Using the 4 R's for improved N management for corn and water quality for MN??

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AGVISE Seminar Series
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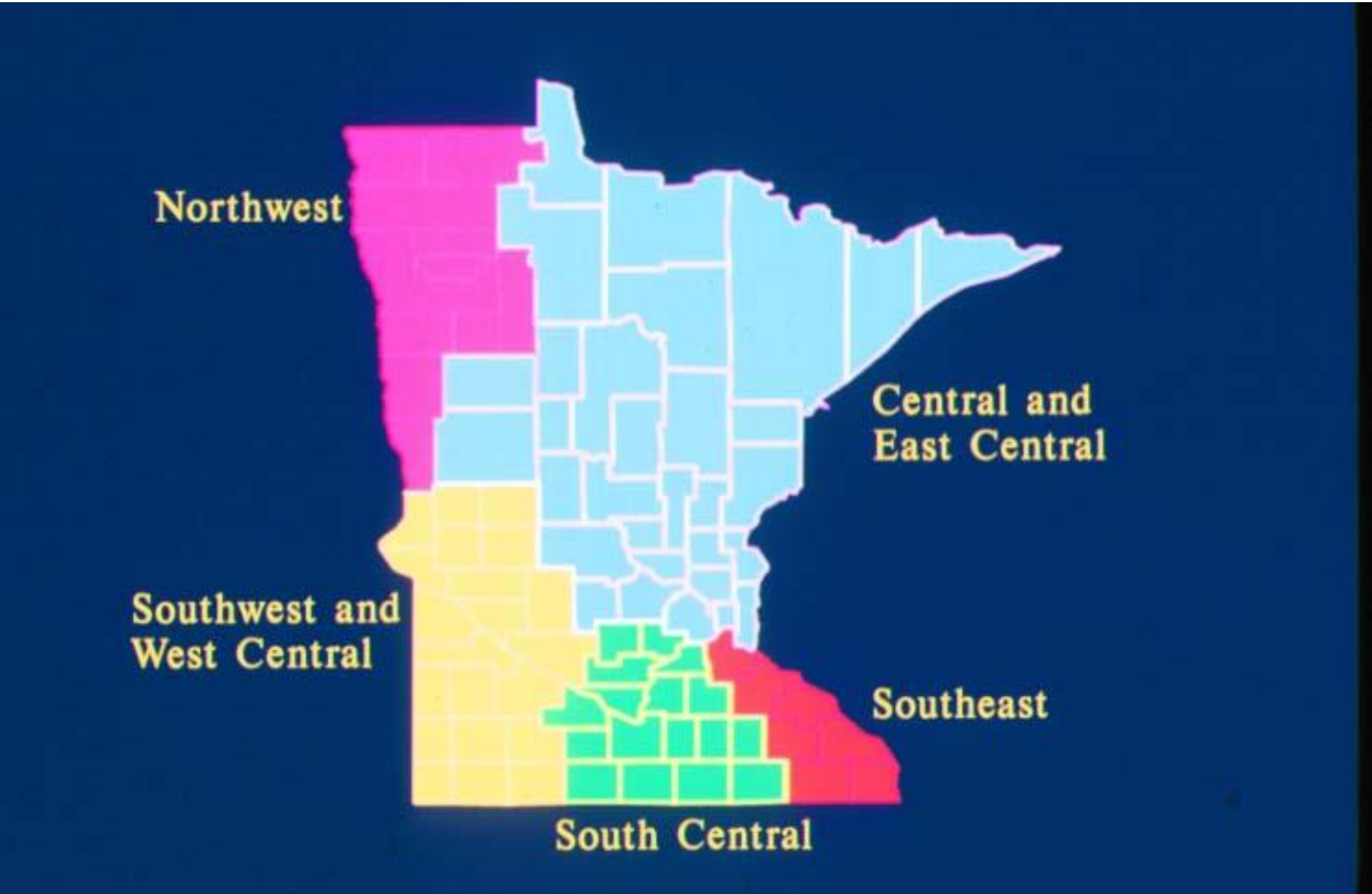
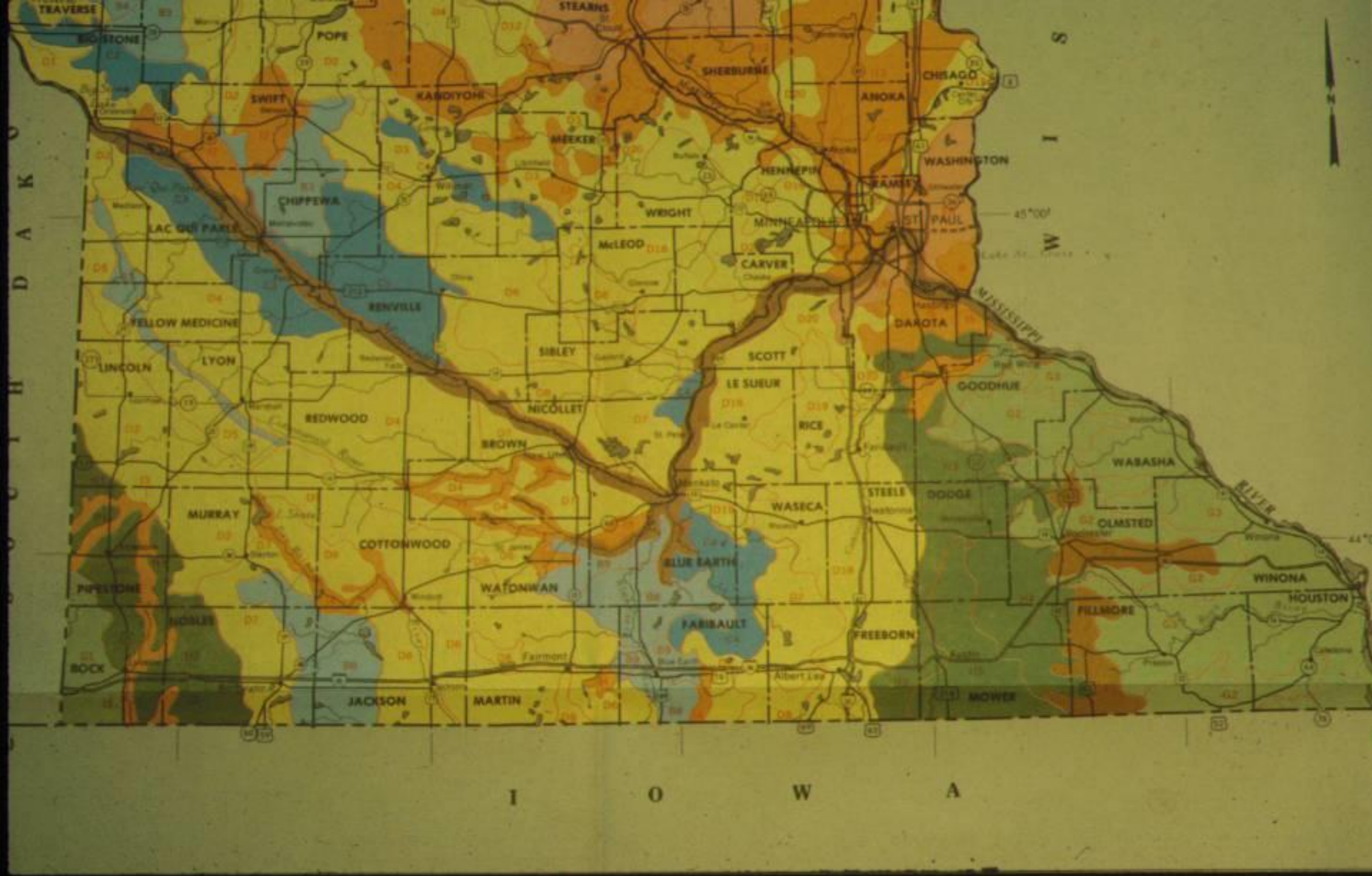
University of Minnesota
Driven to Discover[SM]

Nitrogen

- Required at higher rates than any other nutrient for optimizing corn yield and profitability
- More than 600,000 tons of N are applied for corn each year in Minnesota alone.
- N BMP’s soil (region) specific in Minnesota.

Region Specific BMPs for N

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WATONWAN
HOUSTON
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Randall

Lynn Betts, NRCS


Randall

RISK

Yield Loss & N Loss

Economic and Environmental

Management Practices

1. Cropping system
2. Rate of N application
3. Time of N application
4. Nitrification inhibitors
5. Source of N
6. Cover Crops

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The Fertilizer Institute launches the 2014 4R Advocate Program this week, calling for entries from retailers to highlight the exceptional nutrient stewardship practices of their grower customers.

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4R Principles

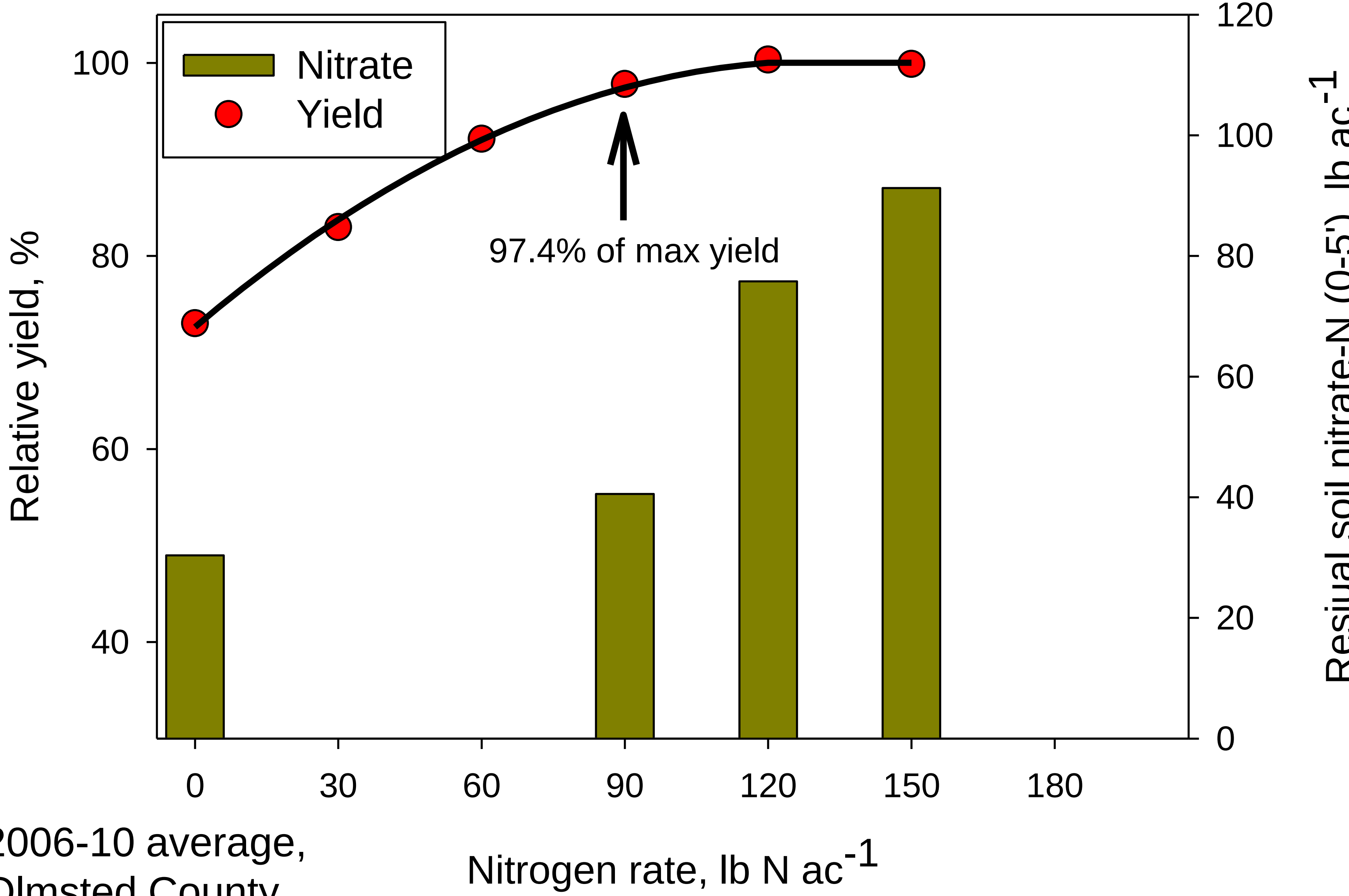
- The 4R nutrient stewardship principles are the same globally, but how they are used locally varies depending on field and site specific characteristics such as soil, cropping system, management techniques and climate.

4R's

- **Right Source** – Ensure a balanced supply of essential nutrients, considering both naturally available sources and the characteristics of specific products, in plant available forms.
- **Right Rate** – Assess and make decisions based on soil nutrient supply and plant demand.
- **Right Time** – Assess and make decisions based on the dynamics of crop uptake, soil supply, nutrient loss risks, and field operation logistics.
- **Right Place** – Address root-soil dynamics and nutrient movement, and manage spatial variability within the field to meet site-specific crop needs and limit potential losses from the field.

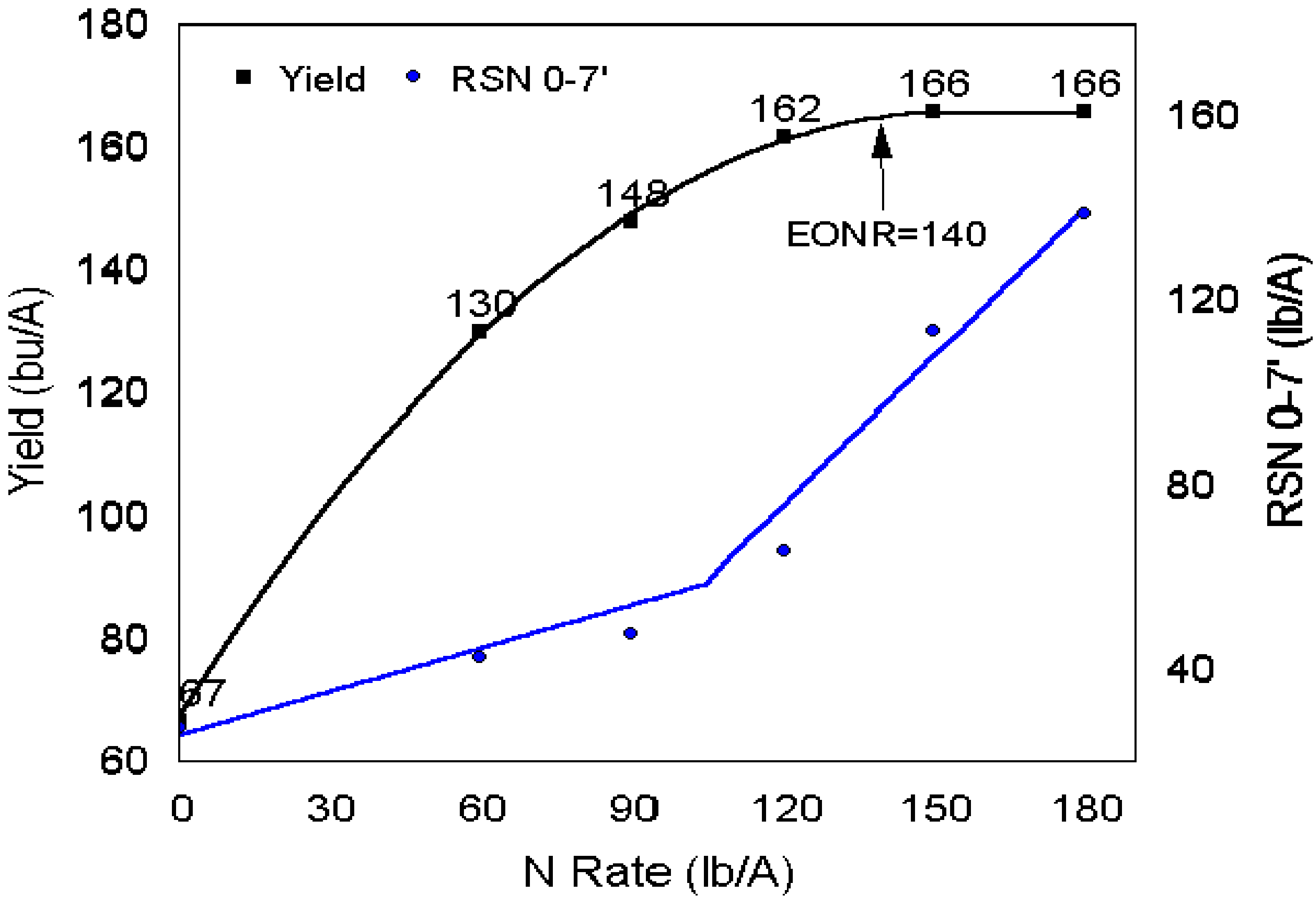
Rate of N Application

Relative corn yield following soybean & residual soil NO_3 (0-5' depth) as affected by N rate (Port Byron)

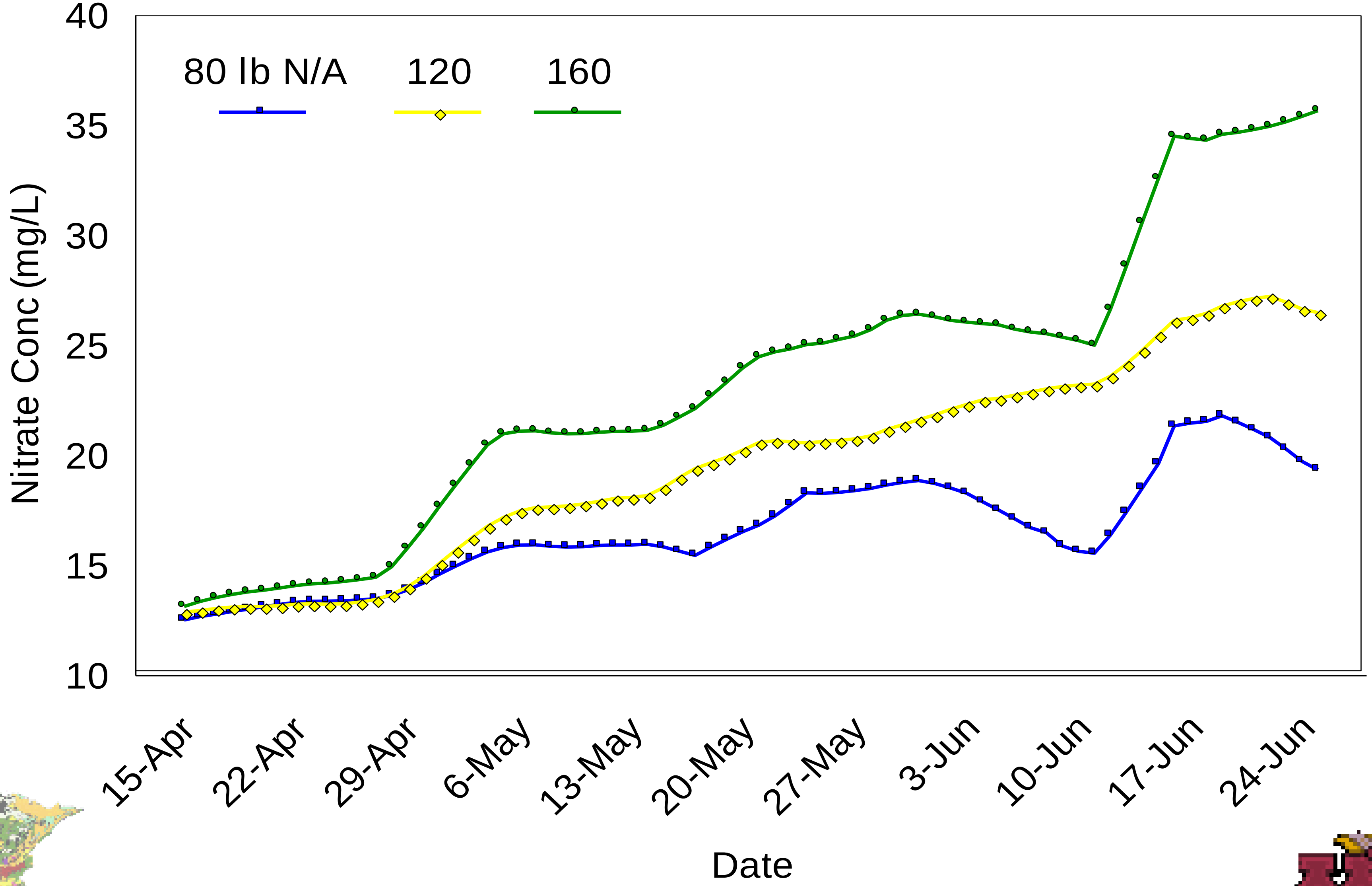


2006-10 average,
Olmsted County

Continuous Corn, 2001–03 Olmsted Co.



Effect of N rate for corn after soybean on NO_3-N concentrations in tile drainage water in 2001.



Time of N Application and N-Serve

April – June Rainfall

30-yr normal =	10.7”
1997 =	8.5” (20% below)
1998 =	11.8” (10% above)
1999 =	15.8” (48% above)

Corn yield as affected by time of application.

	Years		
Time/Placement	1997-’98	1999	3-yr Avg.
		Yield (bu/A)[1/]	
Fall/under row	188	145	174
April/between rows	188	181	186

[1/] Across all four tillage systems.

Primary points

- Although 3-yr average tillage system yields ranged from 176-184, there was no interaction between Time of N and Tillage

- Spring N in 1999 increased grain yield by 36 bu/A, silage yield by 1.3 T/A, and N recovery by 42% compared to a late October application.
    - fall N can be risky

Corn yield as influenced by N-Serve, time of application, and N-Serve at Waseca, 1981-82.

N Treatment		Time of Application	
Source	N-Serve	Fall	Spring
		- - - Yield (bu/A) - - -	
None	--	104	
Urea	No	157	164
"	Yes	155	167
An. Ammonia	No	162	168
"	Yes	170	173

Corn grain yield after soybeans as affected by fall and spring application of N-Serve with anhydrous ammonia at Waseca, 1994-99.

	N-Serve	
Time of Application	No	Yes
	- - - 6-Yr Avg. Yield (bu/A) - - -	
Fall (late Oct.)	161	171
Spr. (April)*	172	176

* A yield response to spring-applied N-Serve occurred in years when June rainfall was excessive, but the 4 bu/A (6-yr avg.) increase was not statistically significant.

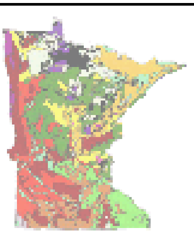
Corn yield, N recovery, and NUE as influenced by time of application and N source at Waseca.

N Management			3-Yr Avg.		
Time	**Source**	**N-Serve**	**Yield**	**N recovery**	**NUE**
			bu/A	%	bu/lb FN
Fall	Urea	No	152	43	0.36
“	“	Yes	158	47	0.42
“	AA	No	168	60	0.51
“	“	Yes	170	63	0.53
Spr. PP	Urea	No	185	76	0.66
“	AA	No	182	84	0.64
--	None	--	112	--	--

Corn production and nitrate loss as affected by time of N application and N-Serve.

N Treatment		7-Year Average			Nitrate-N
		Corn	N	Economic	Loss in
Time	N-Serve	Yield	Recovery	Return	Drainage
		Bu/A	%	$/A	Lb/A/Inch
Fall	No	131	31	67	3.8
“	Yes	139	37	78	3.1
Spring	No	139	40	85	3.1
Split	No	145	44	97	3.3
LSD (0.10) =		4			

1987-93, Waseca, MN



Nitrogen (NO_3) Loss from Tile Drainage

Lamberton 1973-1985

- Site history
  - no N or manure for previous 10 yrs
  - corn, soybean, small grain rotation
- Soil: Normania cl, mod. well drained
- Crop: Continuous corn
- Fertilizer N Rates (Spring), 1973-79
  18 (as starter), 100, 200 & 400 lb N/A
- 12 - 45'x50' separated drainage plots (3 reps)

1973-75 Nitrate-N Concentration

Annual	Year		
N rate	1973	1974	1975
lb N/A	- - - - - - - - mg/L - - - - - -		
18	13	19	19
100	15	25	23
200	13	37	43
400	12	65	81
Annual flow (inches)	1.46	3.58	5.04

1973-75 Nitrate-N Loss

Annual	Year		
N rate	1973	1974	1975
lb N/A	- - - - - - - - lb N/A - - - - - -		
18	4	15	17
100	5	20	22
200	4	27	53
400	5	48	107

- Corn yields were poor (70-110 bu/A) – Dry
- No movement of nitrate below 6’

1976-79 Nitrate-N Concentration

Annual	Year			
N rate	1976	1977	1978	1979
lb N/A	- - - - - - - - -	mg/L	- - - - - - - - -	
18	*	28	21	16
100	*	48	53	47
200	*	73	119	106
400	*	150	191	172
Annual flow (Inches):		0.56	1.99	8.21

* = Drought, no tile flow

1976-79 Nitrate-N Loss

Annual N rate	Year 1976	1977	1978	1979
lb N/A	- - - - - - - - - -	lb N/A	- - - - - - - - - -	
18	*	4	10	30
100	*	6	26	82
200	*	6	43	165
400	*	18	87	374[1/]

* = Drought, no tile flow & no grain yield.

[1/] Nitrate moved below 10' with 400-lb rate

- Corn yields (1977-79) = 131-139 bu/A.

Waseca 1975-1980

- Site history
  - corn in 1974, 150 lb N/A
- Soil: Webster cl, poorly drained
- Crop: Continuous corn
- Fertilizer N rates (Spring), 1975-79
  0, 100, 200, & 300 lb N/A
- 12 – 45' x 50' separated drainage plots (3 reps)

1975-80 Nitrate-N Concentration

1975-79	Year[1/]			
N rate	1977	1978	1979	1980[2/]
lb N/A/yr	- - - - - - - mg/L - - - - - - -			
0	13	16	13	9
100	41	28	19	10
200	58	45	32	12
300	85	65	44	23
Ann. Tile Flow (In.)	4.8	5.6	17.1	2.9

1/ No drainage occurred in 1975-1976 – Dry.

2/ N was not applied in 1980.

Nitrate-N Leaching Depth

Lamberton: 400 lb N/A (1973-79)

1983 to 19’

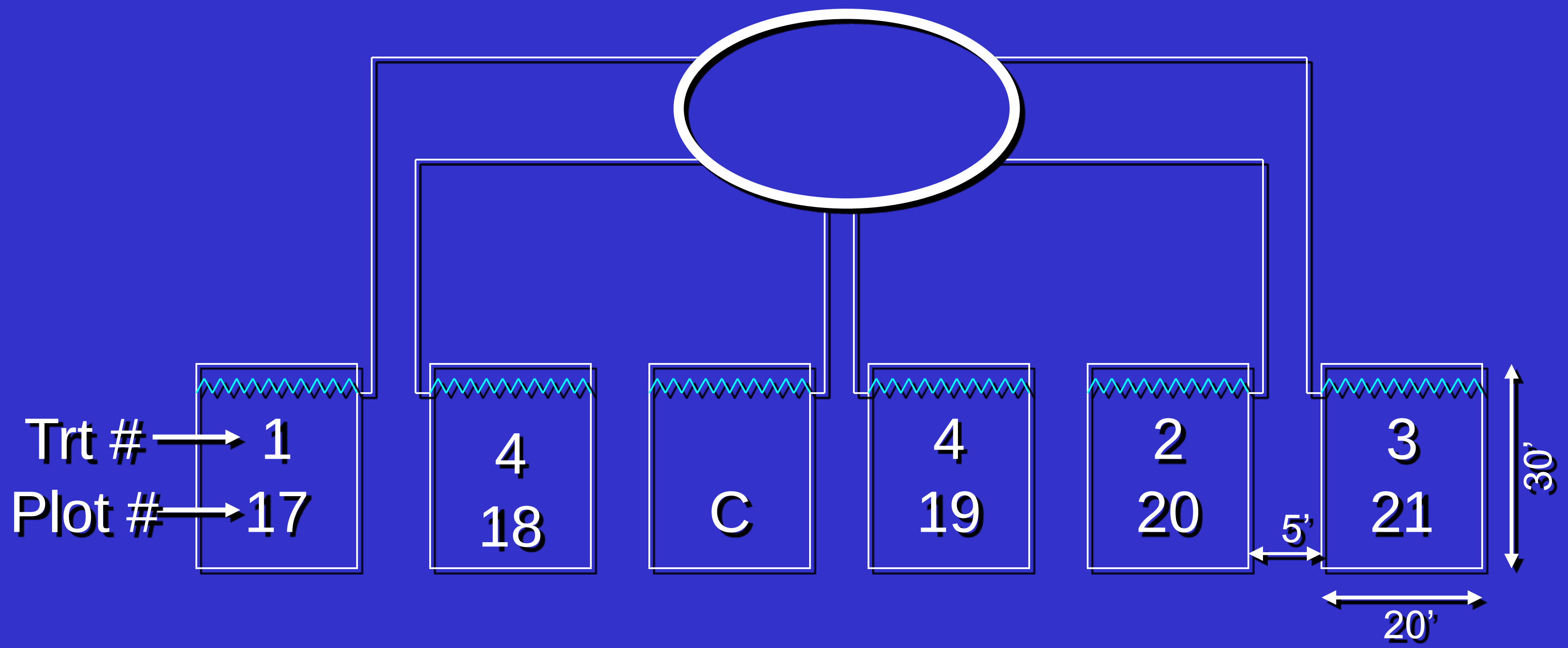
1985 to 20’, 2X as much in 12-20’ as in 0-5’

Waseca: 300 lb N/A (1975-79)

1979 to 10’

denitrification loss??

Corn-Soybean Rotation Drainage Study, Waseca



Time and Rate of N Application and Nitrification Inhibitors (N-Serve)

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

Parameter	Time of N Application		
	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.

Conclusions

- Adding a nitrification inhibitor (N-Serve™) to fall-applied anhydrous increased corn yield and NUE, while reducing nitrate concentration in tile drainage.
- A preplant application of anhydrous increased yield an average of 12 bu/ac in 7 of 15 years (wet springs) at Waseca.

Effect of N rate on yield of corn after soybean, net return to fertilizer N, and nitrate-N concentration in tile drainage at Waseca (2000–2003).

N Treatment			4-Yr Yield	4-Yr FW
Time	Rate	N-Serve	Avg.	NO_3-N conc.
	lb /A		bu/A	mg/L
---	0	---	111	---
Fall	80	Yes	144	11.5
Fall	120	Yes	166	13.2
Fall	160	Yes	172	18.1
Spr.	120	No	180	13.7

Nitrate-N concentrations and losses in tile water as affected by rate and time of N application at Waseca.

N application			FW	2000-2003		
			NO_3-N	NO_3-N Lost		
Rate	Time	N-Serve	Conc.	C	Sb	Total
lb N/A			mg/L	-- lb/A/4 cycles - -		
80	Fall	Yes	11.5	115	90	205
120	Fall	Yes	13.2	121	99	220
160	Fall	Yes	18.1	142	139	281
120	Spr.	No	13.7	121	98	219

Conclusions

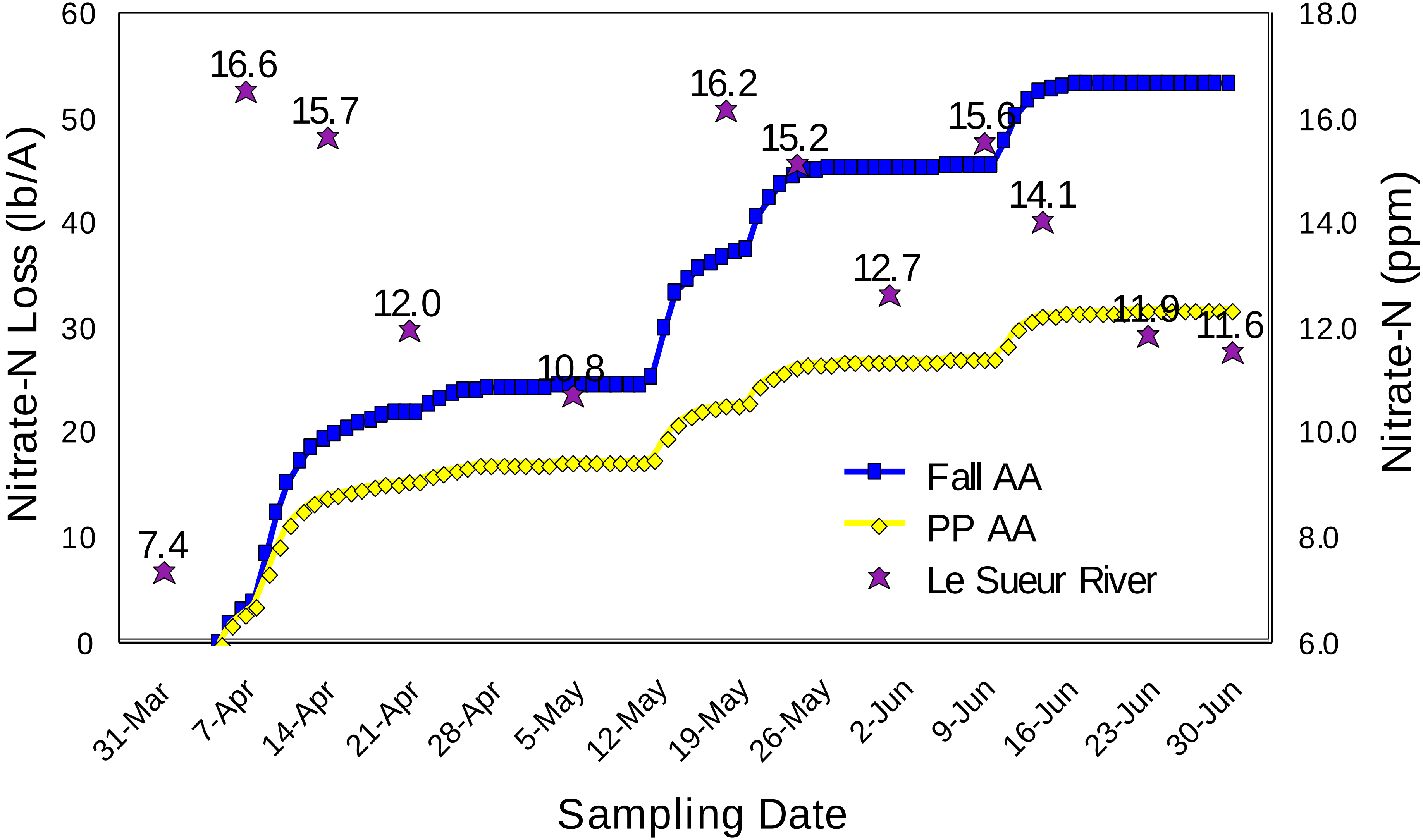
- Nitrate losses were reduced 27% by decreasing the application rate from 160 lb N/A to the recommended rate of 120 lb N/A for corn after soybean without reducing yield.
- Nitrate losses were reduced 14% by decreasing the application rate to 80 lb N/A from the recommended 120-lb rate BUT yields were reduced by 17%.

Fall vs. Spring N Summary

Corn Yield: often higher with Spring N

Nitrate-N: Little difference in concentration or loss between Fall and Spring application, if proper/right N rate is used.

1999 tile water NO_3-N loading at Waseca vs. NO_3-N concentrations in the Le Sueur River 2.3 miles from Mankato.



Source of N

- Some fertilizer N sources perform better than others.

Spring N Source Study at Waseca

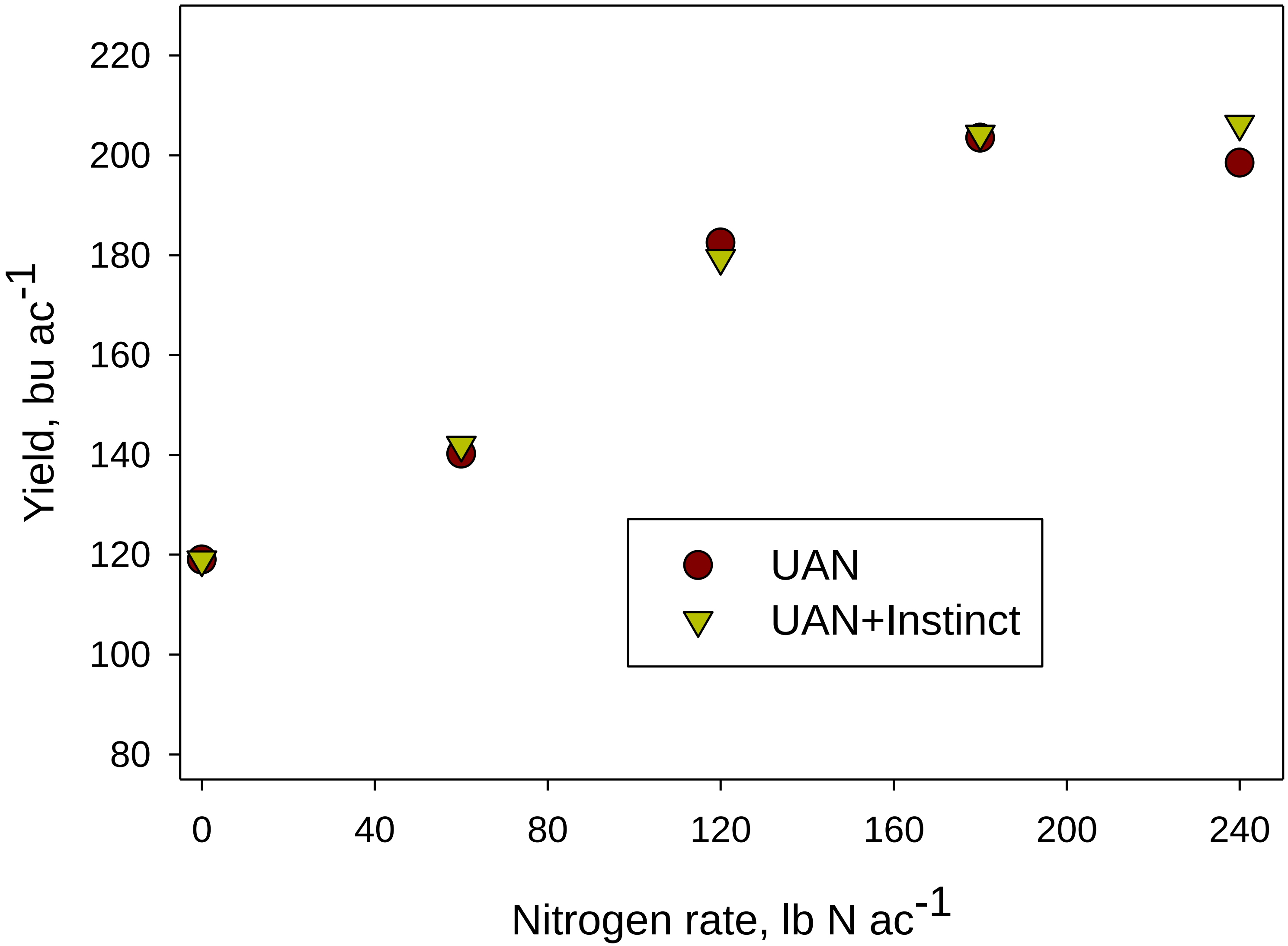
- Nitrogen Sources
  - AA, urea, UAN
- Time of N application
  - Preplant incorporated and pre-emerge
- Nitrification inhibitors
  - N-Serve™
- Corn following soybean at 100 lb N/ac

Spring Nitrogen Source (2007-2010)

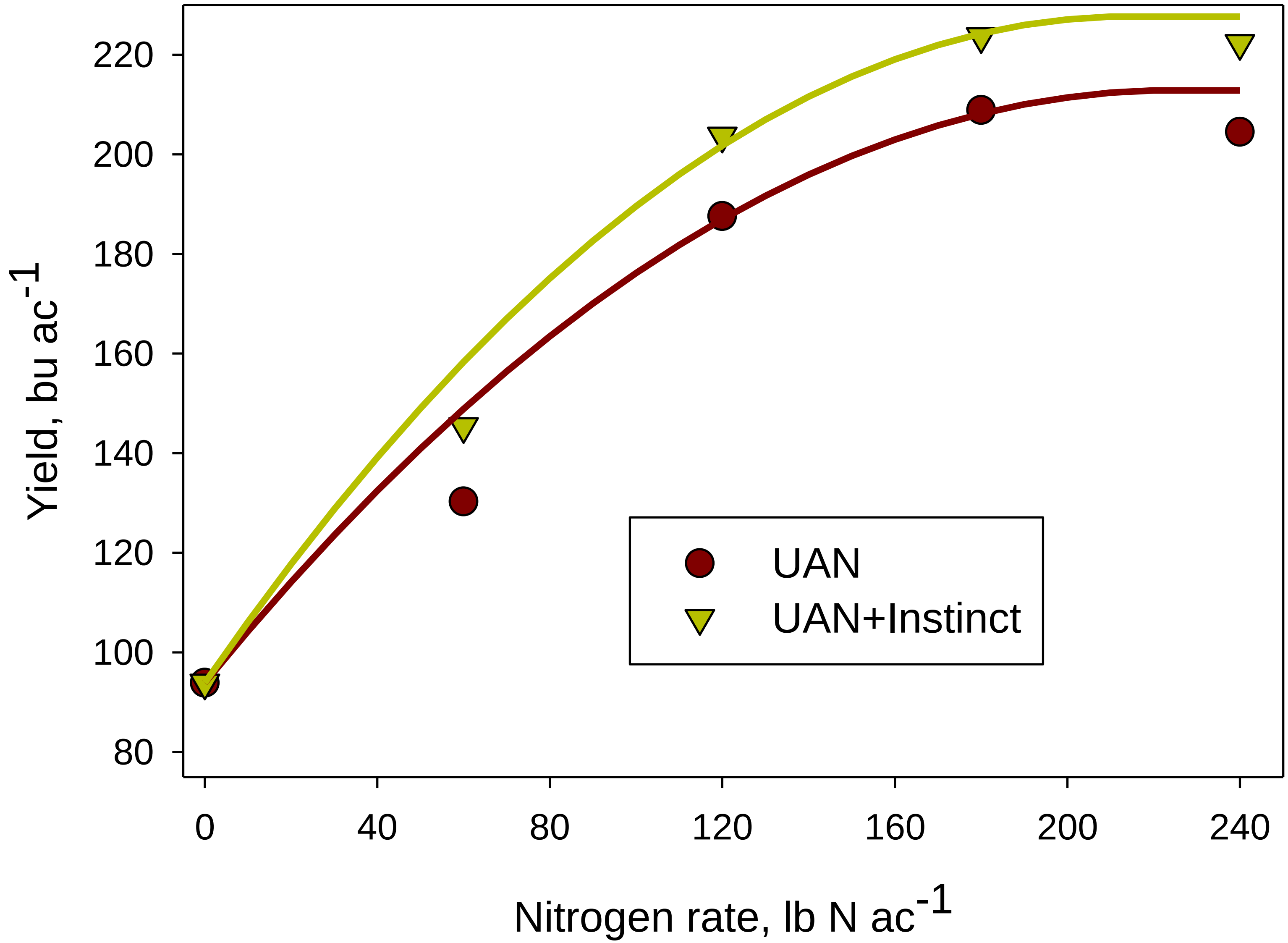
N	N Management		Grain	NUE
Source	Time	N-Inhibitor	Yield	Fert. N
			bu/A	bushel/lb N
Check	None	No	117 d	
AA	PP	No	170 ab	0.59
AA	PP	N-Serve	176 ab	0.60
Urea	PPI	No	182 a	0.66
UAN	PPI	No	171 bc	0.55
UAN	**Pre**	**No**	**166 c**	**0.49**

The Effects of Nitrogen Source and Time of Application with and without a Nitrification Inhibitor

Continuous corn yield as affected by N rate (UAN) and Instinct (Webster cl) in 2012.



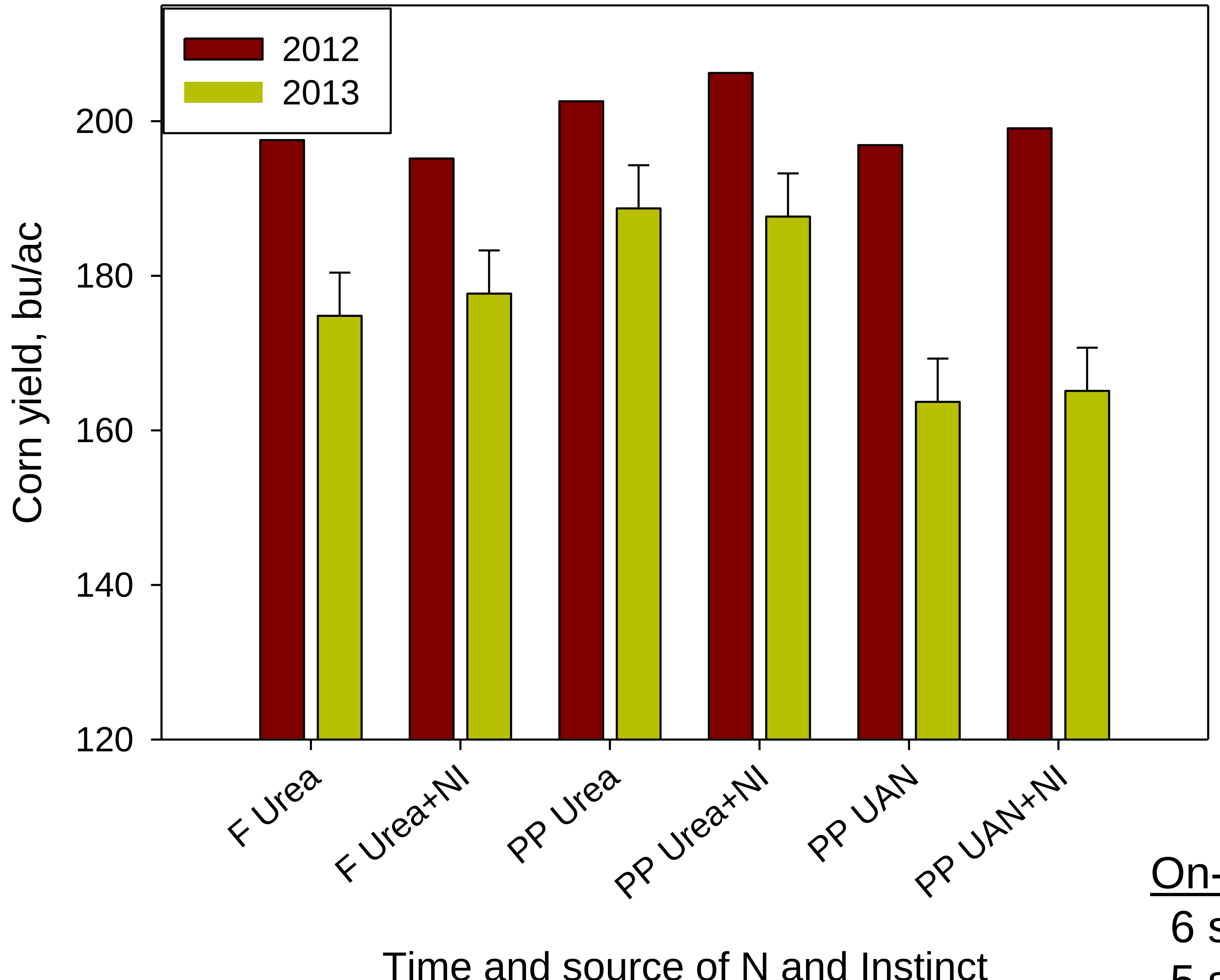
Continuous corn yield as affected by N rate (UAN) and Instinct (Webster/Nicollet cl) in 2013.



Corn yields as affected by Instinct and N rate (stream injected UAN at V2).

- In a dry spring (2012) corn grain yields were not affected by Instinct.
- In the wet spring of 2013 (6” of rain in 19 days after application) corn yields were greater with Instinct .

Corn yield as affected by N source, time of application and Instinct in south-central, MN.



<u>On-farm N study</u>

6 sites in 2012

5 sites in 2013

Effect of N Source and Timing on corn yield after soybean at Waseca.

N Treatment	Year 2011	2012	2013	3-Yr Avg.
	- - - - - Yield (bu/A) - - - - -			
Urea	188 a	168 a	193 ab	183
Urea + Instinct	187 a	170 a	197 a	185
AA	189 a	183 a	190 bc	187
AA + N-Serve	190 a	183 a	188 c	187
Fall	188 a	171 a	188 b	182
Spring	190 a	178 a	196 a	188
			Wet spr.	

2007 - 2010 Summary

Funding provided by AFREC

4-Yr Hydrologic Characteristics

	Precipitation		Drainage	
Year	May-Sept.	Departure	Total	Time
	inches	%	Ac-in	
2007	24.99	+22	11.6	48% in Oct.
2008	17.01	-17	3.3	91% in A-Jun
2009	11.00	-46	0.8	64% in O-Nov.
2010	34.61	+69	21.0	28% in Mar.
				46% in Sept.

Funding provided by AFREC

4-Yr Nitrate-N Results

Crop	N		Nitrate-N	
Rotation	Rate	Time	4-Yr Avg. Conc.	4-Yr Total
	lb/A		mg/L	lb/A
C-S-Corn	0	--	6.1	37.7
“	60 + 40	SPL	7.8	44.8
“	120	PP	8.2	52.1
S-C-Corn	0	--	4.6	34.0
“	60 + 80	SPL	7.9	64.2
“	160	PP	8.8	62.8
C-C-Soy	0	--	5.5	30.5
“	0	--	8.4	40.9
“	0	--	8.7	38.3

Funding provided by AFREC

4-Yr Corn Yield Results

Crop Rotation	N Rate	N Time	Grain Yield	Total N uptake	NUE
	lb N/A		bu/A	lb N/A	bu/lb N
C-S-Corn	0	--	113	72	--
"	60 + 40	SPL	182	141	0.69
"	120	PP	186	142	0.61
	Significance:		NS	NS	--
S-C-Corn	0	--	66	45	
"	60 + 80	SP	172	135	0.76
"	160	PP	165	137	0.62
	Significance:		NS	NS	--

Funding provided by AFREC

<u>4-Yr Corn Yield Summary</u>

1) Corn yields were 15 bu/A (9%) greater for C-S-<u>Corn</u> than for S-C-<u>Corn</u>.
2) Corn grain yield and total N uptake were similar between the 100% preplant N rate and the 85% N rate split-applied.
3) NUE (bu/lb N) was consistently greater for the split-applied 85% N rate. (Need to consider economics).

Funding provided by AFREC

Acknowledgement

- The authors are most grateful to the Agricultural Fertilizer Research and Education Council (AFREC) and Minnesota Corn Growers for financial assistance for this research project.

Funding provided by AFREC

CROPPING SYSTEMS

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.	Nitrate-N Loss
	Inches	ppm	lb/A
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

Conclusions

- Cropping system has greater effect on hydrology and nitrate losses than any other management factor! (RISK)
- Perennial crops (alfalfa and grasses) compared to row crops (corn and soybean) reduce
  - Drainage volume by 25 to 50%
  - Nitrate loss by > 95%

Relative effectiveness of management practices to reduce nitrate losses in ….

	Tile Drainage		Ground water
Practice	N. Corn Belt	S.&C. Corn Belt	N. Corn Belt
Cropping system	VH (100)*	VH	VH (100)*
Rate of N	L–H (10-40)	M-H	L-H (10-50)
Time of N	L (5-20)	M	M-H (20-50)
Source of N	VL (0-10)	VL	L (0-15)
Man. vs. Fert.			
Tillage	VL (0-10)	L	VL (0-10)
Cover crop	L (5-20)	M	L (5-20)

* Scale of effectiveness (0 – 100)

Engineered Tile Systems

- Controlled drainage
- Drainage through perennial buffers
- Bio-reactors
- Constructed wetlands
- Closed loop management
- Two-tier ditches

Christianson, L.E., and R.D. Harmel. 2015. 4R Water Quality Impacts: An assessment and synthesis of forty years of drainage nitrogen losses. J. Environ. Qual. October. Technical Report.

- Reviewed and quantitatively analyzed nearly 1000 site-years of subsurface tile drainage N load data to develop a more comprehensive understanding of the impacts of 4R practices (application of the right source of nutrients, at the right rate and time, and in the right places) within drained landscapes across North America.

- They concluded that some of the 4R practices for reducing nitrate-N loads were stronger than others.
  - Optimizing N rate was important and will continue to receive primary research and regulatory focus
  - The lack of significant differences between N application timing or application methods (placement and source) was inconsistent with the current emphasis placed on timing as a WQ improvement strategy.
    - ✓ Application timing analysis was complicated by differences in application rates between timing treatments; highest application rates resulted in greatest N losses.

Will the 4R approach to N management be successful in reducing nitrate-N losses to surface and ground water to meet the goals of Nitrogen Loss Reduction Strategies being established??

- They are directionally correct but will NOT accomplish the goals themselves.
- Engineering options can be helpful depending on geographic location and landscape.
- Shifting acreage away from corn to other cropping systems is the most effective strategy as it decreases N inputs to the landscape and consequently reduces N losses to water significantly.

Thanks

Questions?

Gyles Randall

http://sroc.cfans.umn.edu