Sulfur response of corn and wheat in ND and NW Minnesota

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Soil and Soil Water Workshop
January 22, 2019, Fargo, ND

NDSU NORTH DAKOTA STATE UNIVERSITY

NDSU Carrington Research Extension Center

PRESENTATION OUTLINE

- Background information on S
- Objectives
- Sites where the studies were conducted
- Materials and Methods
- Results
- Conclusions
- Considerations for farmers
- Outlook for future studies

BACKGROUND

- S deficiency concerns began in the 80's in Europe; 80's or early 90's in the US
- Reasons:
  - Low atmospheric S deposition
  - Greater S removal by higher yielding crops
  - More acreage of S demanding crops (alfalfa, canola)
  - Increased no-till acreage and high amounts of crop residues
  - Cold and excessive wetness or dryness reduce microbial breakdown of SOM an availability

- Deficiency symptoms
  - First appear on young leaves (light green to yellow). Why?
  - Light green and stunted plants

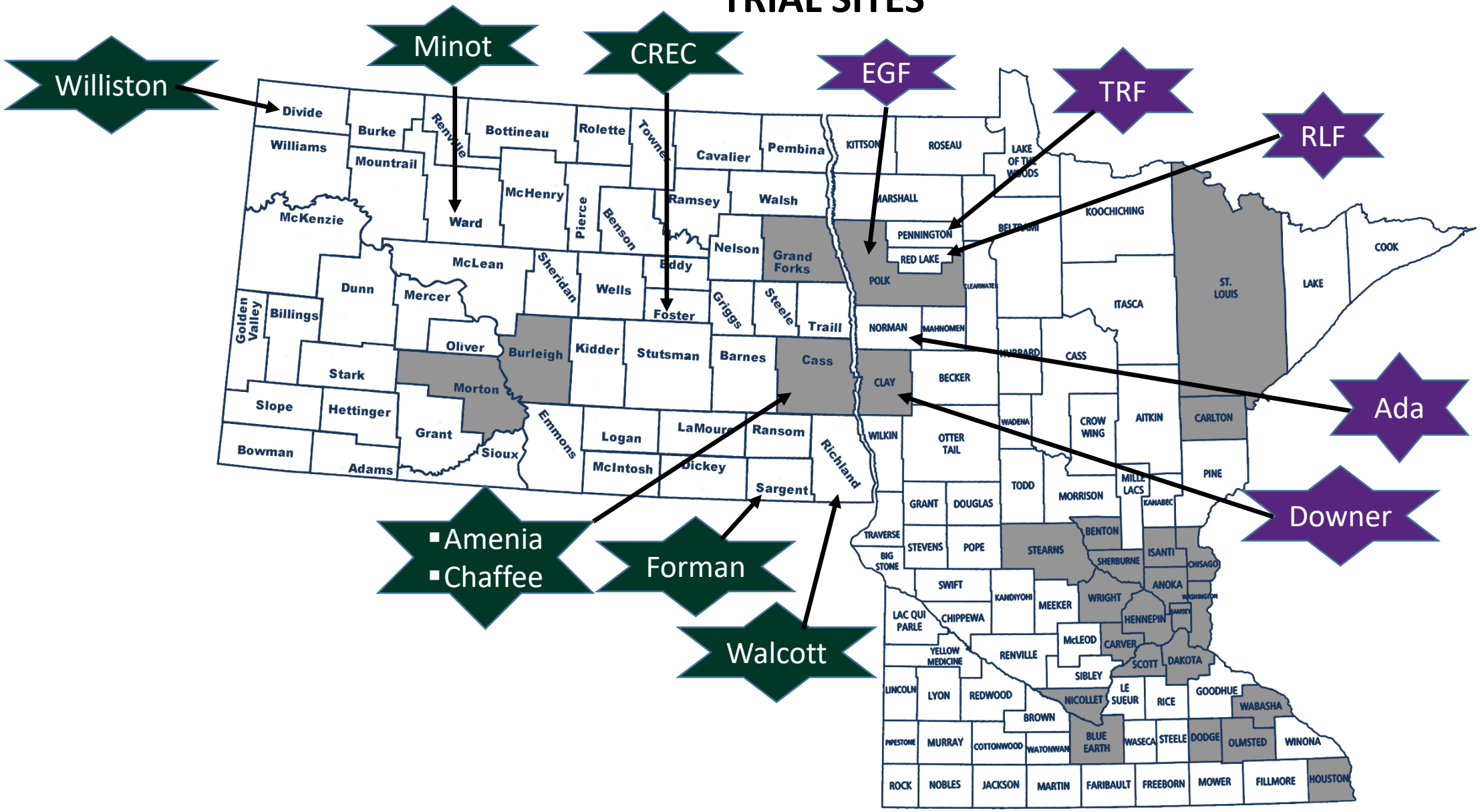
- Over generalization of immobility of S in plants (Monaghan et al., 1999)

OBJECTIVES

- Assess the impact of S on grain yields and protein
- Assess the economic implications of S fertilization?
- Determine if S application affects N need by the wheat and corn

MATERIALS AND METHODS

TRIAL SITES



Map Courtesy: http://geology.com/county-map/minnesota.shtml

MATERIALS AND METHODS

WHEAT TRIALS

- N and S Rates in Western MN (2015 to 2017)
  - 0, 60, 120, 180, 240 lbs N/ac
  - 0, 10, 20 lbs S/ac (source: ammonium sulfate)

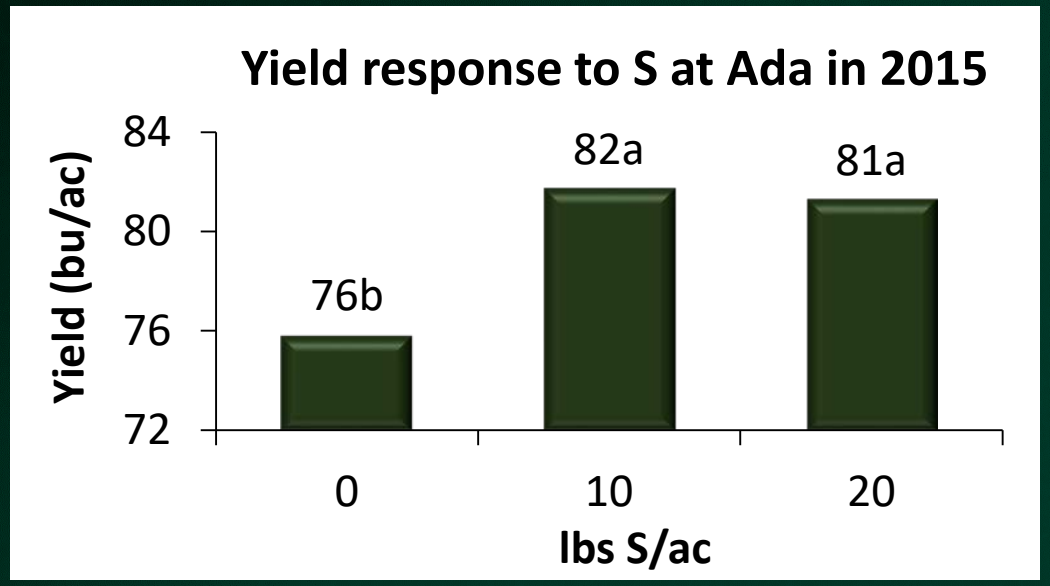
- N and S rates in ND (2014 to 2017)
  - 0, 50, 100, 150, 200 lbs N /ac
  - 0, 10, 20, lbs S/ac (source: ammonium sulfate)

- Experimental design: RCBD with a split-plot arrangement
- Four replicates at each site

RESULTS (WHEAT, MN)

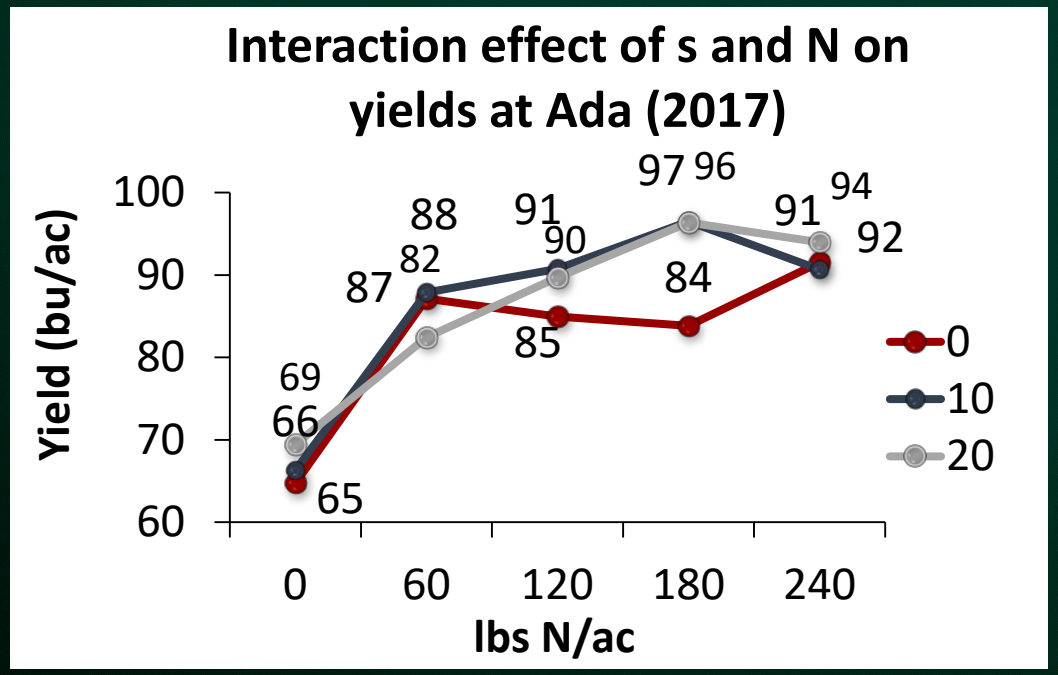
Yield and protein response to S and N in Minnesota (ANOVA)

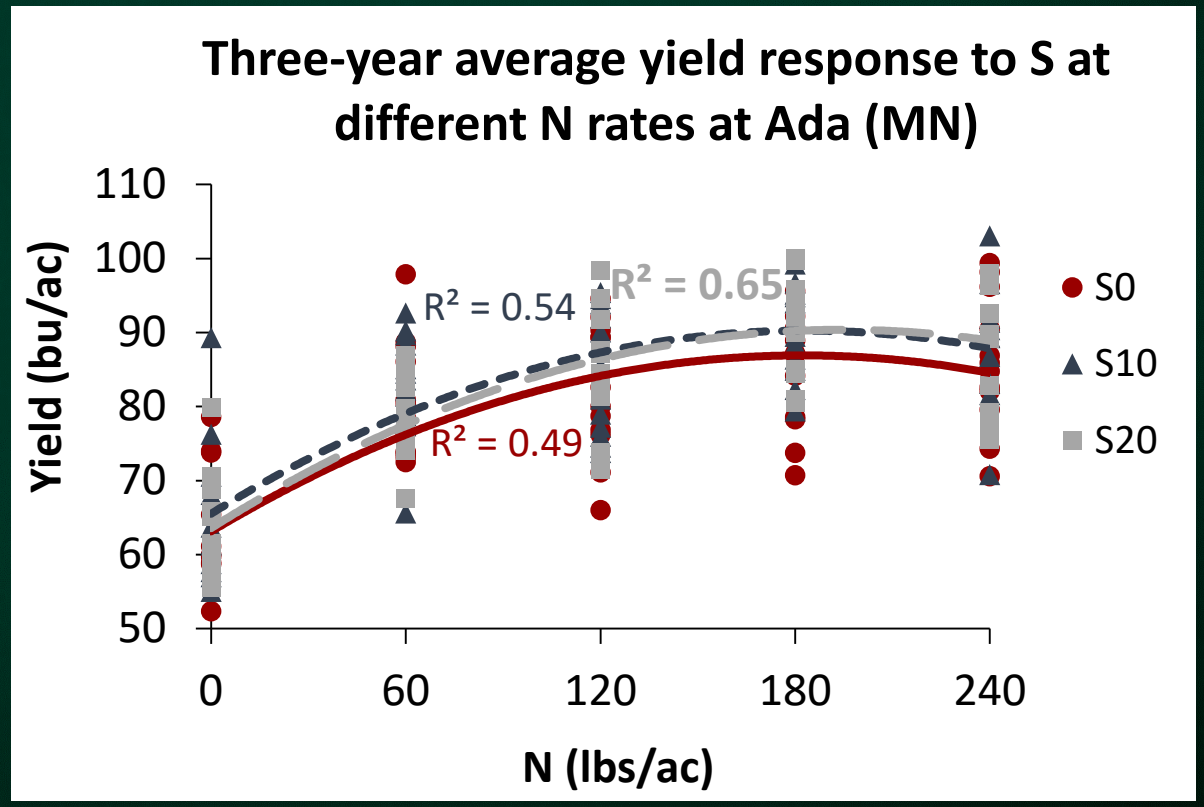
		Ada		Thief River Falls		East Grand Forks	
		Sandy Loam, SOM = 2.3%		Sandy Loam, SOM = 2.3%		Silty Clay Loam, SOM = 3.7%	
Year	**Effect**	**Yield**	**Protein**	**Yield**	**Protein**	**Yield**	**Protein**
2015	N	**<0.0001**	**<0.0001**	ns	**<.0001**	ns	**0.0067**
	S	**0.0031**	**0.0435**	ns	**0.0456**	ns	ns
	N x S	ns	ns	ns	ns	ns	ns
		Ada		**Thief River Falls**		**Red Lake Falls**	
		Sandy Loam, SOM = 2.4%		Sandy Loam, SOM = 2.6%		Loam, SOM = 3.6%	
2016	N	**<.0001**	**<.0001**	**0.0029**	**<.0001**	**0.028**	**<.0001**
	S	ns	ns	**<.0001**	ns	ns	ns
	N x S	ns	ns	ns	ns	ns	ns
		Ada				**Gentilly**	
		Sandy Loam, SOM = 2.6%				Loam, SOM = 3.2%	
2017	N	**<.0001**	**<.0001**			**0.0223**	**<.0001**
	S	**0.0112**	ns			ns	ns
	N x S	**0.0239**	ns			ns	ns



Significance of treatment effects on 3-year average yields (2015 -2016) at Ada

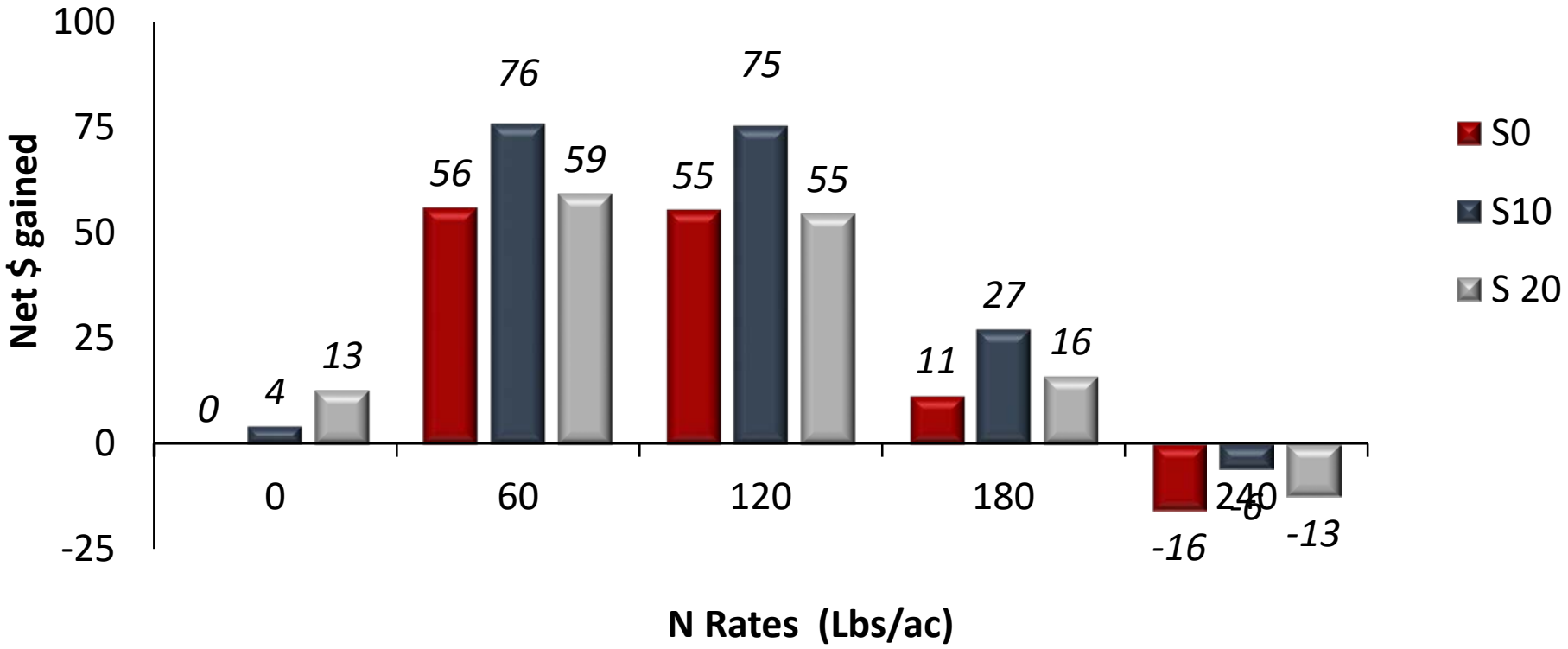
N	**<.0001**
S	**0.0766**
N x S	0.8602





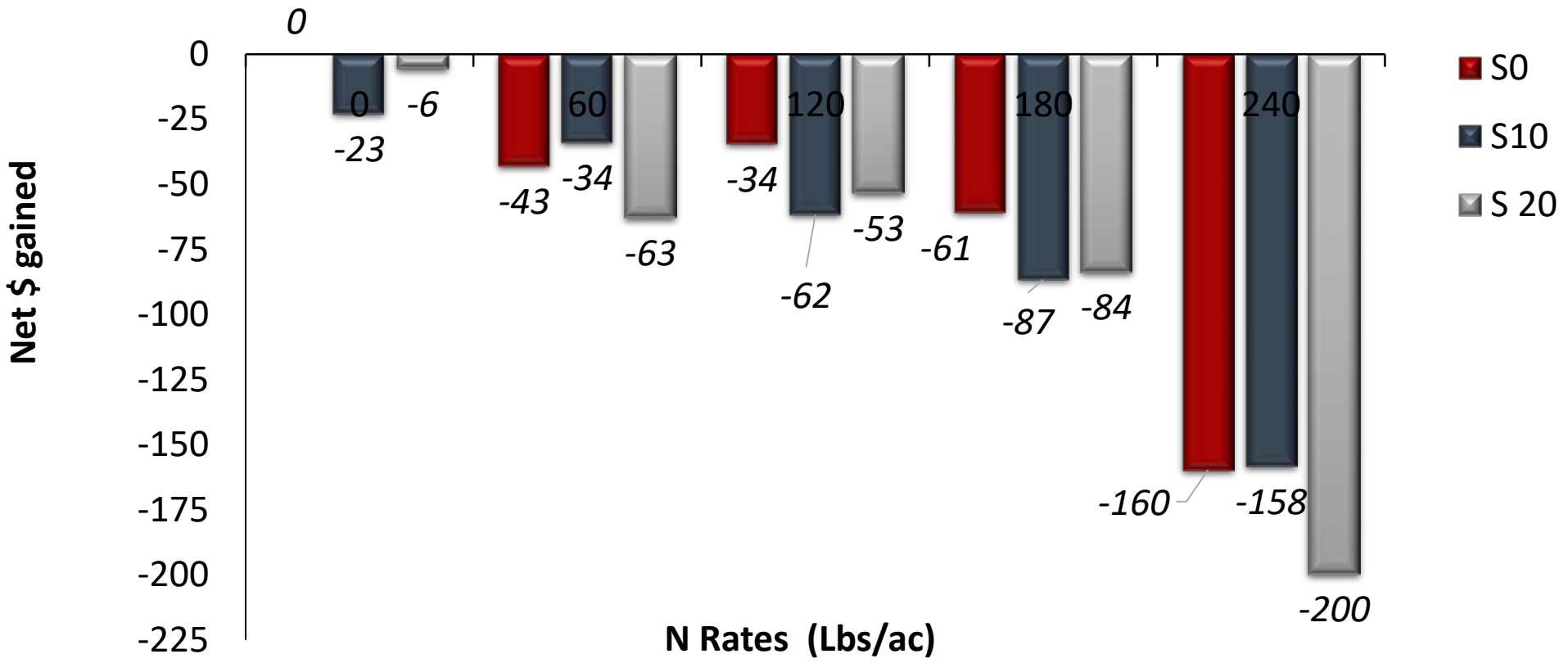
Estimates of how much N to maximize wheat yields (averaged across three years) at three S rates at Ada, MN (2015 - 17)			
S Rate	Estimated N (lbs/ac) to Maximize yield	Estimated maximum yield (bu/ac)	Estimated N (lbs) to produce a bushel
S0	186	87	2.13
S10	193	92	2.11
S20	197	91	2.17

Net gain in income due to N and S fertilizer applied with versus the control treatment (No added N or S), Ada (2015)

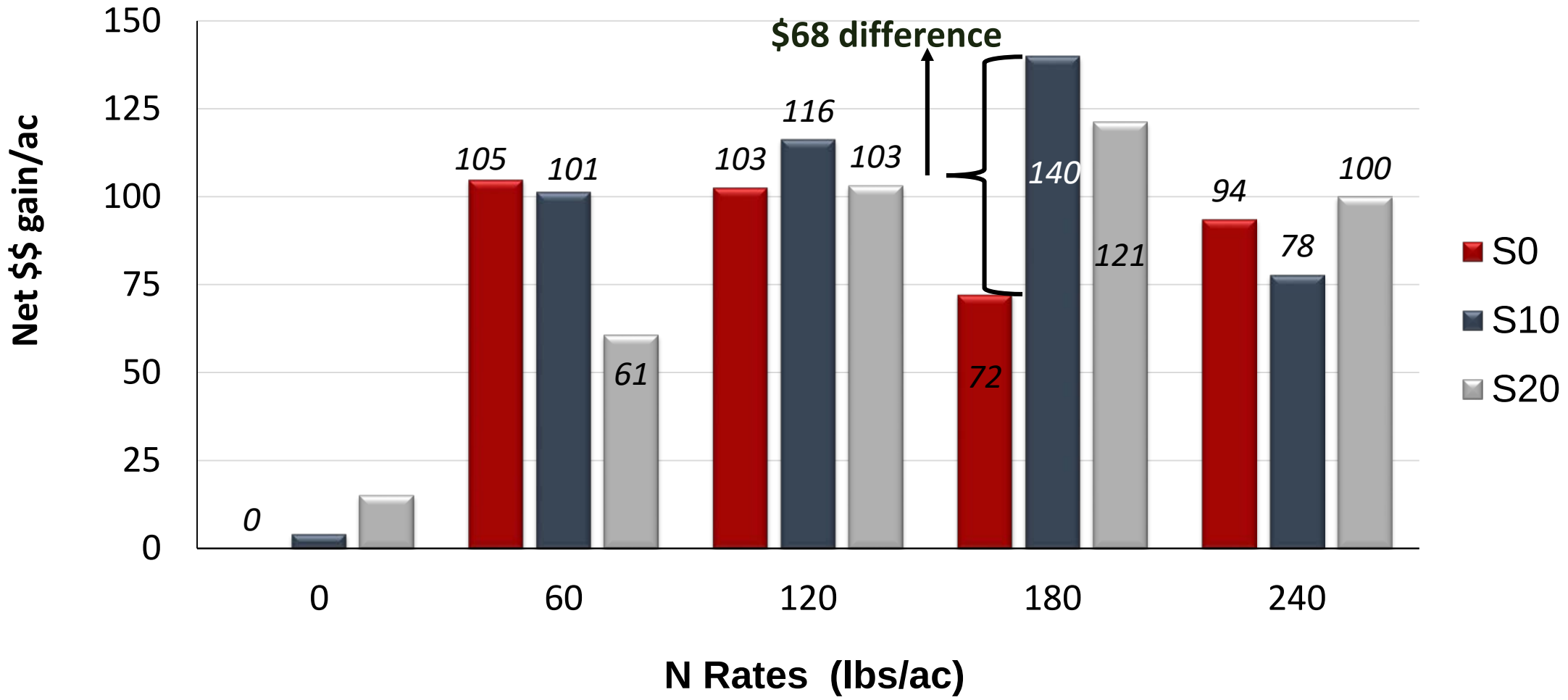


Urea N ($/lb)	0.4
AS ($/lb)	0.7
Application ($/A)	6.2

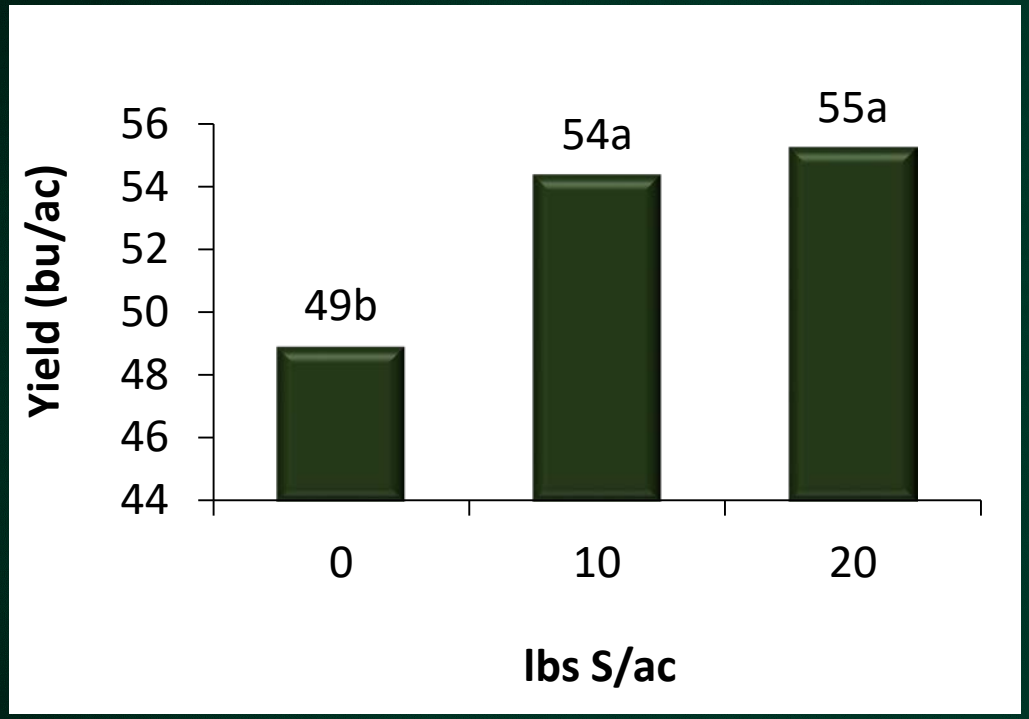
Net gain in income due to N and S fertilizer applied with versus the control treatment (No added N or S), Ada (2016)



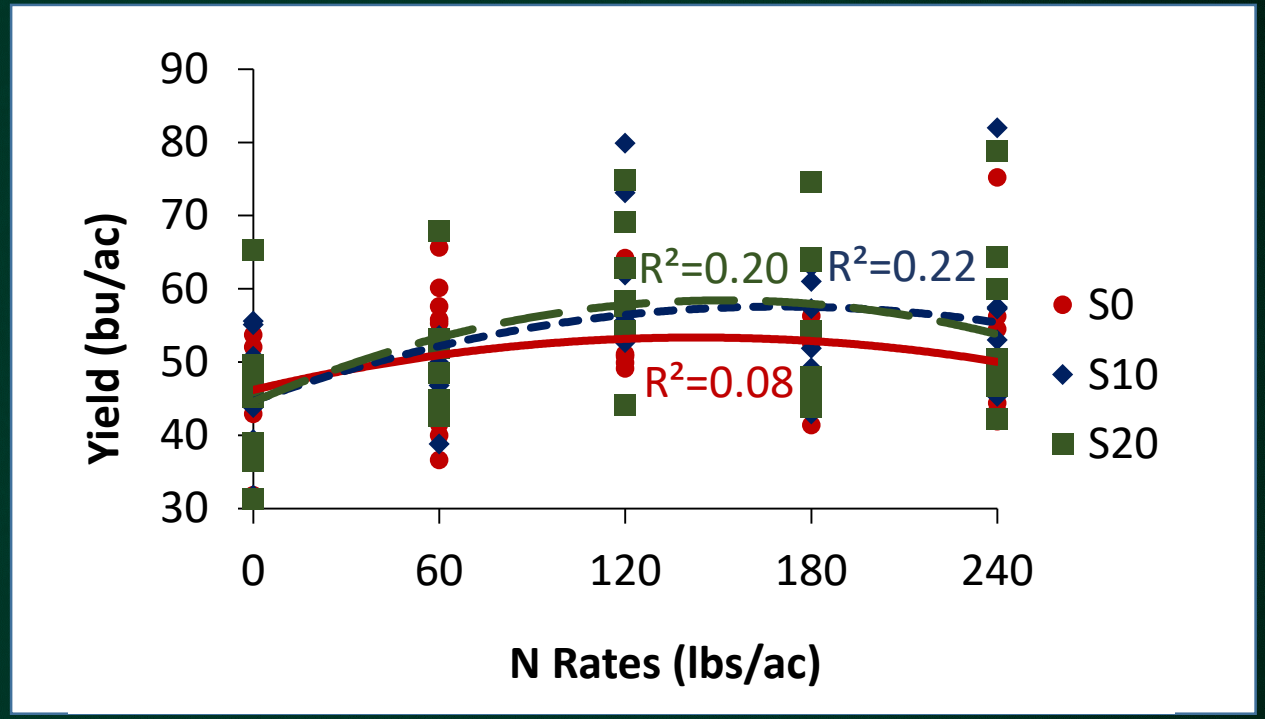
Net $$ gained from N and S fertilizer applied versus the control treatment (no added N or S), Ada (2017)



Yield response to S at Thief River Falls in 2016



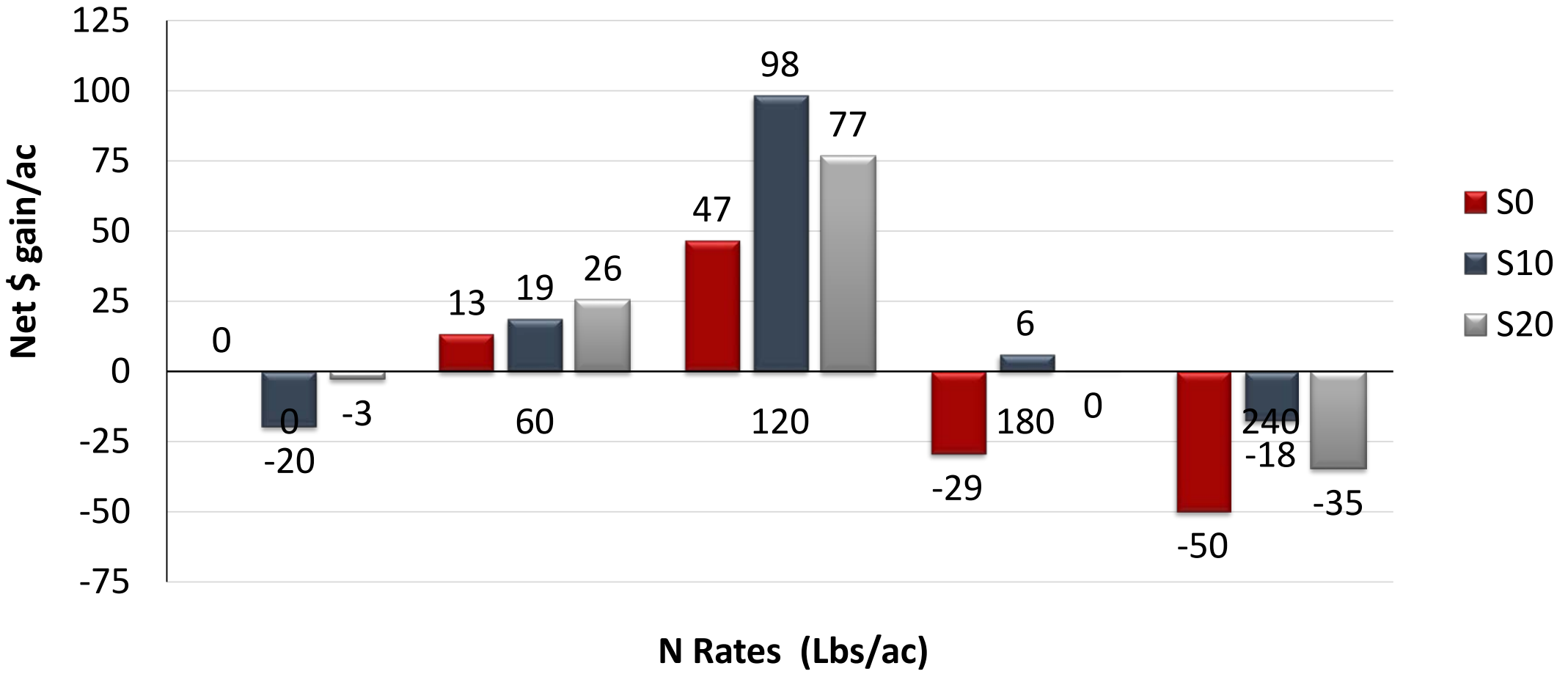
Wheat yield (2-yr average) response to S at different N rates at TRF (MN)



Significance of treatment effects on 2-year average yields (2015 and 2016) at TRF

N	**<.0044**
S	0.3087
N x S	0.8404

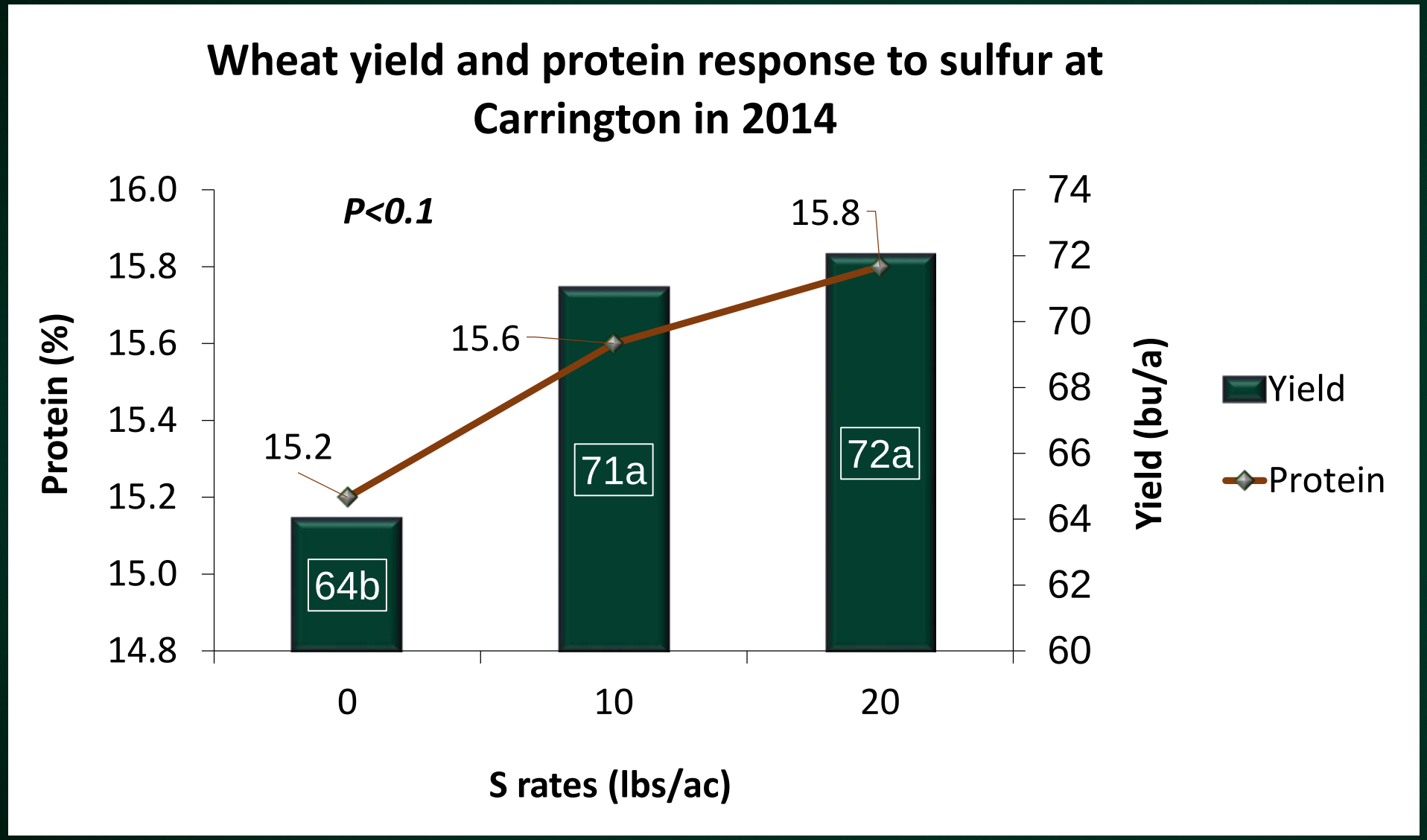
Net $ gained from N and S fertilizer applied versus the control treatment (No added N or S), TRF (2016)



Coefficients of determination (R^2) relating yield and protein to flag leaf S, N, and N:S ratio at Ada and TRF

	2015		2016		2017	
Effects	Yield	Protein	Yield	Protein	Yield	Protein
	Ada					
S	**0.52**	0.10	0.39	0.4**9**	**0.59**	0.30
N	**0.68**	**0.67**	0.04	**0.59**	**0.76**	**0.67**
N:S ratio	0.18	0.20	0.07	0.04	0.13	0.00

Effects	TRF			
S	0.012	0.05	0.27	0.006
N	0.030	0.20	0.32	0.045
N:S ratio	0.002	0.04	0.08	0.002

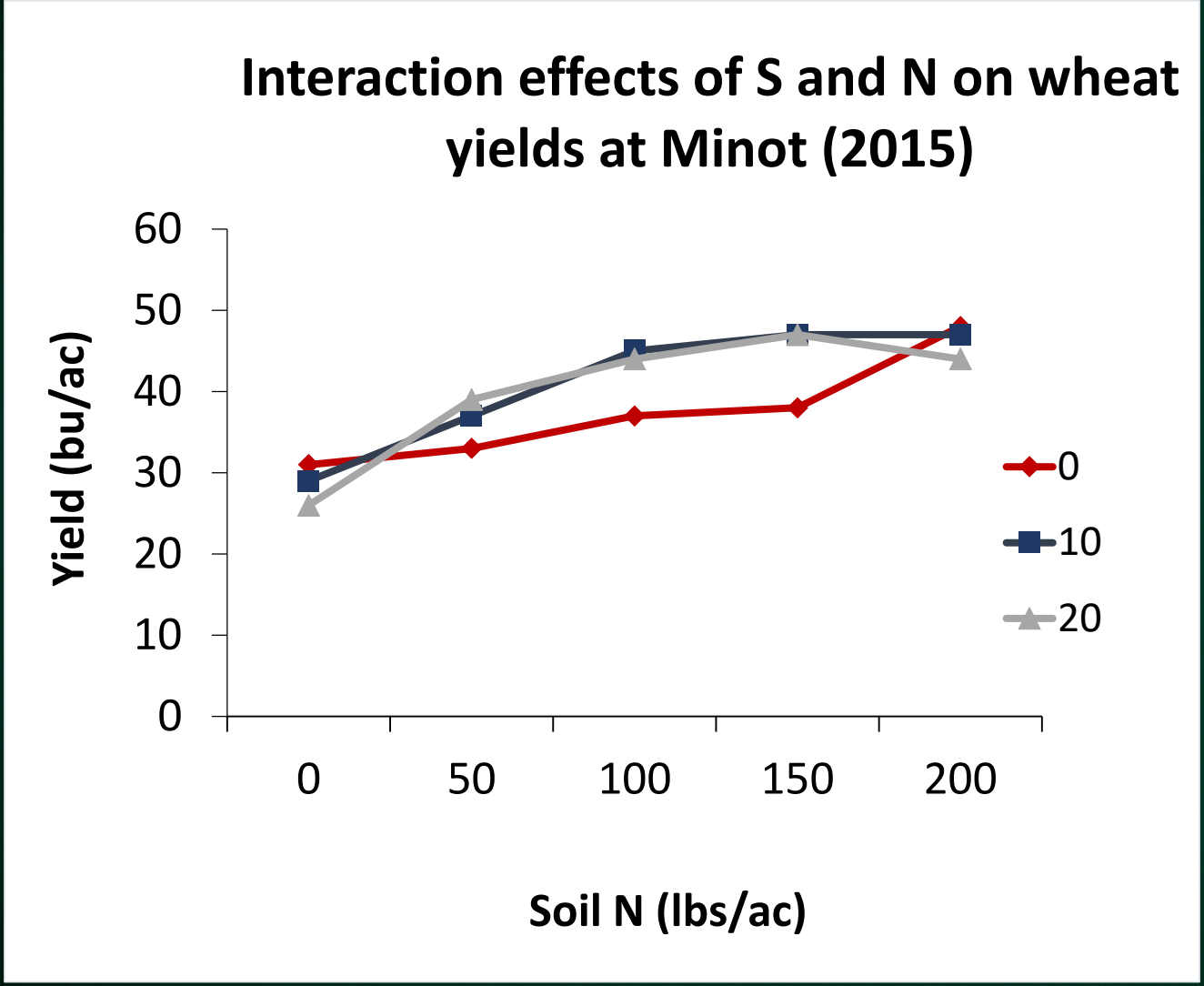


Site description
SOM: 4%
Texture: Loam
N rate: 150 lbs

- Site description: SOM was 4%, loam soil, N rate at 150 lbs

Significance of N and S effects on grain yield and protein of wheat loam soils in ND

		Carrington		Minot		Forman		Williston	
Year	Effects	-------SOM = 4.4%-------		------SOM = 2.8%------					
		Yield	Protein	Yield	Protein				
2015	N	0.1102	**0.0089**	**<.0001**	0.0853				
	S	0.9786	0.1067	**0.0003**	0.3567				
	N x S	0.0559	0.1380	**<.0001**	0.2047				
		Yield	Protein	Yield	Protein	Yield	Protein	Yield	Protein
		------SOM = 3.6%-----		-----SOM = 3.3%-----		-----SOM = 4.5%-----		-----SOM = 2.3-----	
2016	N	0.9281	**<.0001**	0.1053	**<.0001**	0.1053	**<.0001**	0.1507	**<.0001**
	S	0.5069	0.9611	0.6857	0.1651	0.6857	0.1651	**0.0002**	**0.0049**
	N x S	0.4004	0.8743	0.9738	0.1845	0.9738	0.1845	0.9880	**0.0001**
		Yield	Protein	Yield	Protein	Yield	Protein		
		------SOM = 2.6%-----				-----SOM = 3.2%-----			
2017	N	**0.0248**	**0.0016**			**<.0001**			
	S	0.7516	0.4512			0.6302			
	N x S	0.1468	0.9829			0.9964			



- S fertilizer resulted in significant yield improvement from the control at 100 and 150 lbs N
- Where N rates were too low (≤ 60 lbs) or too high (200 lbs), yield differences were not significant between S fertilized treatments and the control

Net $$ gained from N and S application, versus the control treatment (No added N or S), Minot (2015)

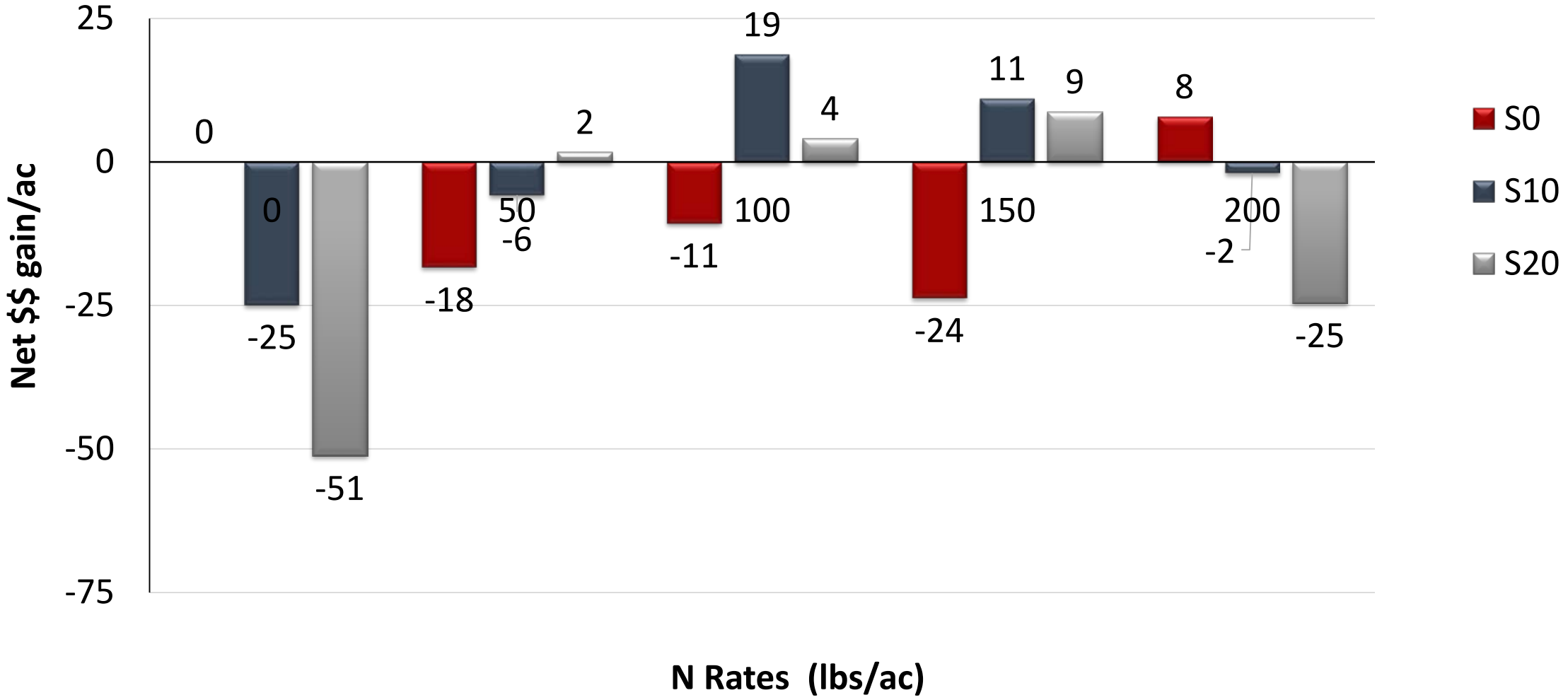
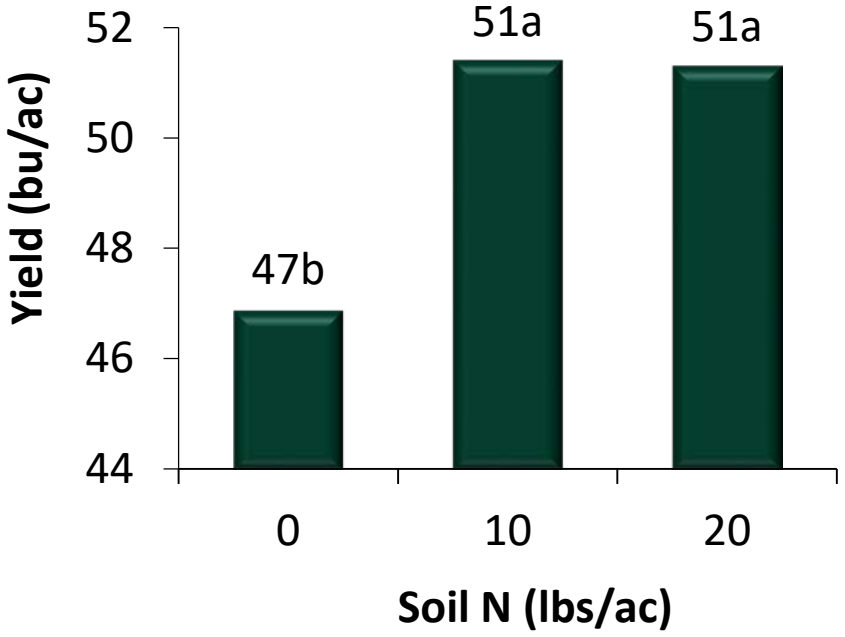
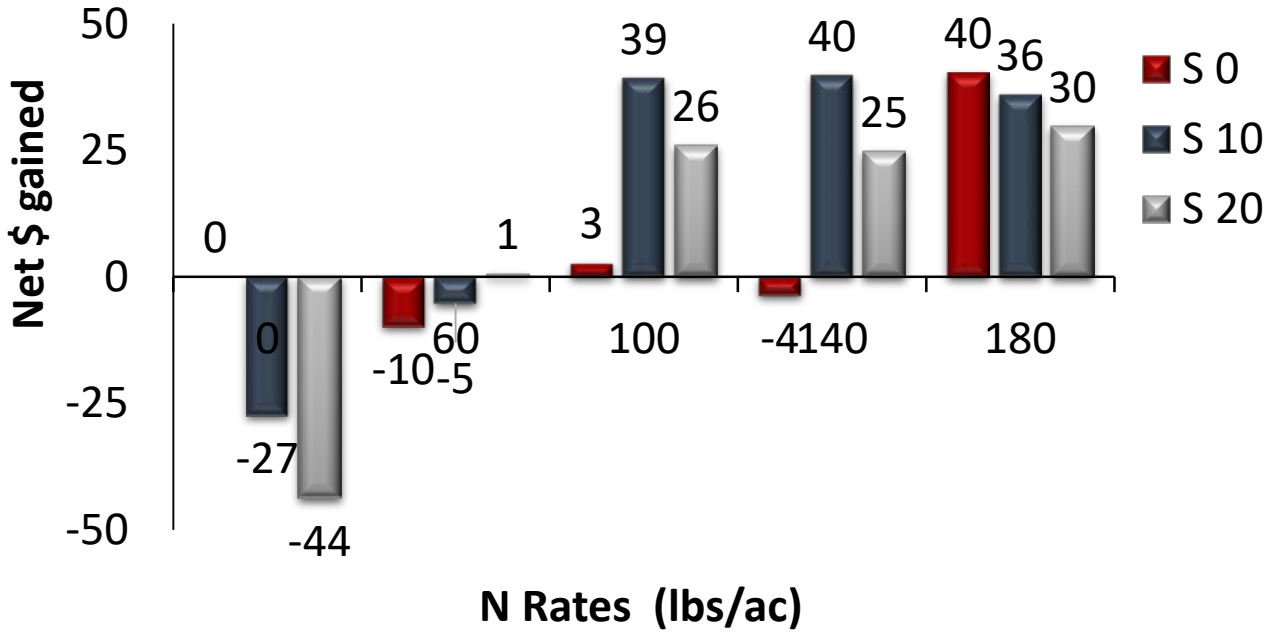


Fig 1. Effect of S on wheat yields at five N rates (Williston, 2016)

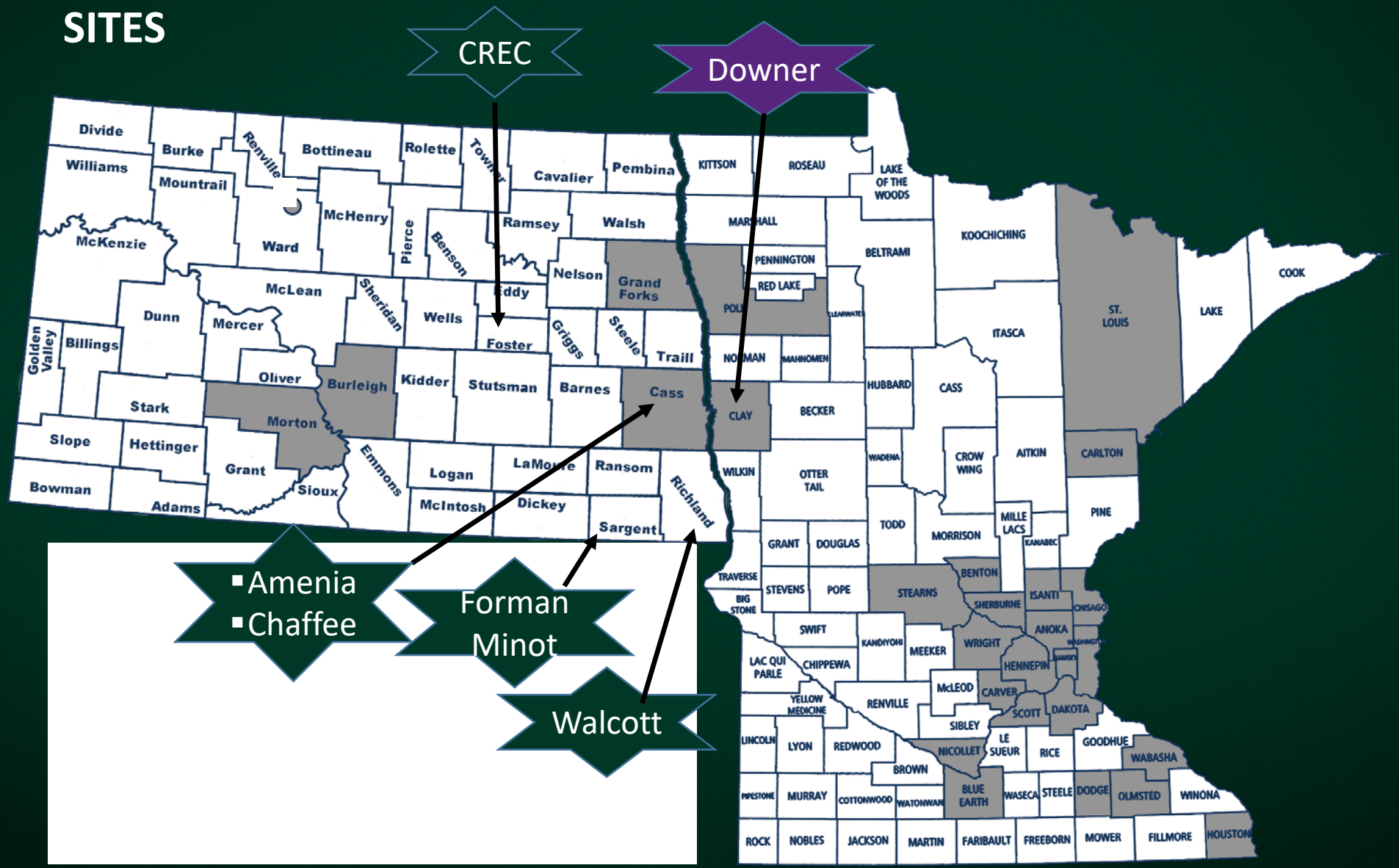


Net gain in income due to N and S fertilizer applied with versus the control treatment at Williston (2016)



CORN TRIALS MATERIALS AND METHODS

SITES



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Map Courtesy: http://geology.com/county-map/minnesota.shtml

MATERIALS AND METHODS
Corn S x N

Sites and years

Forman, 2016

- N - blanket N rate (220 lbs/ac)
- S Rates: 0, 10, 20, 30, 40 lbs S/ac

Forman (2017); Oakes (2018 and 2019)

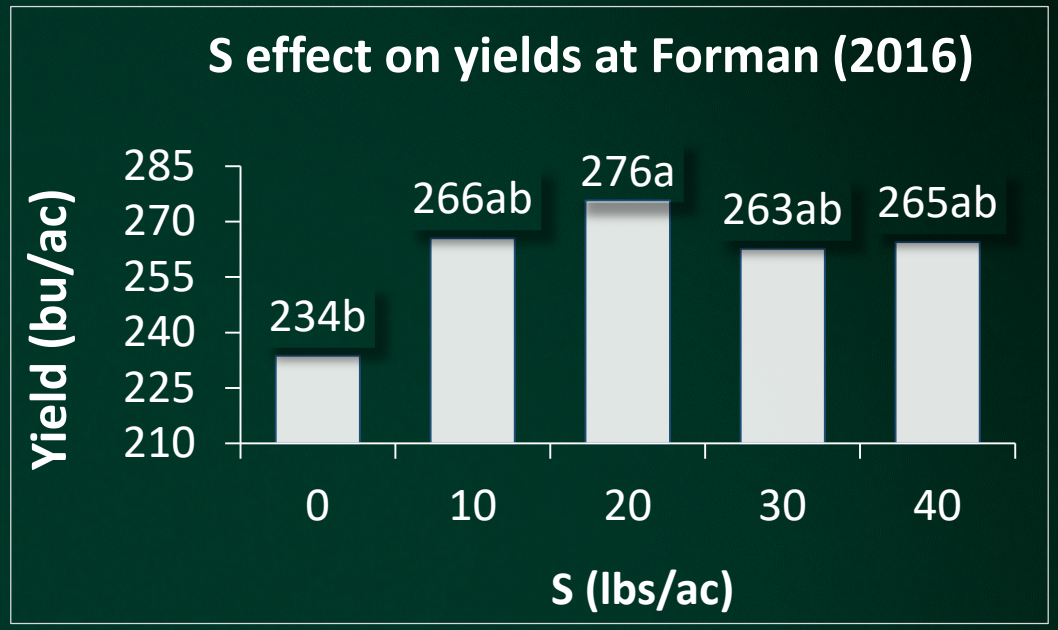
- N rates: 0, 60, 120, 180, 240 lbs N/ac
- S Rates: 0, 10, 20 lbs S/ac

- **Carrington**
  - N: 0, 25%, 50%, 100%, 125% recommended N rate/ac
  - S: 0, 10, 20 lbs S/ac

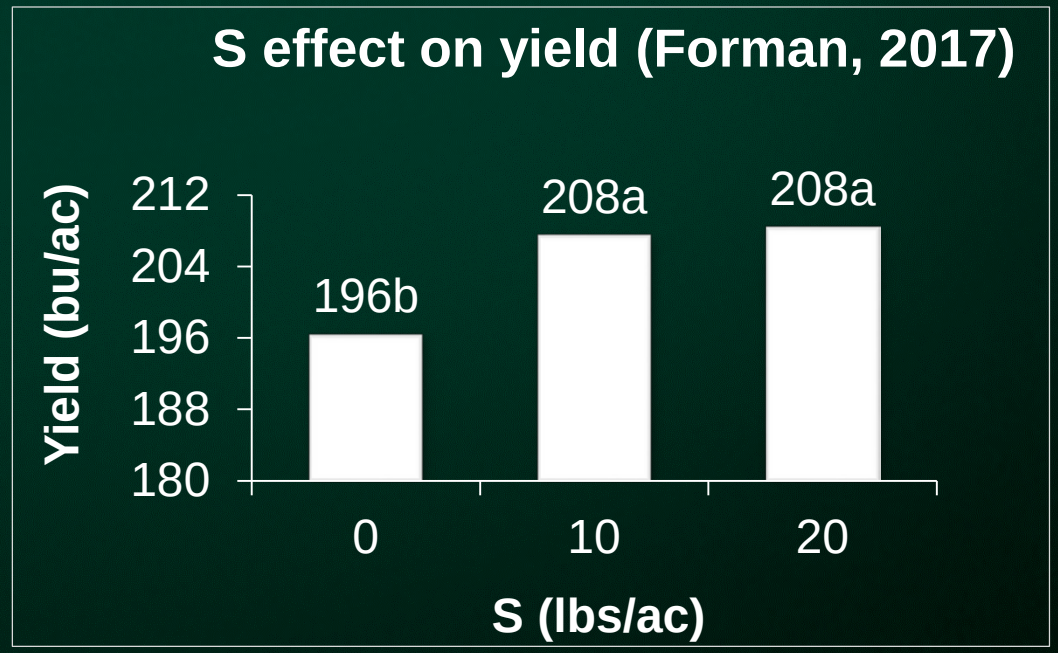
- Experimental design: RCBD with a split-plot arrangement
- Four replicates at each site

RESULTS

- Carrington (3 years), loam soil, SOM > 3%)
  - S did not impact yields at Carrington in any of the three years (2017 to 2019)



- Forman (2 years), loam soil, SOM > 3%
  - S significantly improved yields in 2016 and 2017



Effect of N and S rates on corn performance (Forman, 2017)

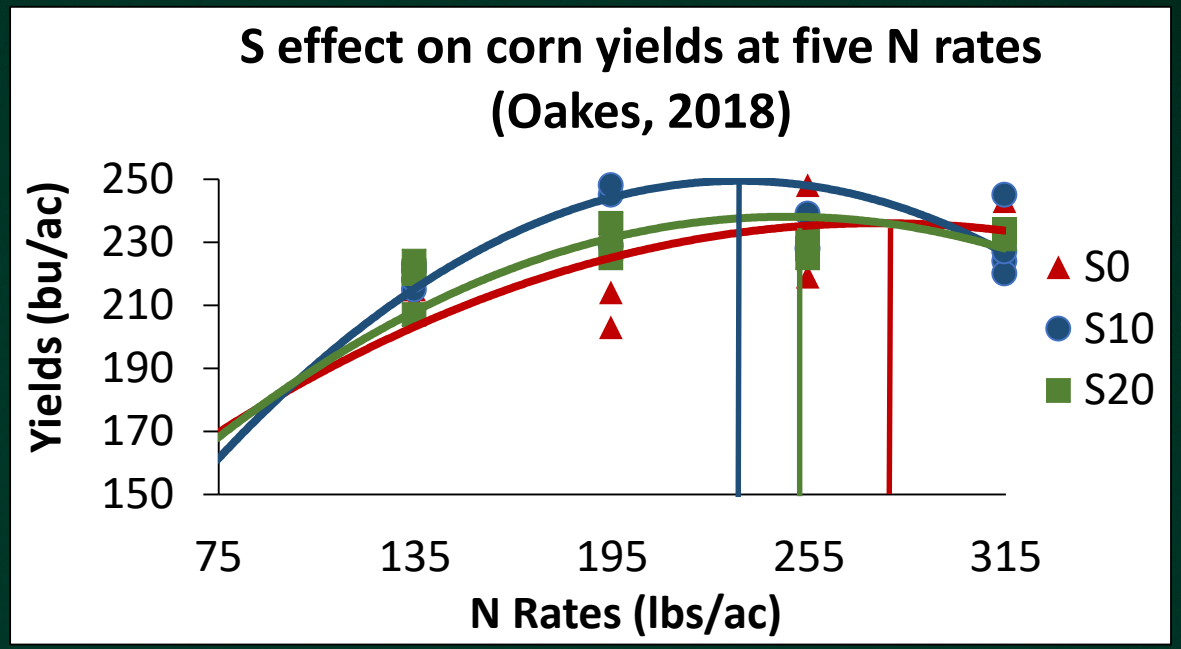
Treatments	Yield	TWT	Protein	Ear leaf N	Ear leaf S	N/S ratio
N (lb/a)	bu/ac	lb/bu	---------- % ----------			
0	168c	55.0	7.48	2.692c	0.170b	15.9b
60	195b	55.5	7.69	2.983b	0.182ab	16.4ab
120	212a	55.8	7.79	3.058b	0.185ab	16.5ab
180	217a	55.4	8.21	3.100ab	0.188ab	16.5ab
240	222a	55.4	8.39	3.333a	0.193a	17.4a
S (lb/a)						
0	196b	55.1b	8.05	2.950	0.175b	16.9
10	208a	55.5a	7.86	3.095	0.187ab	16.6
20	208a	55.6a	7.84	3.055	0.189a	16.1
Effects	----------*Pr > F*----------					
N	**<.0001**	0.1121	**0.0063**	**<.0001**	**0.0207**	**0.0051**
S	**0.0031**	**0.0501**	0.5484	0.1425	**0.0159**	**0.0542**
N x S	0.309	0.9045	0.2836	0.4888	0.3893	0.3391

Soil analysis		
SOM (0-6 in)	N (0-24 in)	S (0-24 in)
4.5%	15 lbs/ac	40 lbs/ac

Interaction effect of N and S on corn Yield at Oakes, 2018

Table 1. Corn treatments Oakes (2018)

Trt	N	S
#	---------Lbs/ac---------	
1		0
2	75	10
3		20
4		0
5	135	10
6		20
7		0
8	195	10
9		20
10		0
11	255	10
12		20
13		0
14	315	10
15		20



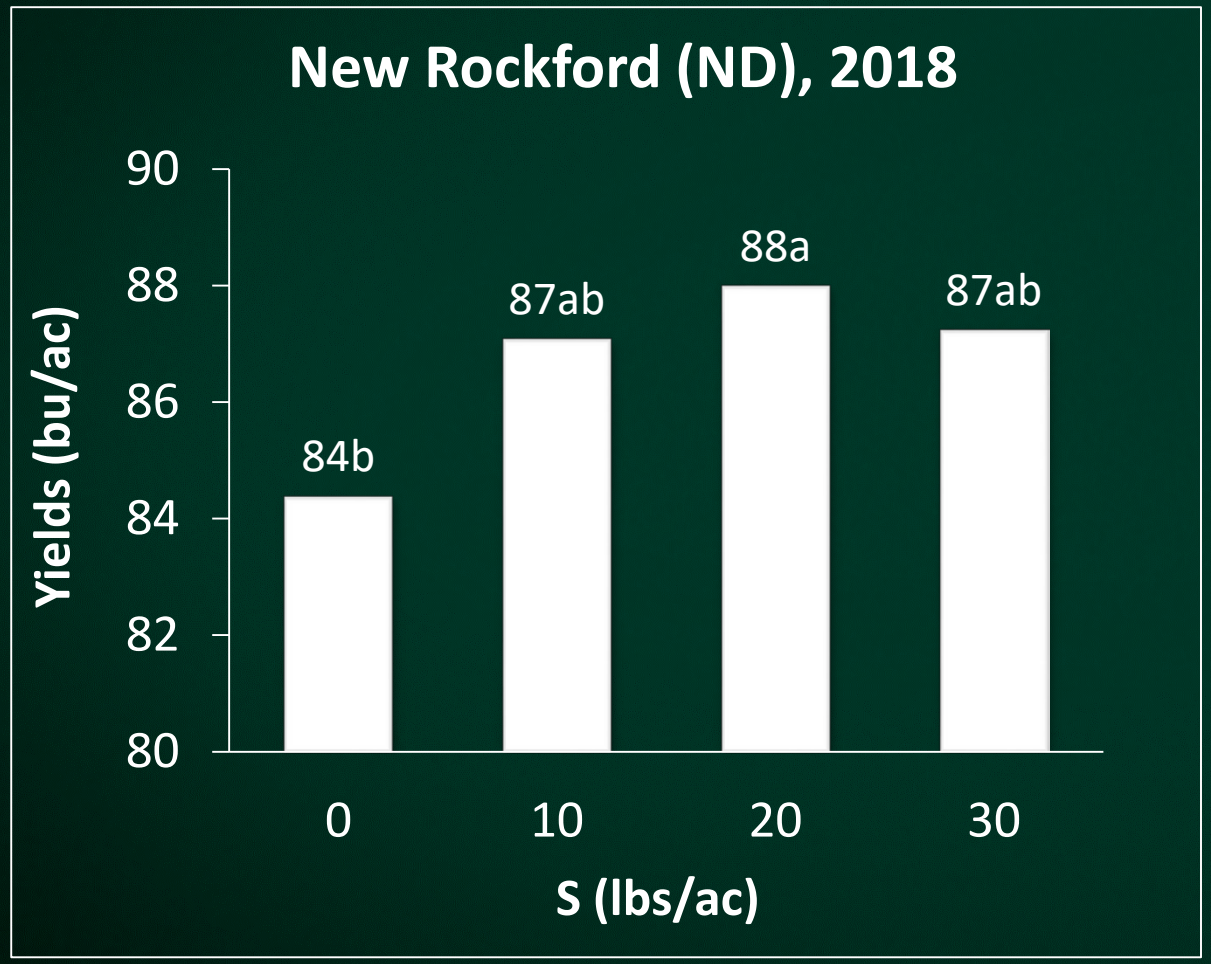
Predicted N requirement to produce maximum yield for each S level in 2018 and 2017

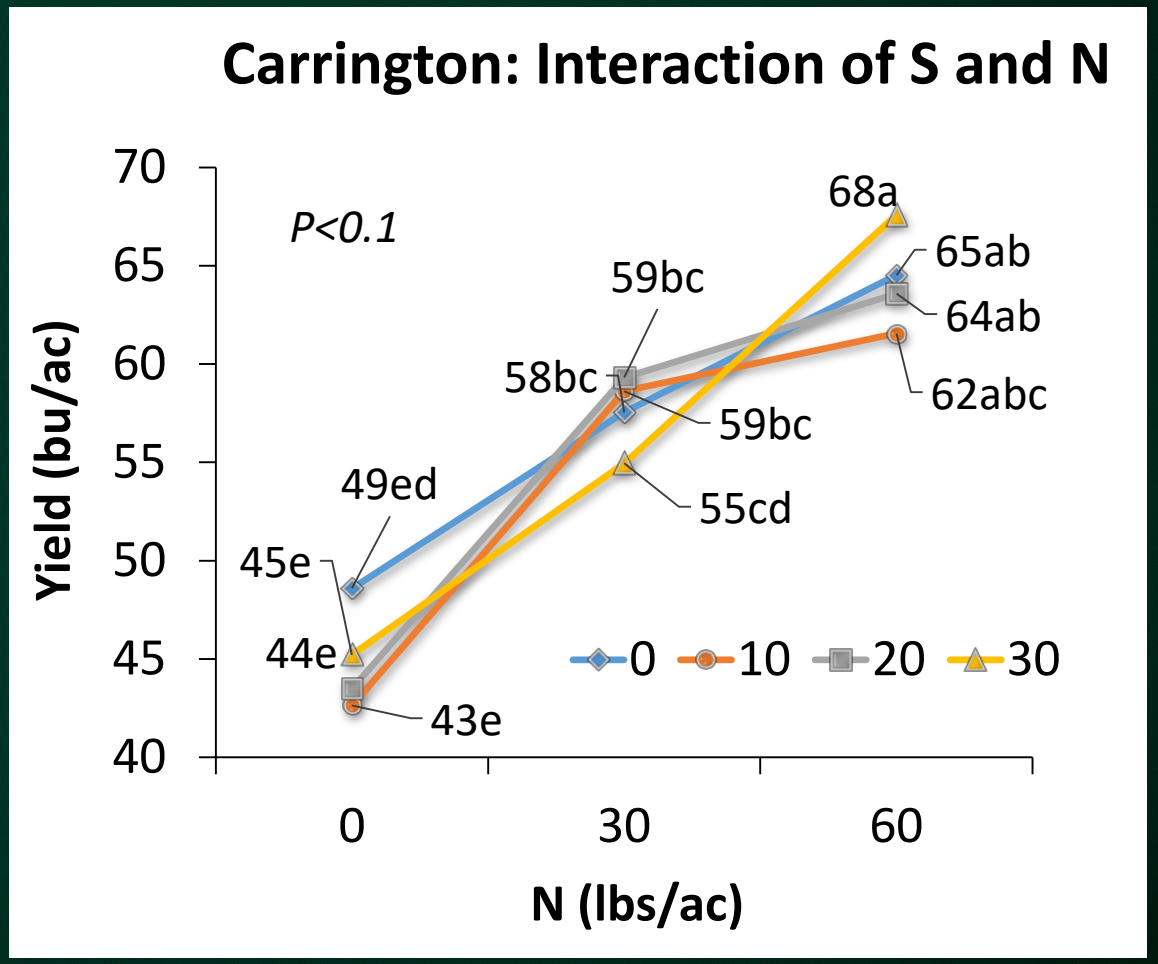
S Rates	Max yield (bu/ac)	N to max yield (lb/ac)	Max yield (bu/ac)	N to max yield (lb/ac)
lbs/a	-----Oakes 2018-----		-----Forman 2017----	
0	239	282	217	224
10	249	233	228	198
20	239	251	-	-

Corn trials at the following five sites did not did not produce significant yield response to S in 2019 (By Dr. Chatterjee)

- Ada (MN)
- Downer (MN)
- Chaffee (ND)
- Walcott (ND)
- Amenia (ND)

Effect of S on barley yields at New Rockford and Carrington (2018)





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S fertilizer considerations for wheat and corn

- Types of S fertilizers
  - Ammonium sulfate
  - K thiosulfate
  - Ammonium thiosulfate
  - Gypsum
  - Straight S (Crop response unlikely in same year of application)

- Where S will be more effective
  - On light soils (sandy) - response very likely
  - Medium texture (sandy loam, loam) soils – response probable to likely
  - Heavy soils (clay loam, clay) – unlikely

- How much to apply
  - 10 lbs of S is adequate and a safe economic rate to apply

SUMMARY

- S fertilizer improved wheat yields in 2 of 8 site-years in MN, and 2 of 8 site-years in ND
- Yield gain from S, ranged between 4 and 7 bushels

- An interaction S and N effect on grain yields suggests that, yields are more likely to improve from S application under adequate S supply, but less likely to influence yields when N is too low or too high

- The results also suggest that the range of N fertilizer rates that would result in profit is very narrow; implying that, very careful N management planning is key to ensuring optimum fertilizer use, and minimizing profit loss

- S significantly improved corn yields (up 30 bu/ac) in South East ND, probably because of the higher yield S demands, and cooler soils from the use of conservation tillage (strip till)
- Application of S above 10 lbs/ac is the maximum rate we would recommend for spring wheat

- 10 lbs S was enough to maximize wheat and corn yields. However, up to 15 lbs may be applied to fields with high risk of S loss through leaching (sandy soils, slopes), and on prolonged wet soils

- Including S in a fertilizer planning to avoid S deficiency is more efficient and less costly than correcting S deficiency

ACKNOWLEDGEMENT

- North Dakota Corn Council
- Minnesota Wheat Commission

Dae Torgerson

THANKS!

10 240	0 240	20 240	0 180	10 180	20 180	20 60	0 60	10 60	0 120	10 120	20 120	0 0	20 0	10 0
401	**402**	**403**	**404**	**405**	**406**	**407**	**408**	**409**	**410**	**411**	**412**	**413**	**414**	**415**
0 60	10 60	20 60	0 120	10 120	20 120	10 0	0 0	20 0	0 240	10 240	20 240	10 180	0 180	20 180
301	**302**	**303**	**304**	**305**	**306**	**307**	**308**	**309**	**310**	**311**	**312**	**313**	**314**	**315**
20 180	0 180	10 180	0 0	10 0	20 0	0 240	10 240	20 240	0 60	20 60	10 60	20 120	0 120	10 120
201	**202**	**203**	**204**	**205**	**206**	**207**	**208**	**209**	**210**	**211**	**212**	**213**	**214**	**215**
0 0	10 0	20 0	0 60	10 60	20 60	0 120	10 120	20 120	0 180	10 180	20 180	0 240	10 240	20 240
101	**102**	**103**	**104**	**105**	**106**	**107**	**108**	**109**	**110**	**111**	**112**	**113**	**114**	**115**

Border

Border

Table 1. Corn yield, grain quality, and ear leaf N and S response to N and S fertilization at Carrington and Oakes, ND (2018)

N Rate	Yield	TWT	Protein	Leaf N	leaf S
lbs/ac	bu/ac	lb/bu	----------%	----------	
0	162c	54.4c	7.22e	2.29c	0.229a
60	218b	55.7b	7.74d	3.40b	0.204ab
120	232a	56.0b	8.22c	3.64ab	0.188bc
180	235a	56.7a	8.55b	3.65ab	0.179bc
240	233a	57.0a	8.78a	3.71a	0.178c
S Rate					
0	214	55.9	8.10	3.49	0.175b
10	219	56.0	8.11	3.42	0.180b
20	215	56.0	8.10	3.50	0.223a
----------***Pr > F***----------					
		<0.000	**<0.000**		
N	**<.0001**	**1**	**1**	**<.0001**	**<.0001**
S	0.1277	0.832	0.9934	0.475	**<.0001**
N x S	**0.0281**	0.6856	0.3133	0.7438	**0.0004**

† Soil N was very high (183 lbs) at CREC. Means followed by same letter within a column of each group are not statistically different (p<0.1)

Significance of treatment effects on yield and protein at all MN sites

Effects	Yield	Protein
N	**<.0001**	**<.0001**
S	0.1200	0.6848
N x S	0.9386	0.4626
Year	**<.0001**	**<.0001**

Fig 1b. Agronomic efficiency of N (AEN), as a function of applied N at three S rates to corn (Oakes, 2018)