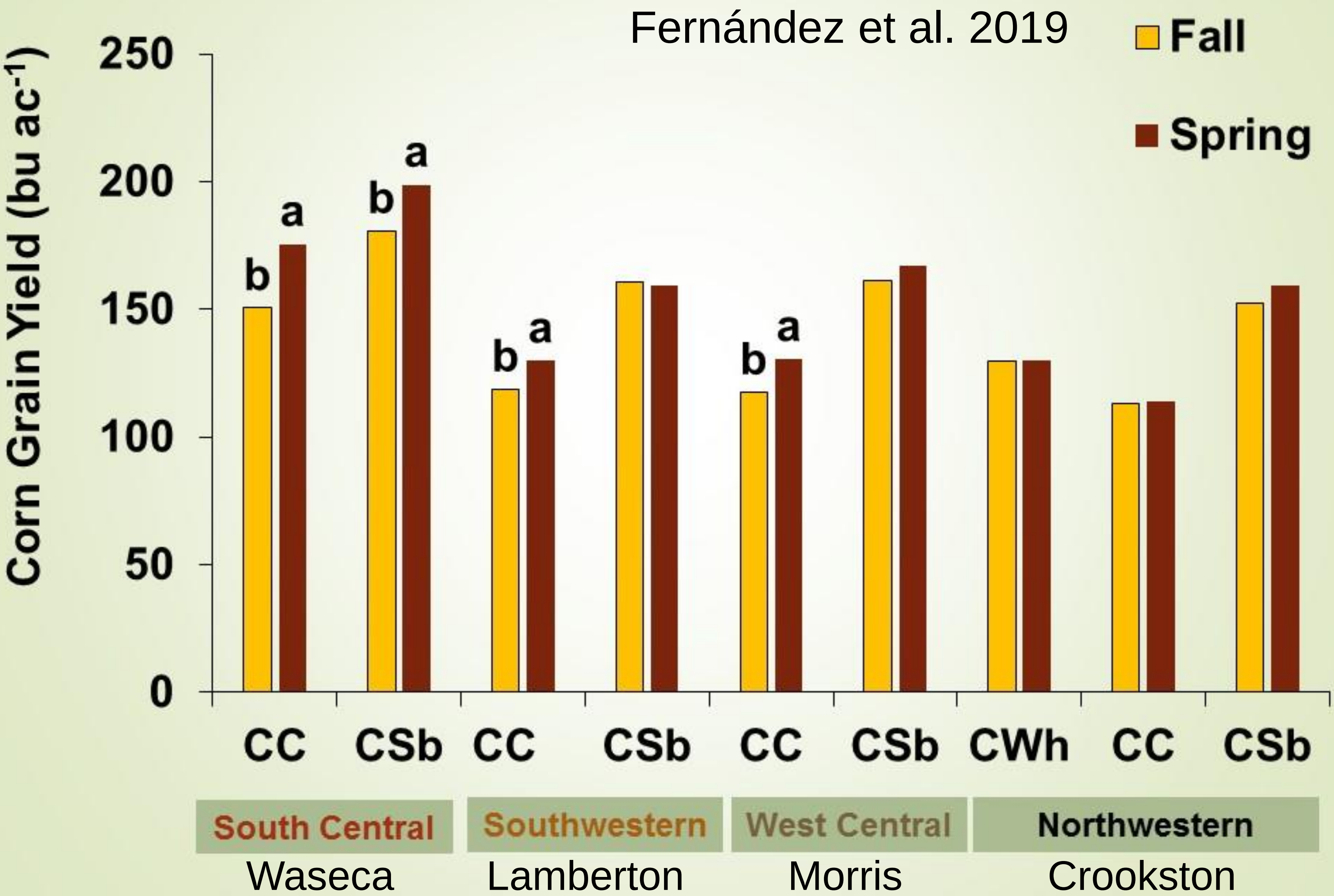
- Effect of N rate and Time of application on corn yield

N source	N time	CC lb N ac^{-1}	CSb-CWh lb N ac^{-1}
Control		0	0
Urea/BI‡	Fall vs Spring	40	40
		80	80
		120	120
		160	160
		200	200
		240	-

‡ Broadcasted and incorporated (BI)

Fernández et al. 2019

Urea - Fall vs Spring Applications



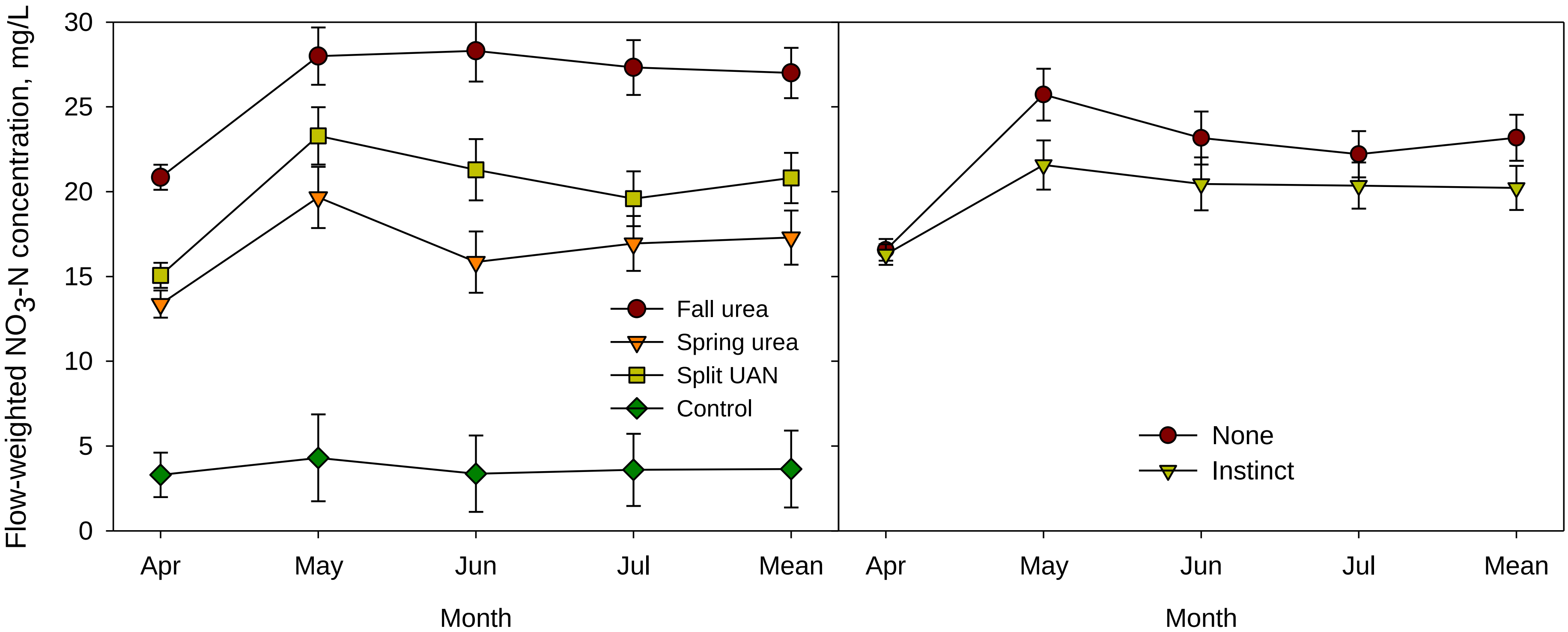
WCROC	Rotation	Time	Response to N	EONR (lb N/ac)	EONR Yield (bu/ac)
2016	CSb	Fall	Quadratic plateau	193	204
	CSb	Spring	Quadratic plateau	168	206
2017	CC	Fall	Linear	240	140
	CC	Spring	Linear	240	182
2018	CC	Fall	Linear	240	157
	CC	Spring	Quadratic plateau	192	164
	CSb	Fall	No N response	0/200	196/163
	CSb	Spring	No N response	0/200	161/193
2019	CC	Fall	Linear	240	183
	CC	Spring	Quadratic plateau	175	168
	CSb	Fall	Quadratic plateau	159	162
	CSb	Spring	Linear	200	158
Difference	CC			-38	10
	CSb (2yr)			8	1
	Overall			-15	5.5

NWROC	Rotation	Time	Response to N	EONR (lb N/ac)	EONR Yield (bu/ac)
2017	CWh	Fall	Quadratic plateau	182	157
	CWh	Spring	Quadratic plateau	111	155
	CSb	Fall	No N response	0/200	149/148
	CSb	Spring	No N response	0/200	176/170
2018	CWh	Fall	No N response	0/200	119/135
	CWh	Spring	Quadratic	86	133
	CSb	Fall	No N response	0/200	149/149
	CSb	Spring	No N response	0/200	138/161
2019	CC	Fall	No N response	0/200	101/118
	CC	Spring	No N response	0/200	106/112
	CSb	Fall	Quadratic	200	181
	CSb	Spring	Quadratic plateau	189	198
Difference	CWh (1yr)			-71	2
	CSb (1yr)			-11	17
	Overall			-41	10

N source/timing, rate and Instinct study

- Site: SROC drainage research facility: Canisteo-Webster clay loam (50' tile spacing), continuous corn
- 19 Treatments: three-factor factorial + a control (0-N)
  - (3) N source/timing: urea fall and spring and UAN split
    - urea broadcast and incorporated
    - UAN split (20-30 lb dribble band at planting + stream inject V4)
  - (3) Rates: 160, 200 and 240 lb N/ac
  - (2) Nitrification inhibitor Instinct: 0 and 35 oz/ac
- Tile plot treatments: (3) source/timings × (2) Instinct at 200-lb N + 160-lb N as spring urea with Instinct + control = 8 treatments × 4 reps = 32 tile plots.

Nitrate-N concentration in tile water (200 lb N/ac) as affected by N source/timing and Instinct in 2013



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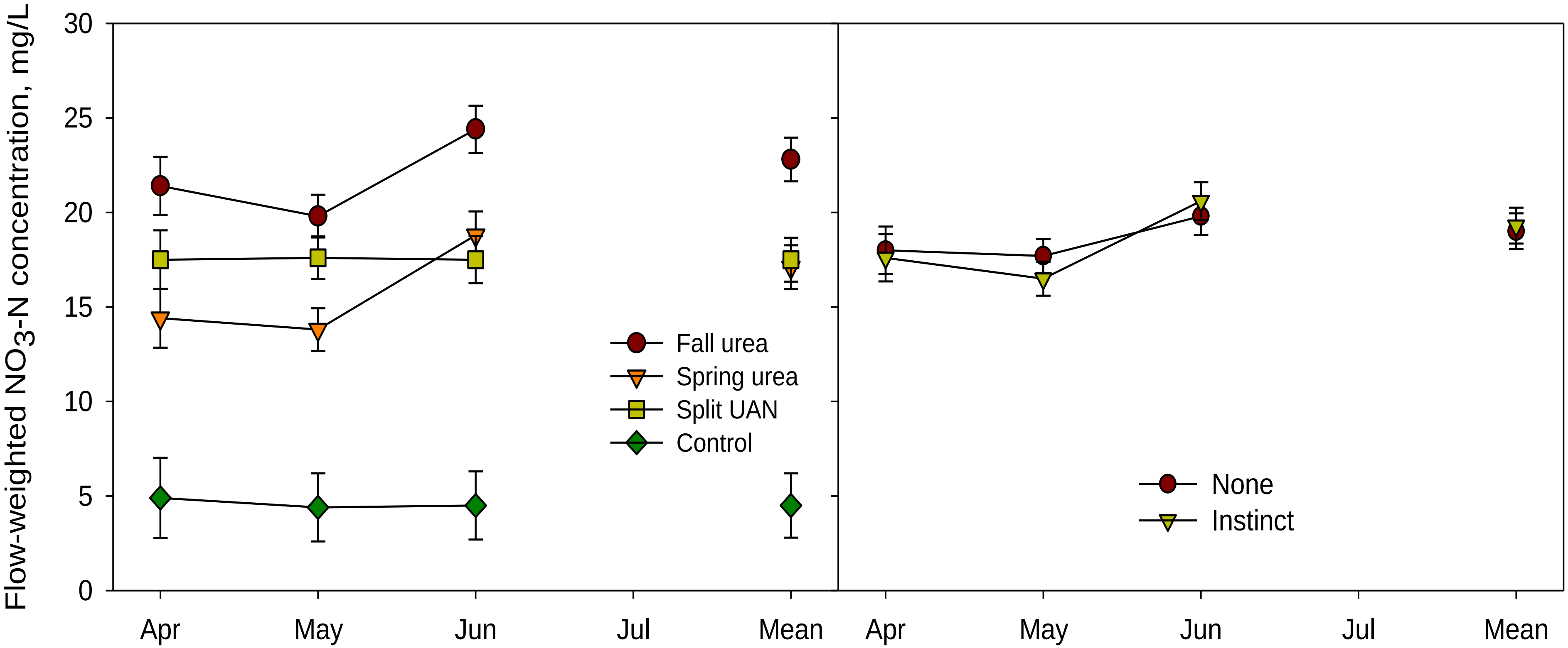
Nitrate-N concentration in tile water (200 lb N/ac) as affected by N source/timing and Instinct in 2014



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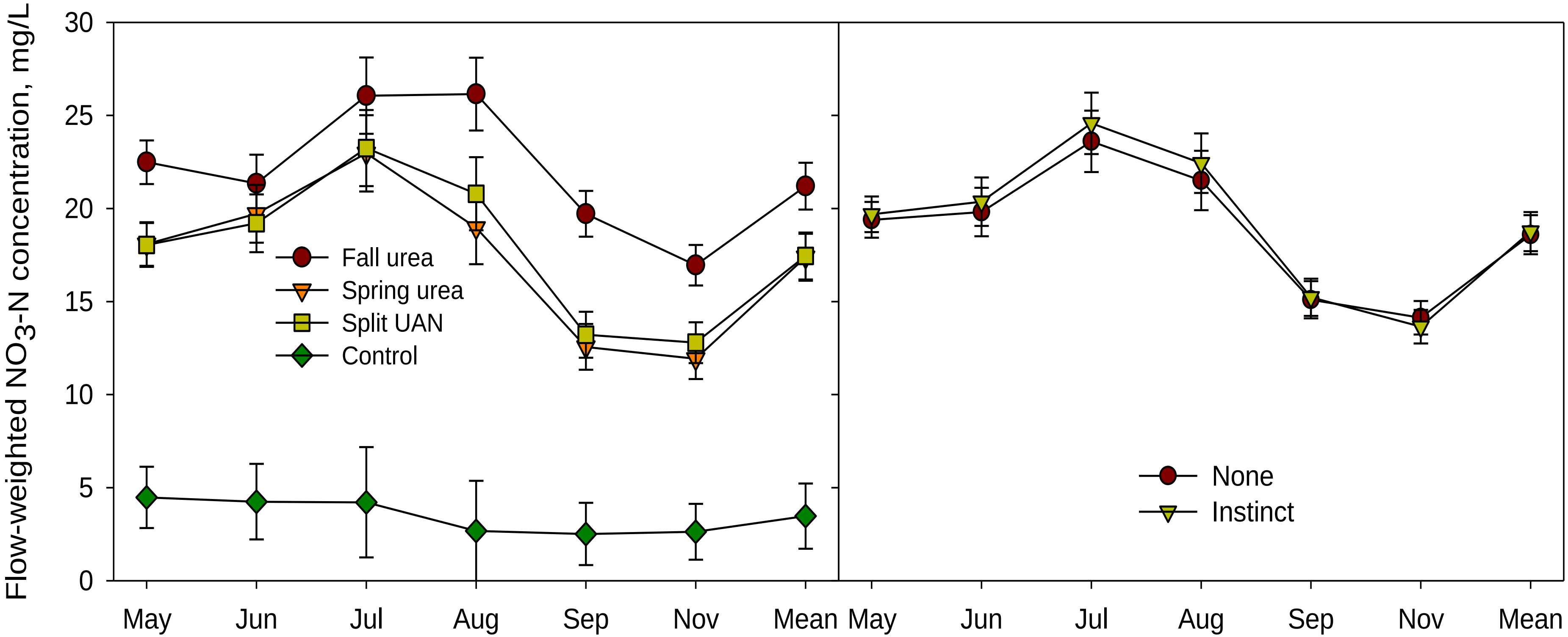
Nitrate-N concentration in tile water (200 lb N/ac) as affected by N source/timing and Instinct in 2015



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Nitrate loss and yield summary

- Fall-applied urea had 38% greater NO_3 loss in tile drainage water than did spring urea, when averaged across 2013 - 2015.

- Grain yields with fall application of urea were:
  - much less than spring urea in 2013, similar in 2012 and 2014, and slightly greater in 2015.
- Adding Instinct to fall-applied urea increased yield and reduced NO_3 concentration and loss in tile drainage water only in 2013.

Acknowledgement

- Funding from the Minnesota Corn Research and Promotion Council and Dow AgroSciences is appreciated by the author.

Nitrification Inhibitors and Enhanced Efficiency Fertilizers

Nitrification Inhibitors

$$NH_4^+ \xrightarrow{\textit{Nitrosomonas}} NO_2^- \xrightarrow{\textit{Nitrobacter}} NO_3^-$$

Ammonium **Nitrite** **Nitrate**

Nitrapyrin
Dicyandiamide

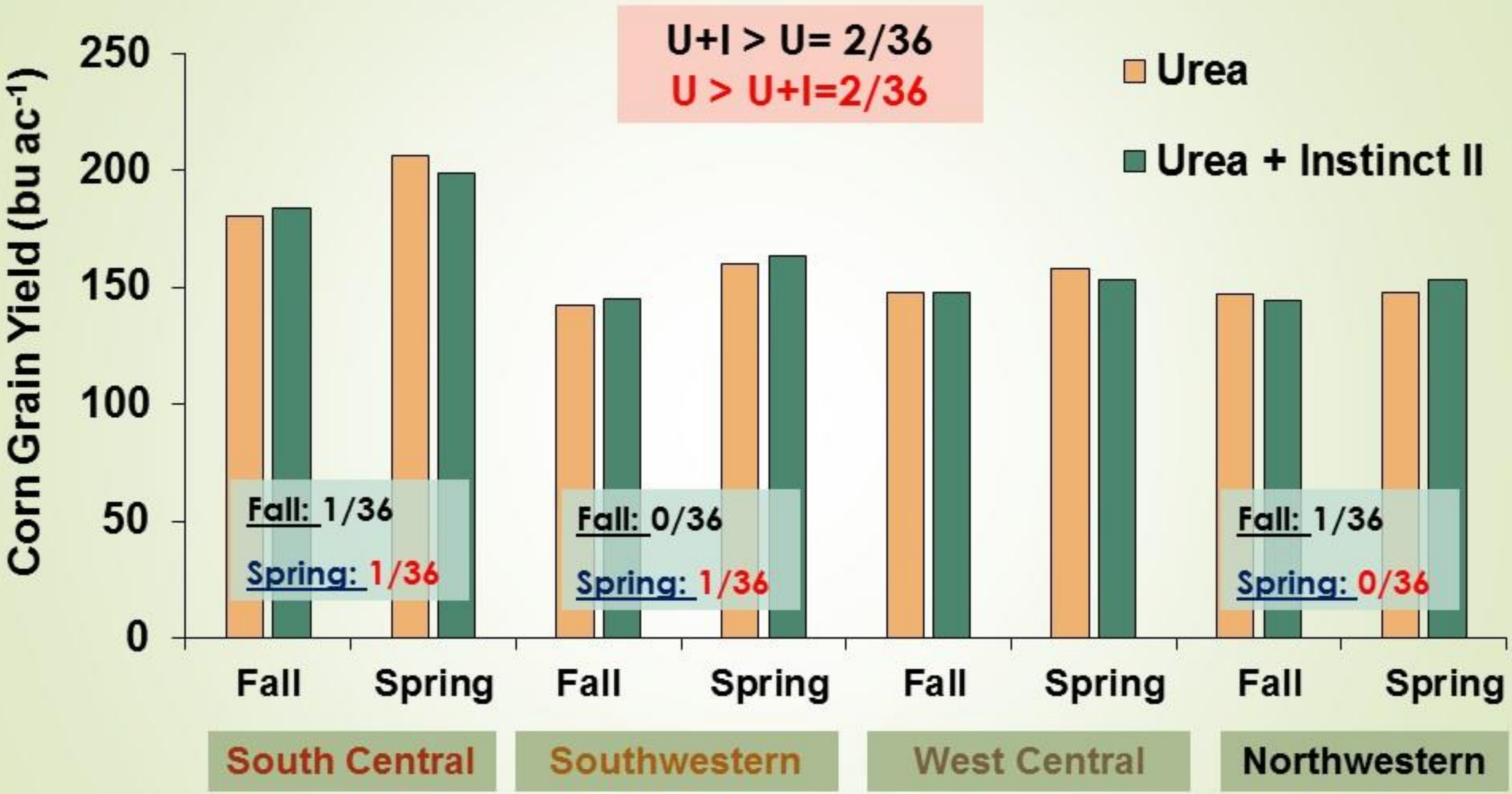
Objectives

- Evaluate the use of Inhibitor and Placement method on corn yield

N source	N time	CC lb N ac^{-1}	CSb or CWh lb N ac^{-1}
Urea (U)	Fall vs Spring	120	80
Urea + Instinct II (U+I)		120	80
Broadcasted and incorporated (BI)	Fall vs Spring	120	80
Subsurface banded (SSB)		120	80

Fernández et al. 2019

Urea - Inhibitor



Fernández et al. 2019

Corn grain yield as affected by N source and application timing at SWROC (Fernandez, 2018).

Treatment	2014	2015	2016	2017	2018	Mean
	Yield bu/ac					
ESN preplant	159	157	170	220	172	176
Urea preplant	149	164	158	206	152	166
ESN/Urea+	160	171	177	216	168	178
Urea/Urea+	145	163	170	206	162	169

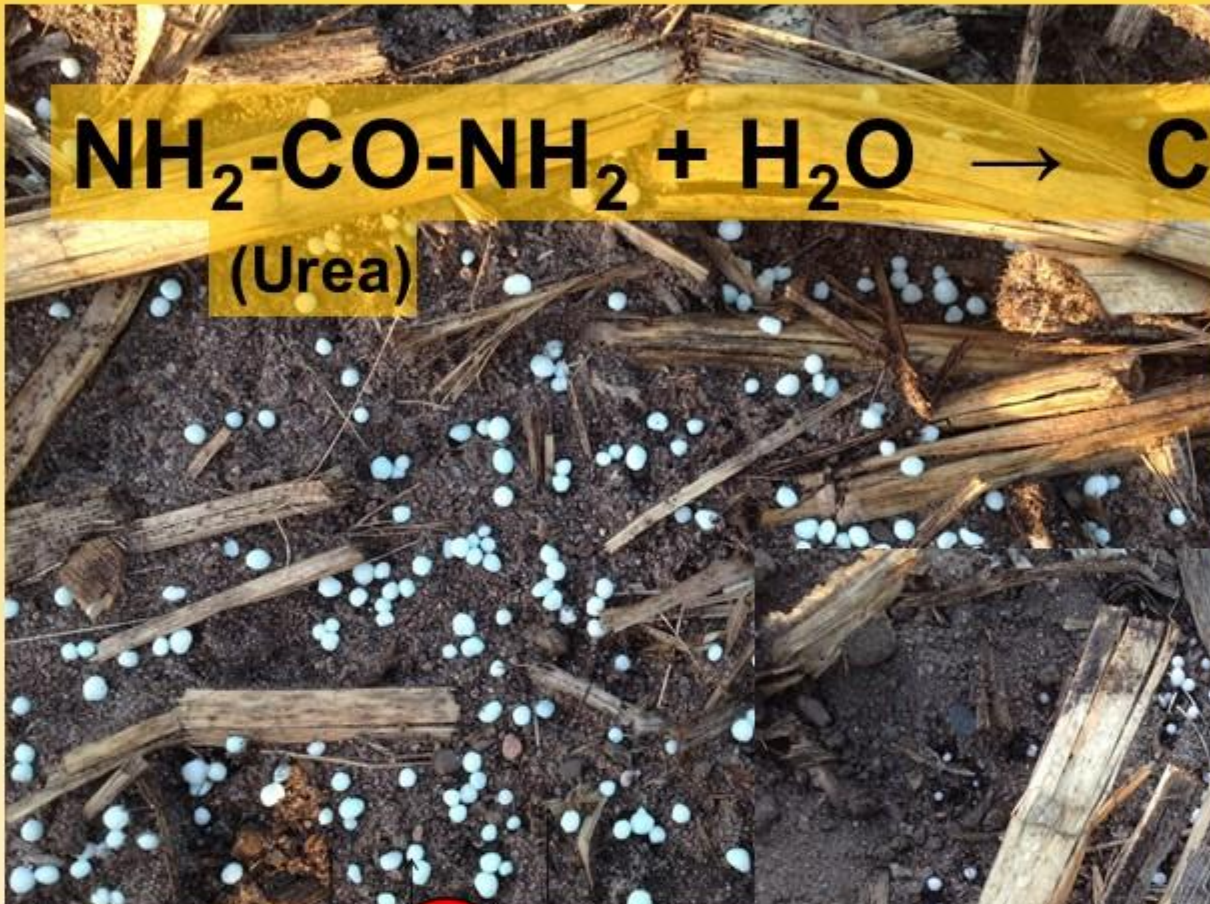
Pre-plant at 180 lb N/ac

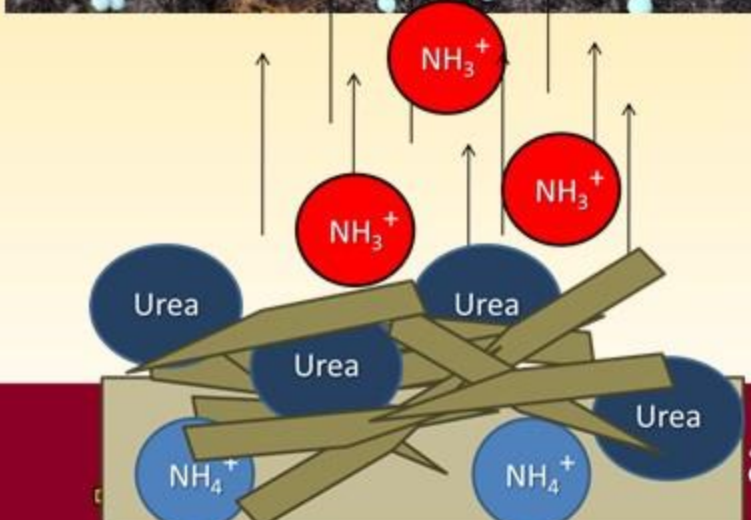
Split 60 pre-plant 120 lb N/ac at V4

Placement and Urease Inhibitors

$$NH_2\text{-}CO\text{-}NH_2 + H_2O \rightarrow CO_2\uparrow + 2\ NH_3\uparrow$$

(Urea)





Deeper Band Placement Reduces Ammonia Loss

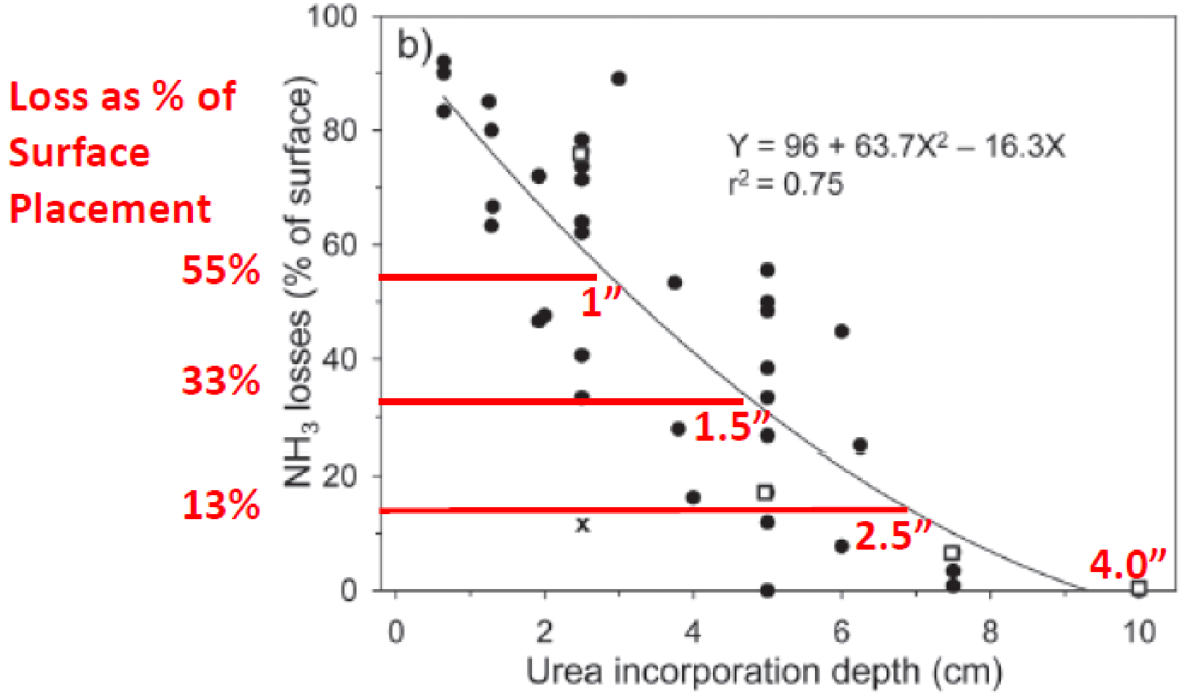
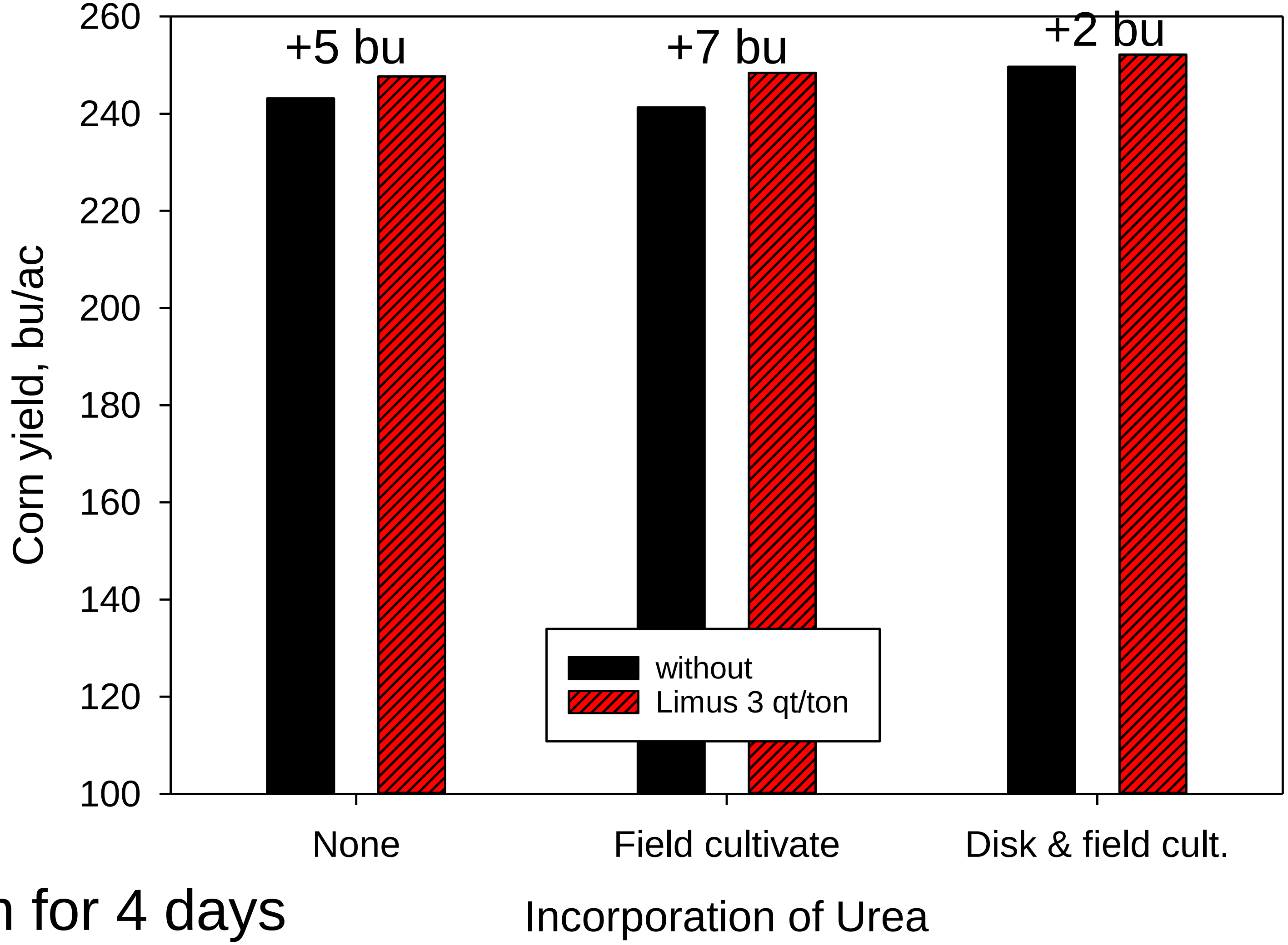


Fig. 4. Summary of literature data on ammonia volatilization response to urea incorporation depth. Volatilization losses were expressed as proportion (%) of applied N (a) and proportion (%) of losses for a surface-application (b). Open squares are observations from this study. One datapoint ("x") from Bouwmeester et al. (1985), for which water accumulation over the band artificially reduced volatilization, was not included in the analysis.

Data from 15 published studies

Rochette et al. JEQ 2014

Corn yield as affected by urea incorporation method and the urease inhibitor Limus™ (Vetsch, 2016).



No rain for 4 days

Field Runoff and Nitrate Losses in NW MN

Tim Radatz
Discovery Farms Minnesota

Stefan Bischof and Jeppe Kjaersgaard
Minnesota Department of Agriculture

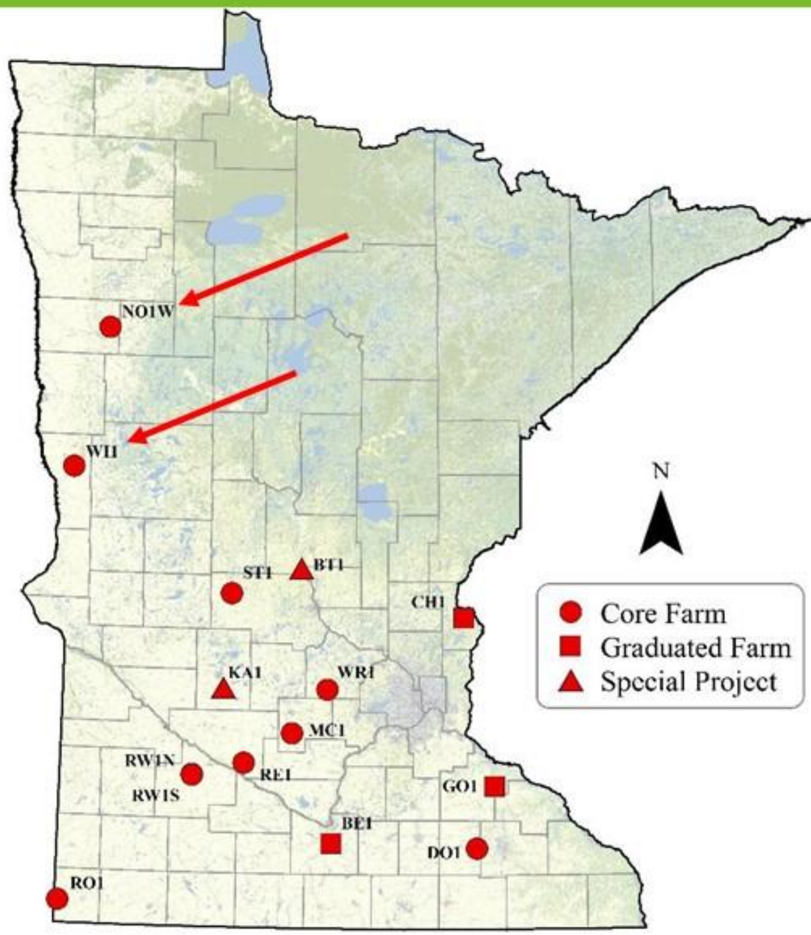
DEPARTMENT OF AGRICULTURE

CLEAN WATER LAND & LEGACY AMENDMENT

DISCOVERY FARMS MINNESOTA

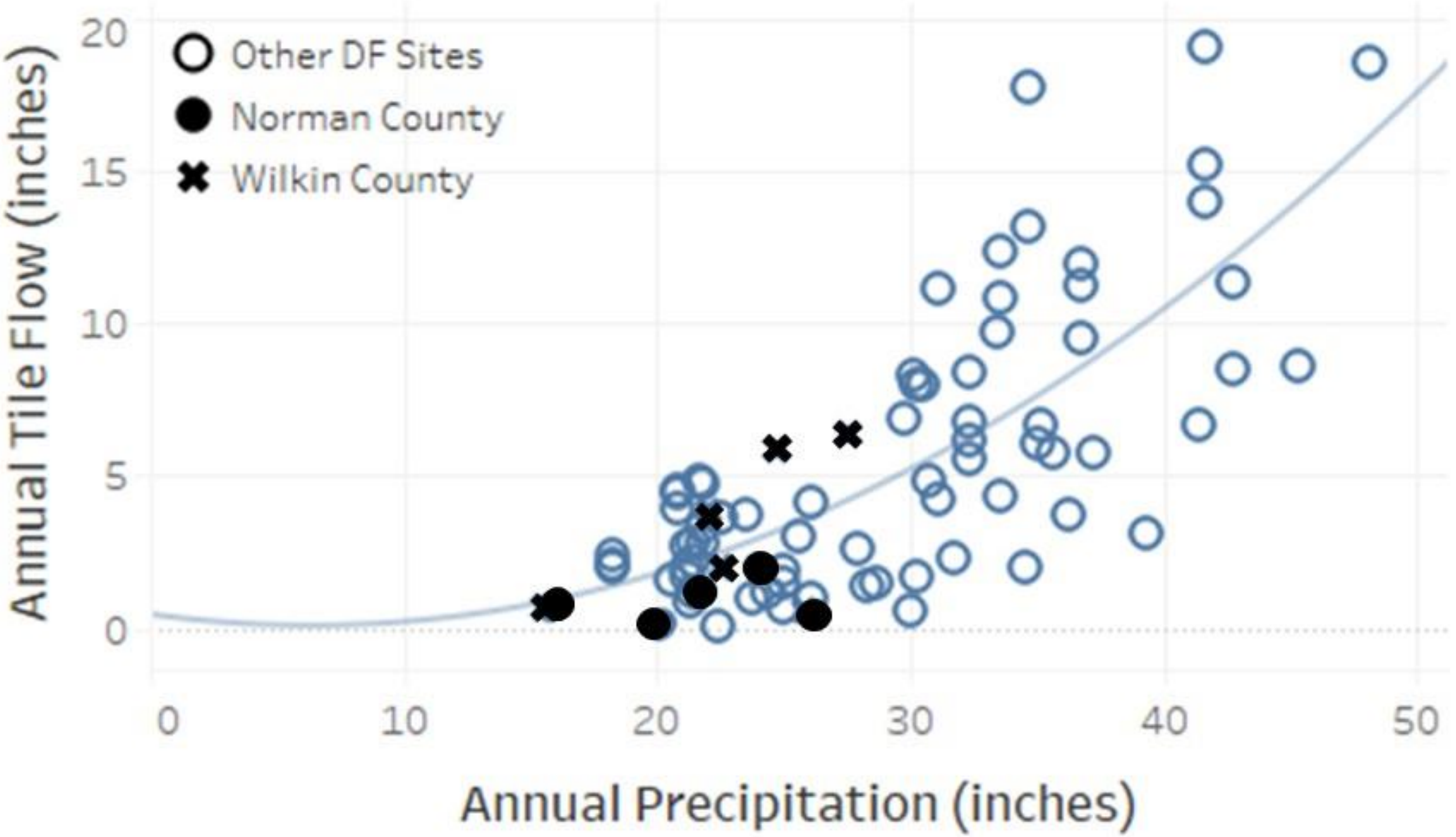
Questions regarding **Discovery Farm Minnesota** data please contact Tim Radatz, radatz@mawrc.org, 608-443-6587

Discovery Farms Minnesota



- Farmer-led Program
- Objective is to Collect Water Quality Information under Real-World Conditions
- Nitrogen, Phosphorus and Sediment Losses is Documented
- Two Locations in the Basin, Subsurface Drainage Only
  - Norman County (2013 –)
  - Wilkin County (2013 – 2018)

Annual Precipitation and Subsurface Drainage

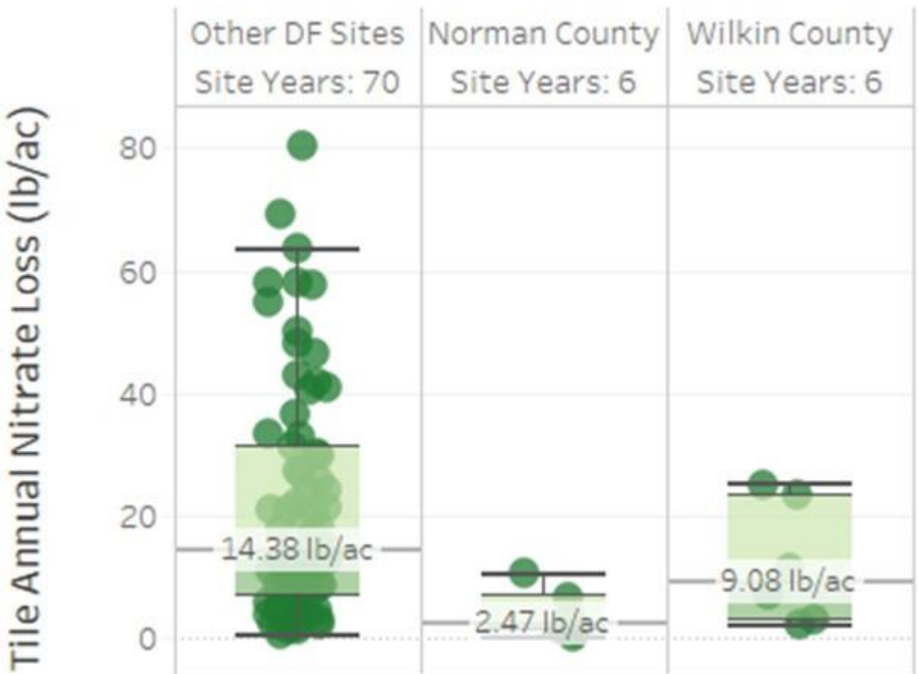


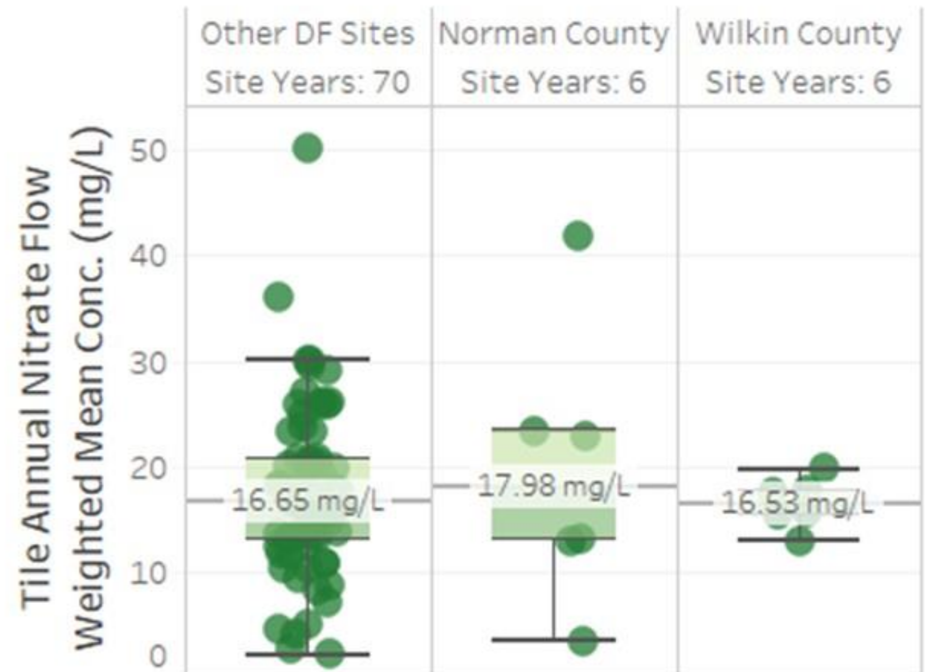
Graphic: Tim Radatz

Nitrogen Losses through Subsurface Drainage

	Norman County				Wilkin County			
Water Year	Crop	Tile flow, in	NO3 (mg/L) FWMC	NO3 (lb/ac)	Crop	Tile flow, in	NO3 (mg/L) FWMC	NO3 (lb/ac)
2013	Corn	0.2	22.8	0.9	Corn	2.0	15.4	7.0
2014	Dry Bean	2.0	23.4	10.5	Corn	5.8	17.7	23.2
2015	Corn	0.7	41.8	6.6	Soybean	0.7	19.7	2.9
2016	Wheat	0.5	12.9	1.4	Corn	0.6	15.6	2.0
2017	Sugar Beet	1.2	13.1	3.5	Corn	6.3	17.4	25.0
2018	Soybean	0.1	3.5	0.1	Soybean	3.8	13.0	11.1

Nitrogen Losses through Subsurface Drainage





Graphic: Tim Radatz

Cover Crops

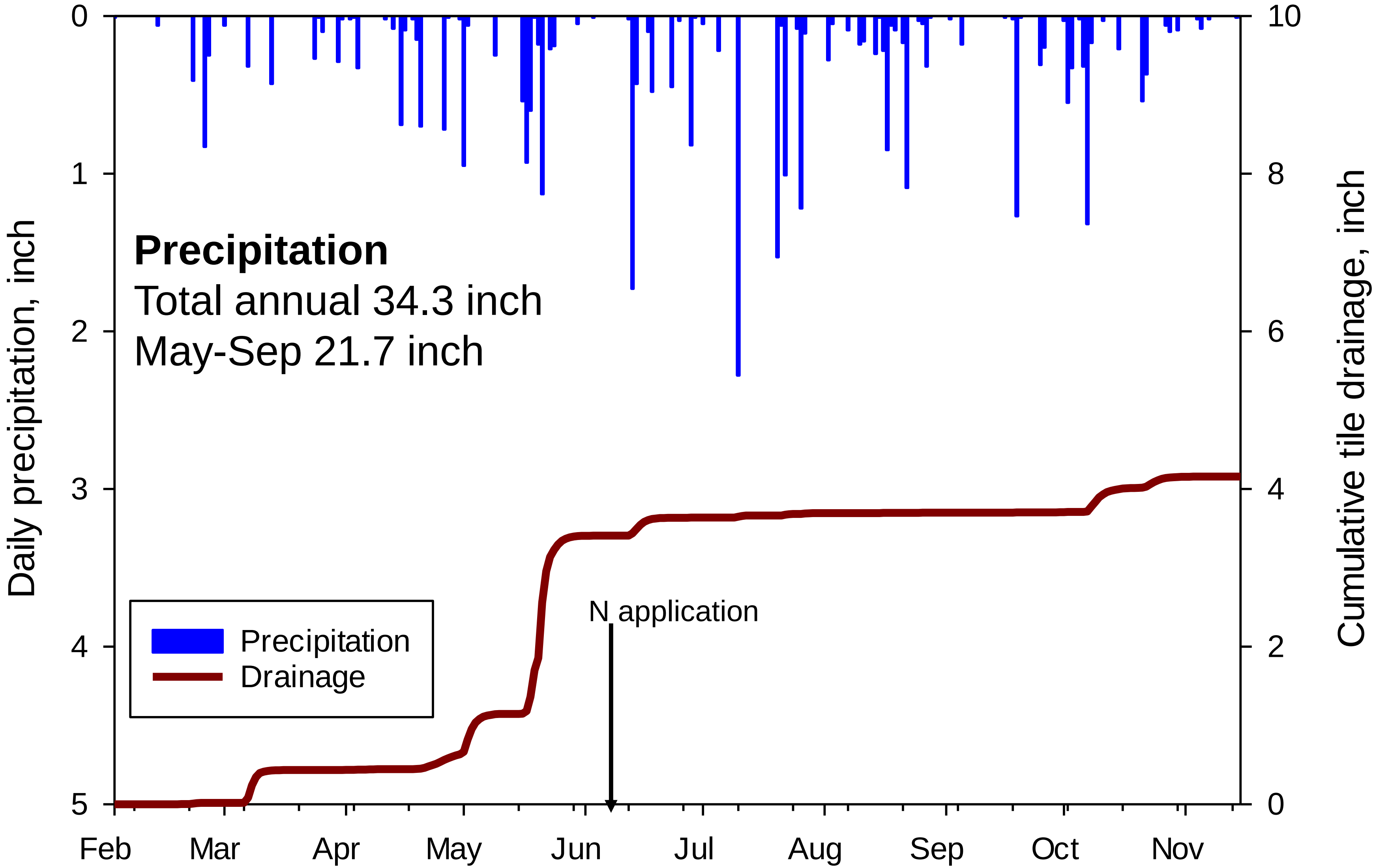
April 17, 2017

Vetsch, 2020

May 7, 2017

Vetsch, 2020

Tile drainage and precipitation in 2017.



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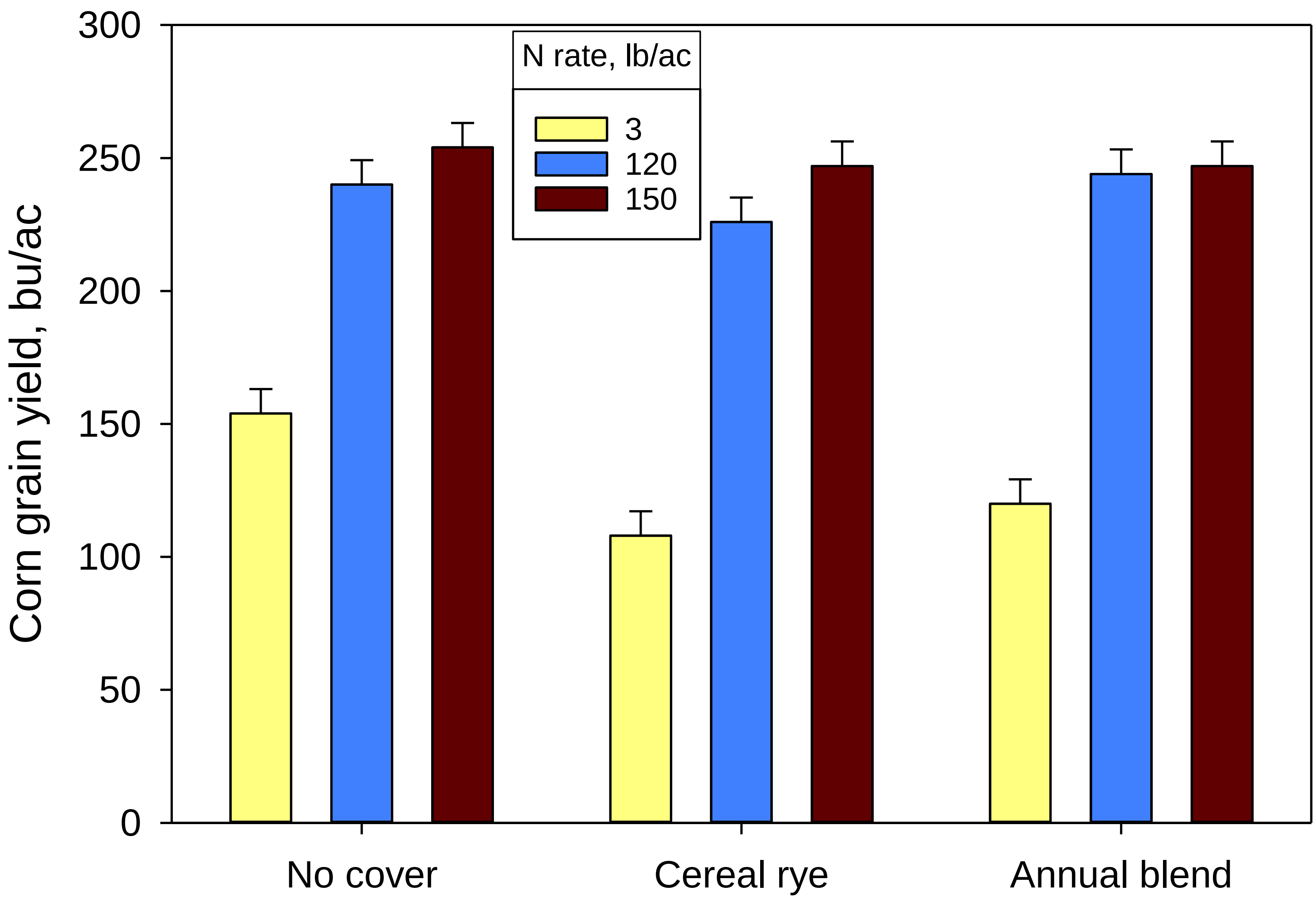
120 lb N/ac w/cereal rye **150 lb w/cereal rye, Sept. 6**

Corn grain yield as affected by cover crop species and nitrogen rate in 2017.



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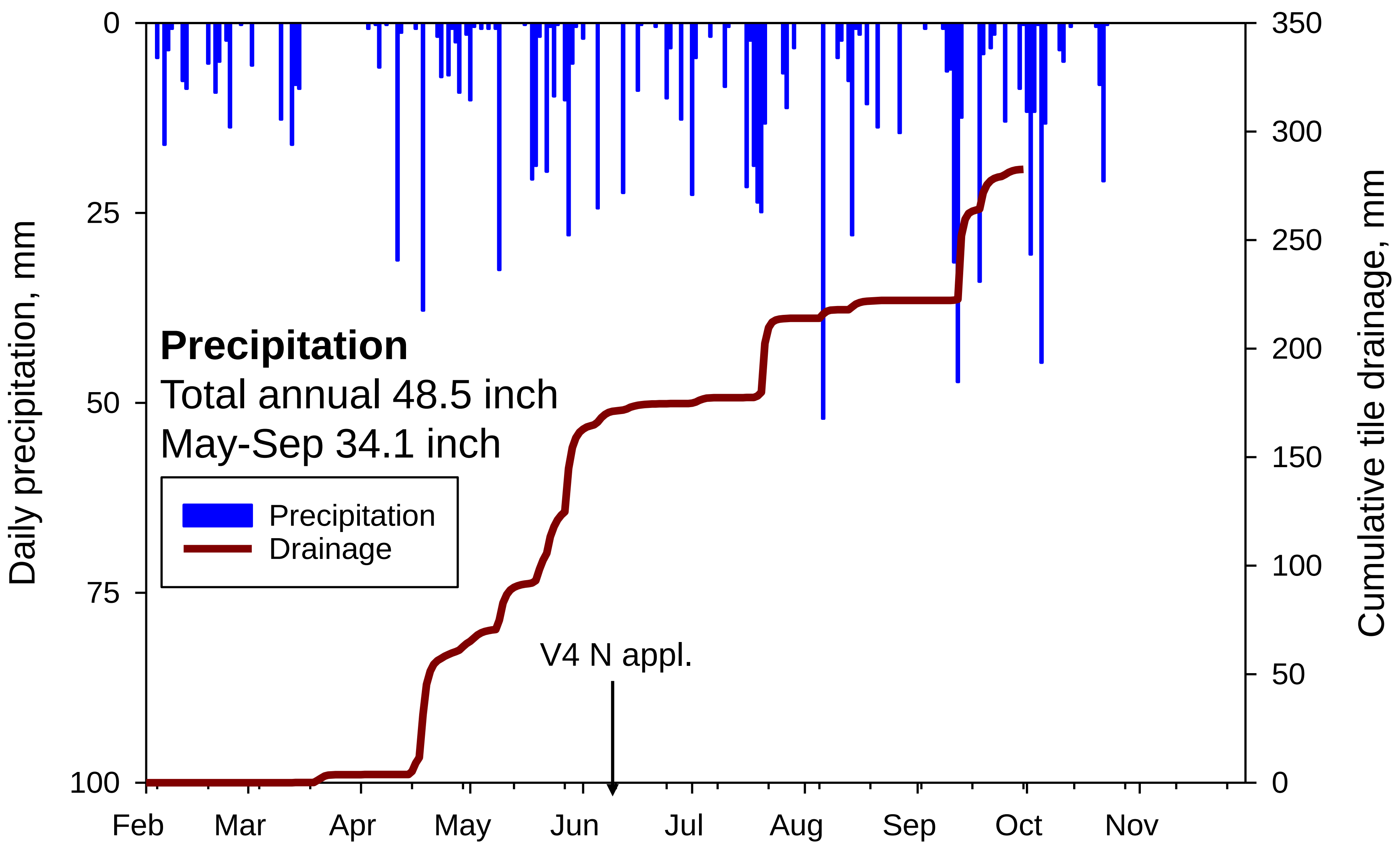
May 4, 2019
112

Tile drainage and precipitation in 2019.



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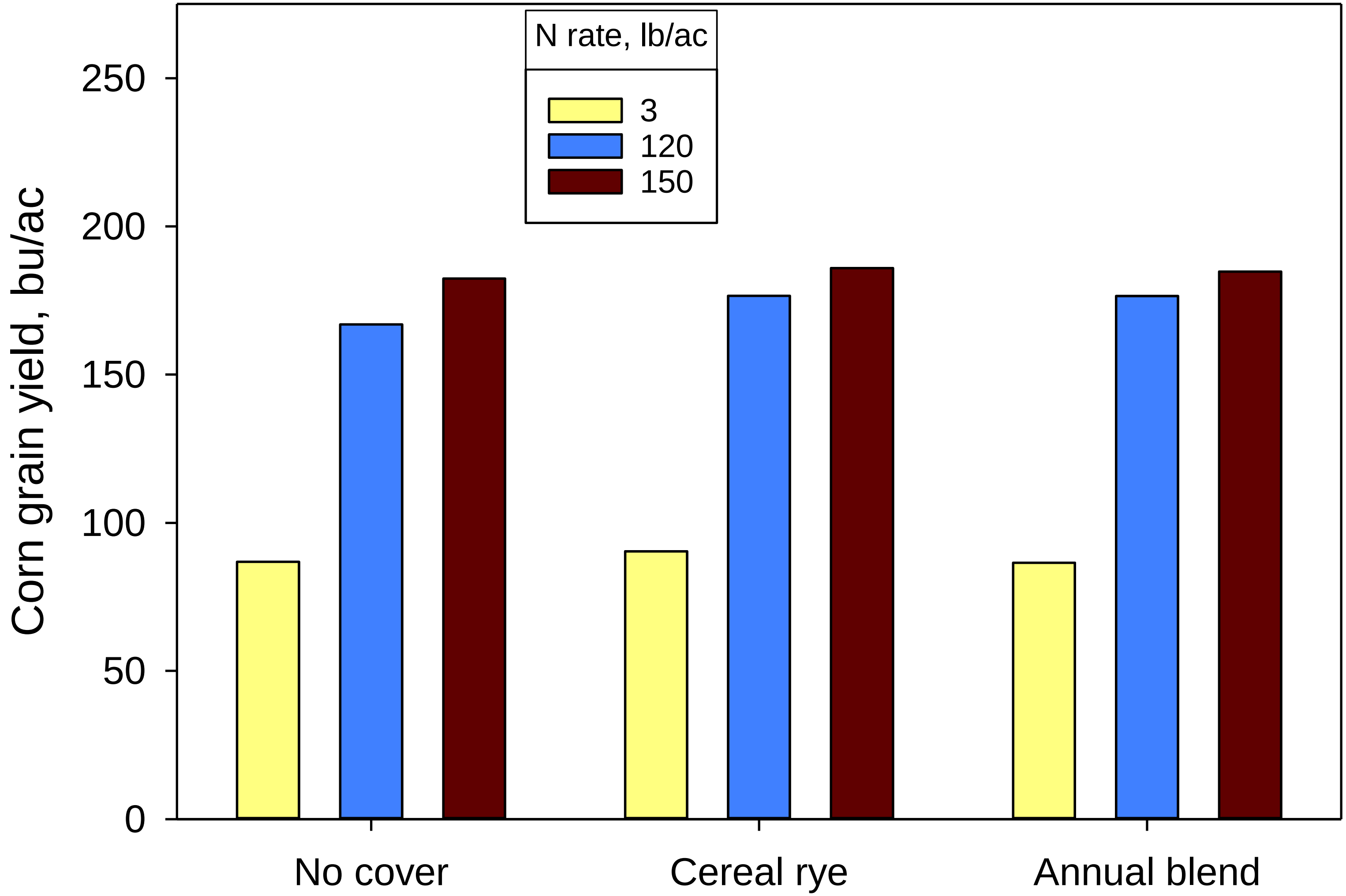
Corn grain yield as affected by cover crop species and nitrogen rate in 2019.



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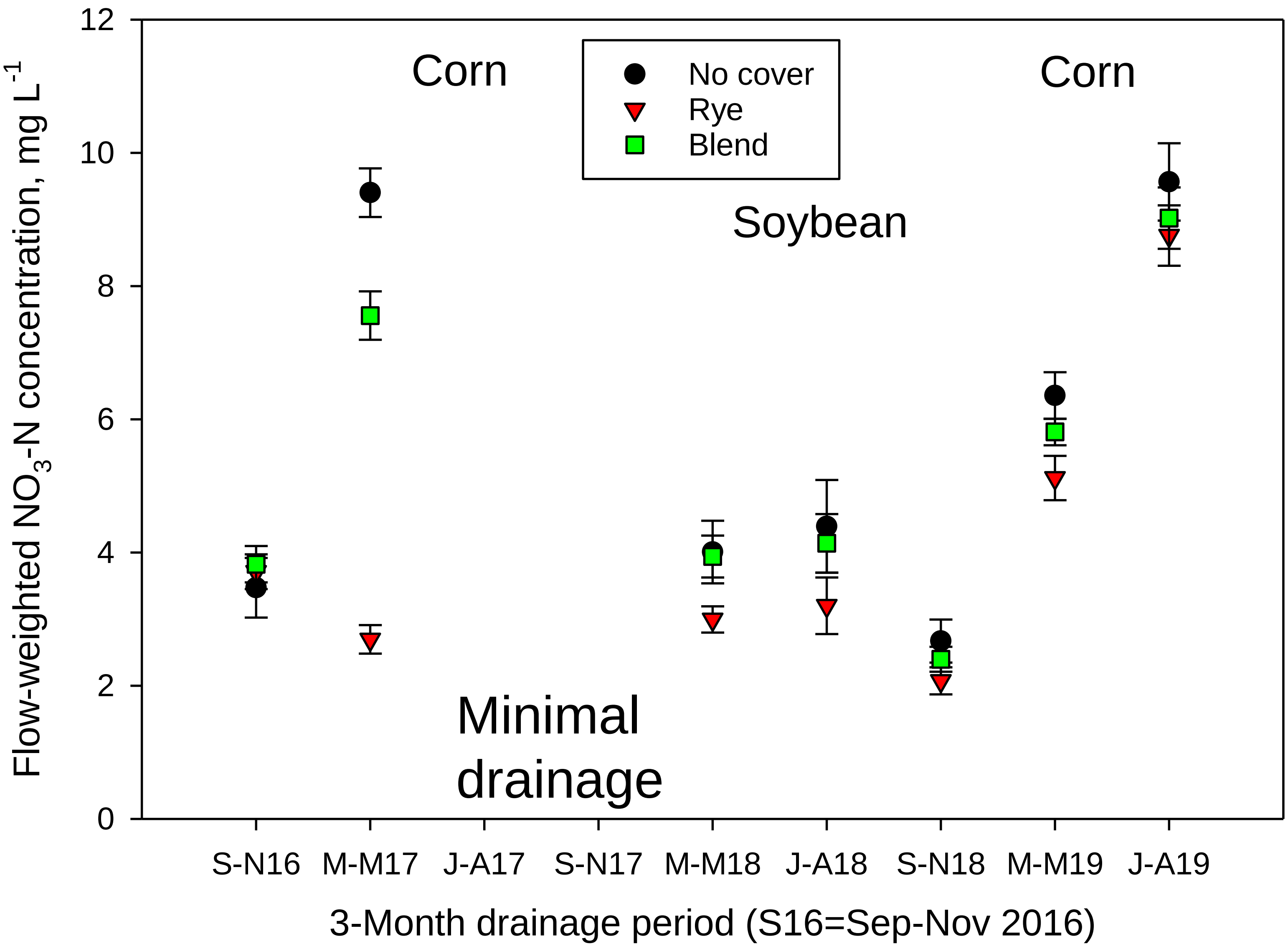
Effects of cover crops on NO_3-N concentration.



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Cover Crop Summary

- A spring terminated cereal rye cover crop reduced NO_3-N concentration and flow-adjusted loss in tile drainage water by 70% in 2017 (corn) and 25% in 2018 (soybean).
  - However, rye cover required a greater N rate to optimize corn yield in 2017 when compared with annual blend.
- These data suggest the potential of late summer seeded (winter terminated) annual covers to reduce NO_3-N in tile drainage in Minnesota is limited.
- Treatments had no affect on soybean yield in 2018 (data not shown).

Take home message

- Our goal/charge is to balance crop production, profitability and water quality.

How do we do it?

- Apply appropriate rates of N using univ. guidelines.
- Use BMP's for source, timing and placement specific to your region/soils (4R management).
- **Resist applying preplant N rates that are considerably greater than guidelines as insurance against N loss.**

Instead

When adverse weather results in N loss, have a plan with your fertilizer dealer to correct the problem in-season with supplemental N.

QUESTIONS

Jeff Vetsch

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