

Sulfur Use in Western MN, What We Know and What We Don't



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Agvise Soil Fertility
Seminars



Soil Fertility



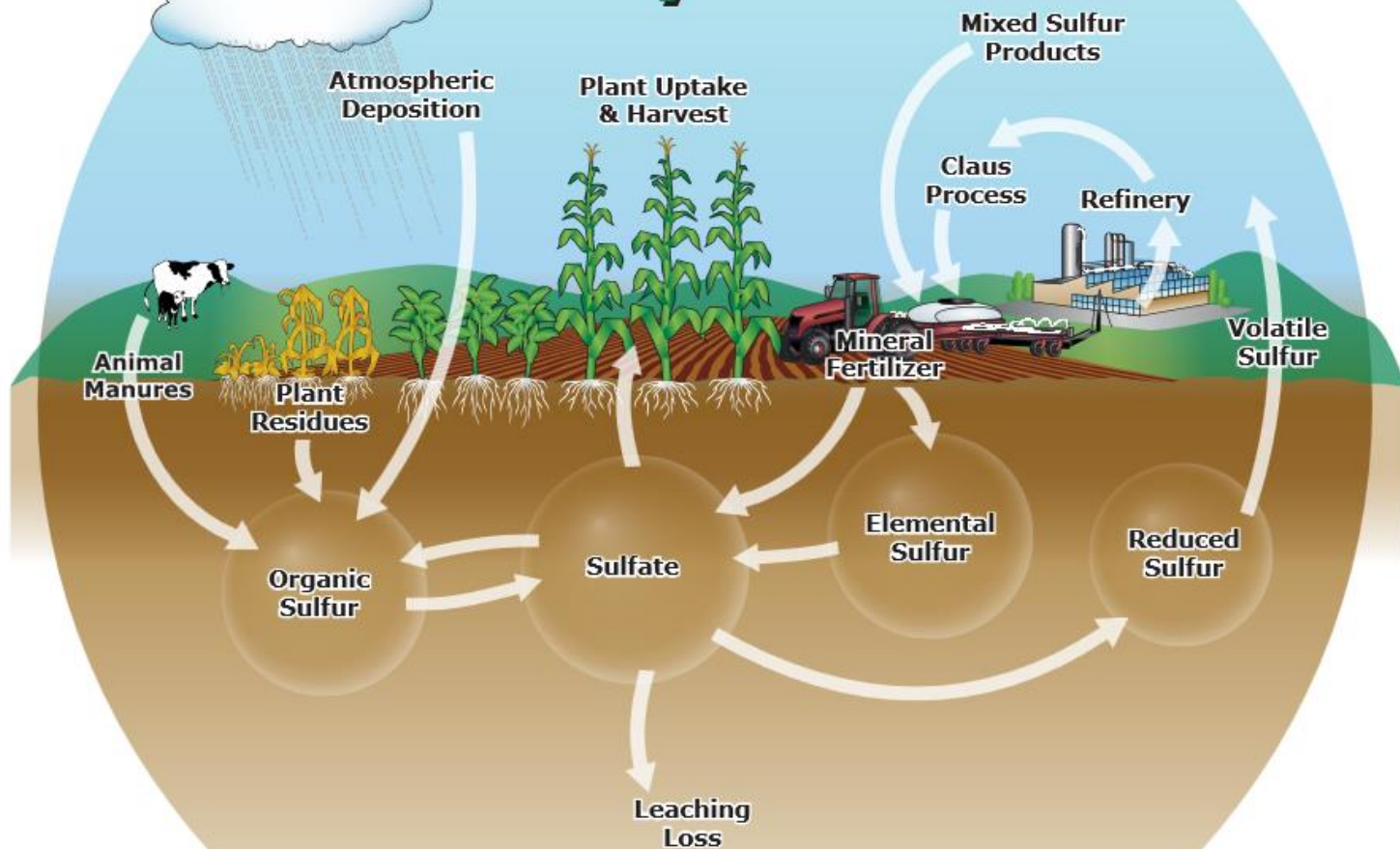
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Sulfur's Role in Plants

- Macronutrient used in similar amounts as phosphorus for many crops
- Component of amino acids
 - Cysteine
 - Methionine
- Sulfur is important for nitrate reduction in plants
 - Deficiency slows down the formation of amino acids and other proteins
- Sulfur influences nitrogen function and utilization in plants
 - Influences photosynthesis
- HRSW removes ~0.1 lb of S per bushel produced, Corn ~0.05 lb of S per bushel



The Sulfur Cycle



Source: IPNI

Corn Sulfur Guidelines for Minnesota

Broadcast sulfur to apply (lbs S per acre)				
		0-6" Soil Organic Matter		
Rotation		0-2	2-4	>4%
Corn-Corn		10-25	10-20	10-15 [†]
Corn-Soybean		10-20	10-15	0
Sandy Soils		25	15-25	10-25

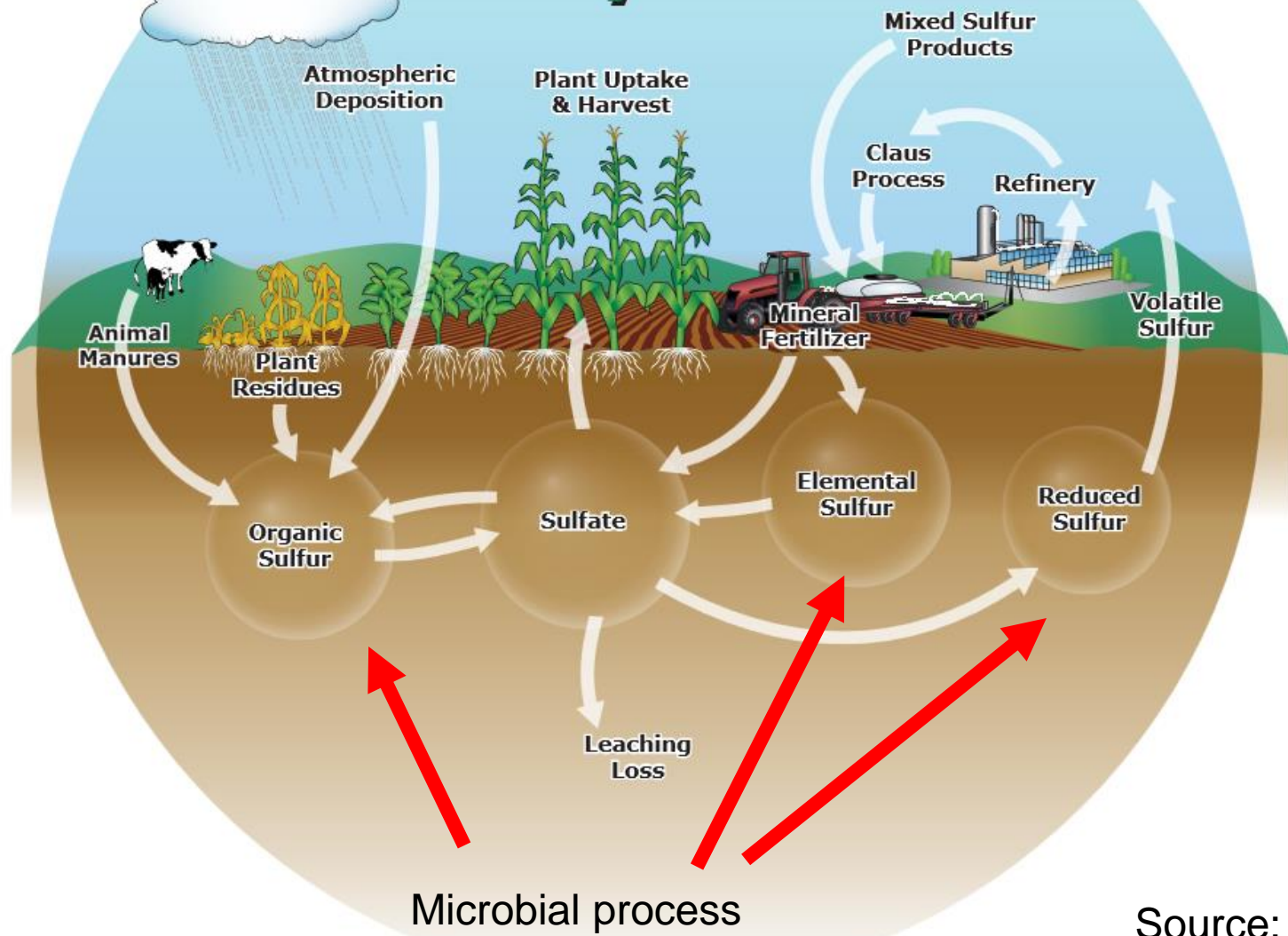
[†]For high residue corn on corn systems

Sulfur Response

- Yield responses are increasing-Why?
 - Sulfate deposition have decreased
 - ~ 5-10 lb/ac/yr in the last 30+ years
 - Sulfur in fertilizer sources (other than S fertilizers) and pesticides have decreased
 - Less manure
 - More crop residue
- What is the most important factor?
 - Two key factors: soil temperature and organic matter concentration



The Sulfur Cycle



Source: IPNI

Step 1: What Crops Respond to Sulfur



Results – S Source x Rate Study

	In-season S rate (lb s/ac)				In-season S rate (lb s/ac)		
	0	12.5	25		0	12.5	25
Soil							
	Grain Yield (bu/ac @13%)				%Protein @ 12%		
Fine	79.1	78.2	78.7		14.6ab	14.5b	14.7a
Sand	95.5ab	96.0a	94.4b		15.2	15.2	15.1

- Pre-plant S did not increase grain yield or protein concentration of 'Glenn'
 - Side-dress AMS did increase grain yield ($P \leq 0.10$)
- Some discussions with producers if the lack of response was due to us using a high protein variety
 - Would the effect be different for a variety like 'LCS-Albany' or 'Faller'?
- Results are inconclusive on potential for response to S



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HRSW Data Summary 2014-2015

Staples

Var.	No S	+S	No S	+S
	YLD (bu/ac)		PRO (%)	
Faller	77	83	16.7	16.8
Glenn	74	80	17.6	18.0
May.	79	77	16.9	17.6
RB07	74	81	17.0	17.1
Select	72	76	16.8	17.5
Vant.	64	67	19.0	19.6
Avg.	74b	77a	17.4b	17.8a

Crookston, Kimball, FF

Var.	No S	+S	No S	+S
	YLD (bu/ac)		PRO (%)	
Faller	81	83	13.7	13.6
Glenn	72	72	15.3	15.2
May.	71	75	15.0	14.8
RB07	79	77	14.0	14.3
Select	68	69	14.9	14.8
Vant.	70	72	15.7	15.6
Avg	74	75	14.8	14.7



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Grain Yield Response to S Applied Prior to Corn in a C-SB Rotation

	Sulfur					
Location	C1	SB1	C2	SB2	C3	SB3
	--Yield Increase bu ac ⁻¹ --					
Red Wing	7	0	22	5.7	41	2.9
Rochester	0	0	14	2.8	13	2.1
Becker	0	0	0	0	0	0
Lamberton	7	0	0	0	0	0



Responses of interest:

- Response at Lamberton (C1) was likely due to residue from the previous corn crop
- Lack of response at Becker may be due to sulfate in the irrigation water



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Net Return over the 6-yr Rotation due to P, K, or S

		Red Wing				Rochester			
Nutrient	Rate	2 yr	4 yr	6 yr	Total	2 yr	4 yr	6 yr	Total
	lb/ac	-----\$/acre-----							
Phosphorus	120	0.0	-48.0	80.0	32	-48.0	-96.0	-8.0	-152
Potassium	100	-4.0	31.0	96.0	123	-40.0	-50.0	4.0	-86
	200	-44.0	47.0	56.0	59	-80.0	-60.0	-11.0	-151
	300	-84.0	30.0	16.0	-38	-120.0	-100.0	-51.0	-271
Sulfur	25	15.5	148.0	180.5	344	-12.5	59.0	73.0	119.5

- P rates are in lb P_2O_5 /ac - 0.40/lb
- K rates are in lb K_2O /ac – \$0.40/lb
- S - \$0.50/lb Corn \$4/bu Beans \$10/bu
- Applied P and K rate may not be the “optimum rate” for each site
- Application cost is not factored into net return



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P-K-S Study Red Wing, MN 6/23/15



No P or S

167 bu/ac

+ P No S

210 bu/ac

+ S No P

218 bu/ac

+ P & S

235 bu/ac



Agricultural Fertilizer Research & Education Council

Response to P – PKS Study

- P response at Red Wing in spite of very high soil tests
- Measured total S in P sources
 - 0-46-0 – 1.8% (4.7 lbs S applied with P trt)
 - DAP – 1.2%
 - MAP – 1.8%
- Response to S in P source at Red Wing would explain response
 - Trifoliate S was increased for S treatments but not for P
 - S in the P source was sufficient to increase corn yield but did not carry over



Sulfur and Grain Yield

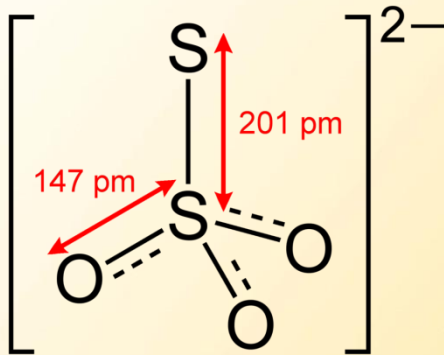
- Alfalfa, corn, and canola are more likely to show a strong response to S
- Small grain crops may respond on eroded ground with the best responses on sandy low organic matter fields
- I would avoid direct application to soybean
 - N + P + S can stimulate vegetative growth
- Sulfur can deplete over time in deficient soils – responses may get greater



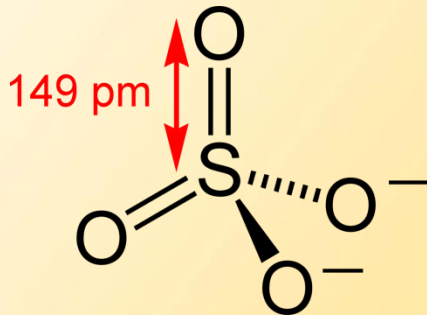
Step 2: Select the Right Source of Sulfur



Sources of Sulfur



Thiosulfate Ion
Not Plant Available
Dissociates into elemental S
And Sulfate



Sulfate Ion
Plant Available



Elemental Sulfur Availability

- Microbial mitigated process
 - Bacteria and Fungi
- Soil temperature and moisture affect oxidation of S to SO_4^{2-}
 - Optimum around 80-90°F
- Oxidation is limited by the surface area of the fertilizer source
 - Larger particles oxidize slower

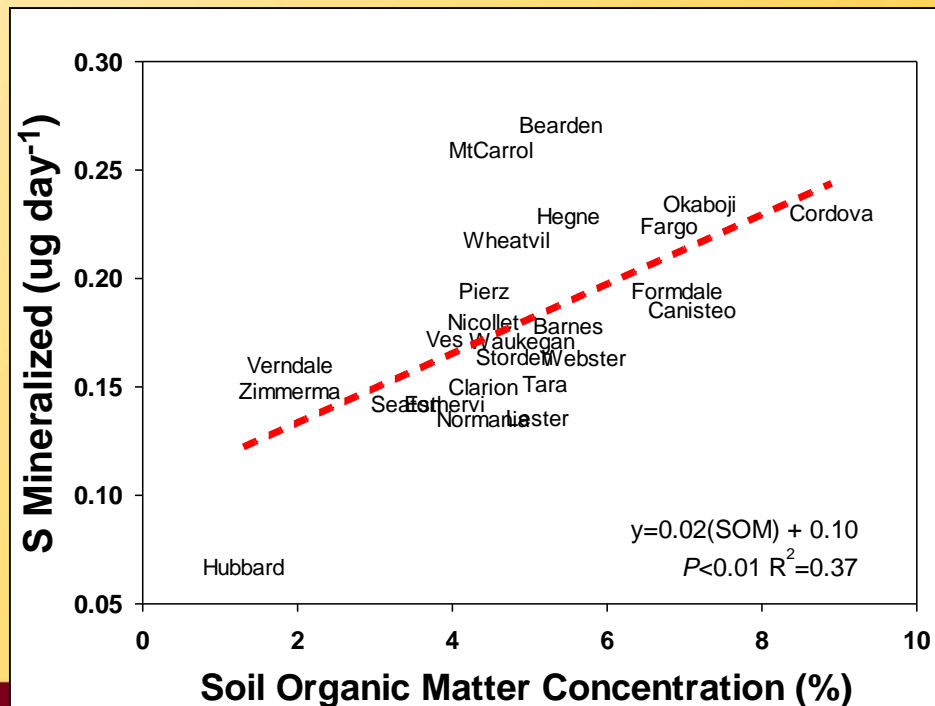


Oxidation of Elemental S Powder @ 90°F



Sulfur Mineralization Rate from SOM

Soil Series	Net S Increase % of Applied	Days To	
		50% Ox -----days-----	Max. Ox
Barnes	113	34	188
Bearden	40	--	167
Canisteo	100	47	234
Clarion	103	22	116
Colvin	63	43	65
Cordova	89	45	179
Estherville	95	15	68
Fargo	100	31	142
Formdale	98	34	160
Hegne	90	51	201
Hubbard	66	33	98
Lester	102	28	146
Mt Carrol	72	70	202
Nicollet	92	19	81
Normania	82	28	109
Okaboji	68	79	206
Pierz	81	30	107
Seaton	107	52	284
Storden	102	52	259
Tara	84	22	87
Verndale	64	56	140
Ves	82	56	210
Waukegan	89	32	134
Webster	88	22	93
Wheatville	95	60	264
Zimmerman	80	20	74



2-Year Average Yield

Fall vs Spring: Elemental & Sulfate-S

S Rate (lb/ac)	Yield (bu/ac)
0	232b
5	235a
10	236a
20	236a

Summary – 4 locations

- No evidence of an effect of Fall vs Spring application on yield
- No difference between sources
- Rate was significant with 5 lbs S producing the maximum yield



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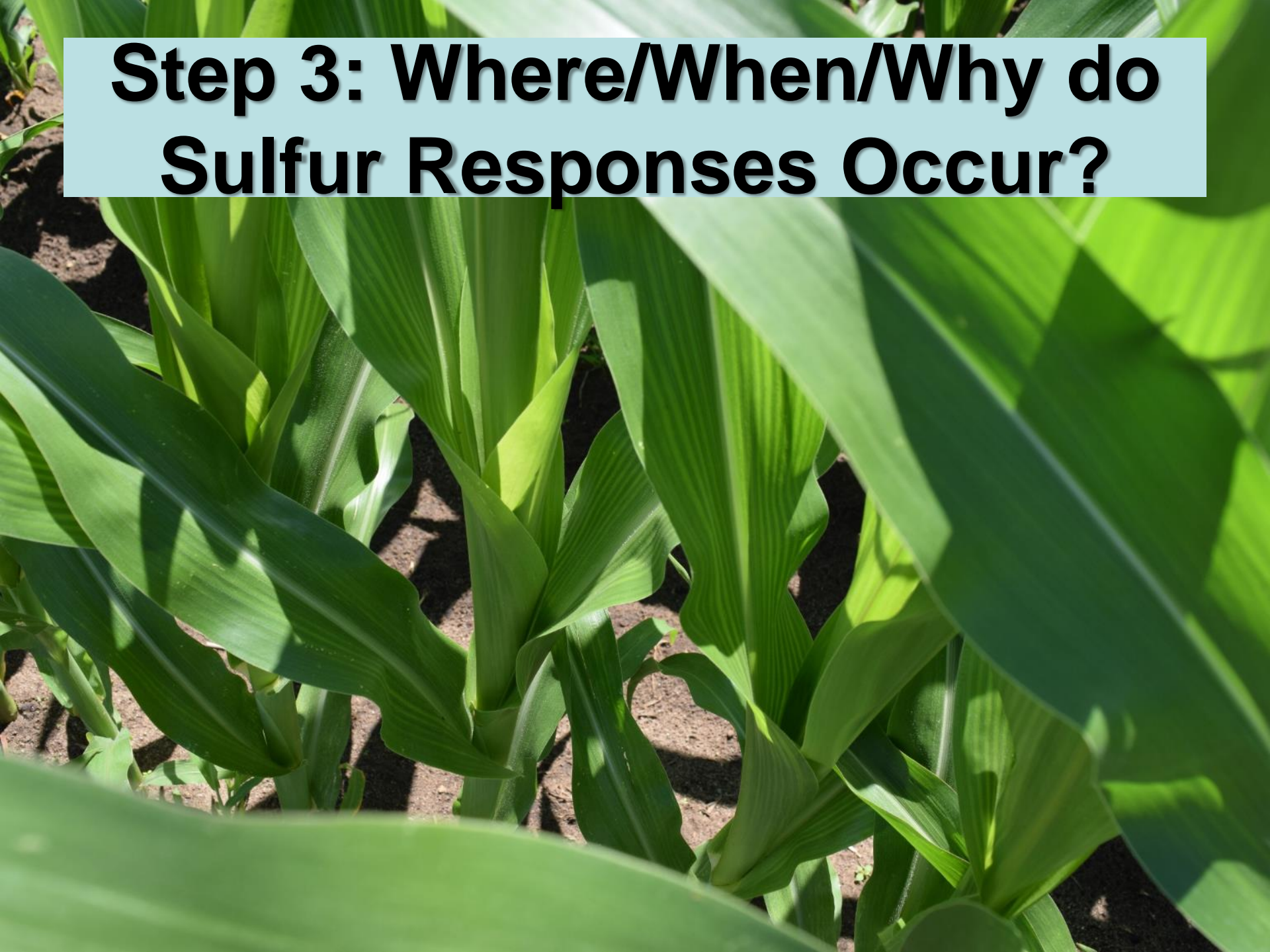
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Strategy for use of Elemental S

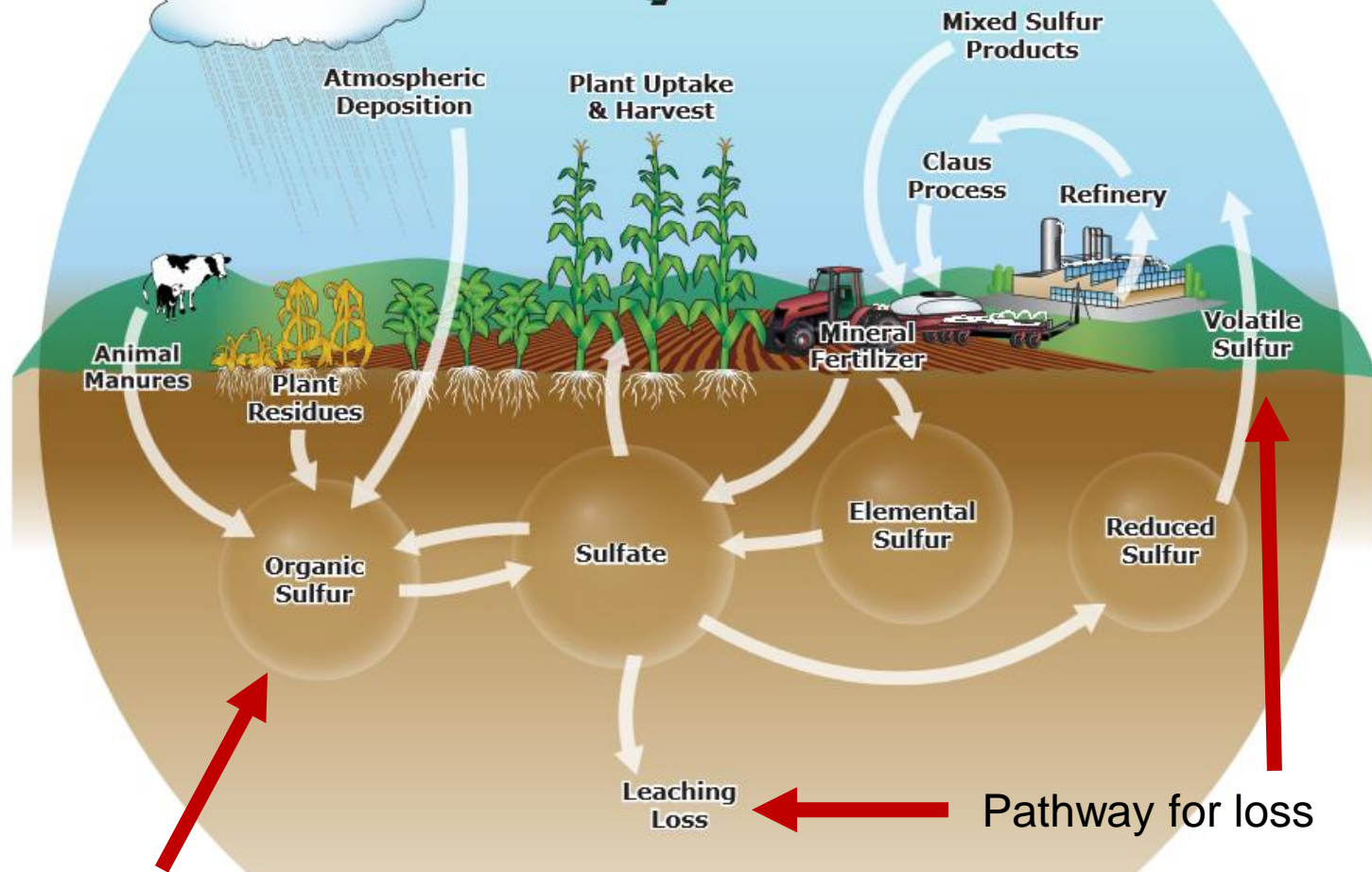
- Elemental S will not provide any available in the early growing season following a spring or fall application
 - This would include MES-10, MES-15, and MEZ which the elemental S is more finely ground
- Oxidation is more likely in July and August
- Repeated application of elemental S may supply plant available S due to sulfate carried over from one year to the next
- Add sulfate with elemental S for early season availability – ATS is a good option



Step 3: Where/When/Why do Sulfur Responses Occur?



The Sulfur Cycle



Large Storehouse of potentially available S

Source: IPNI

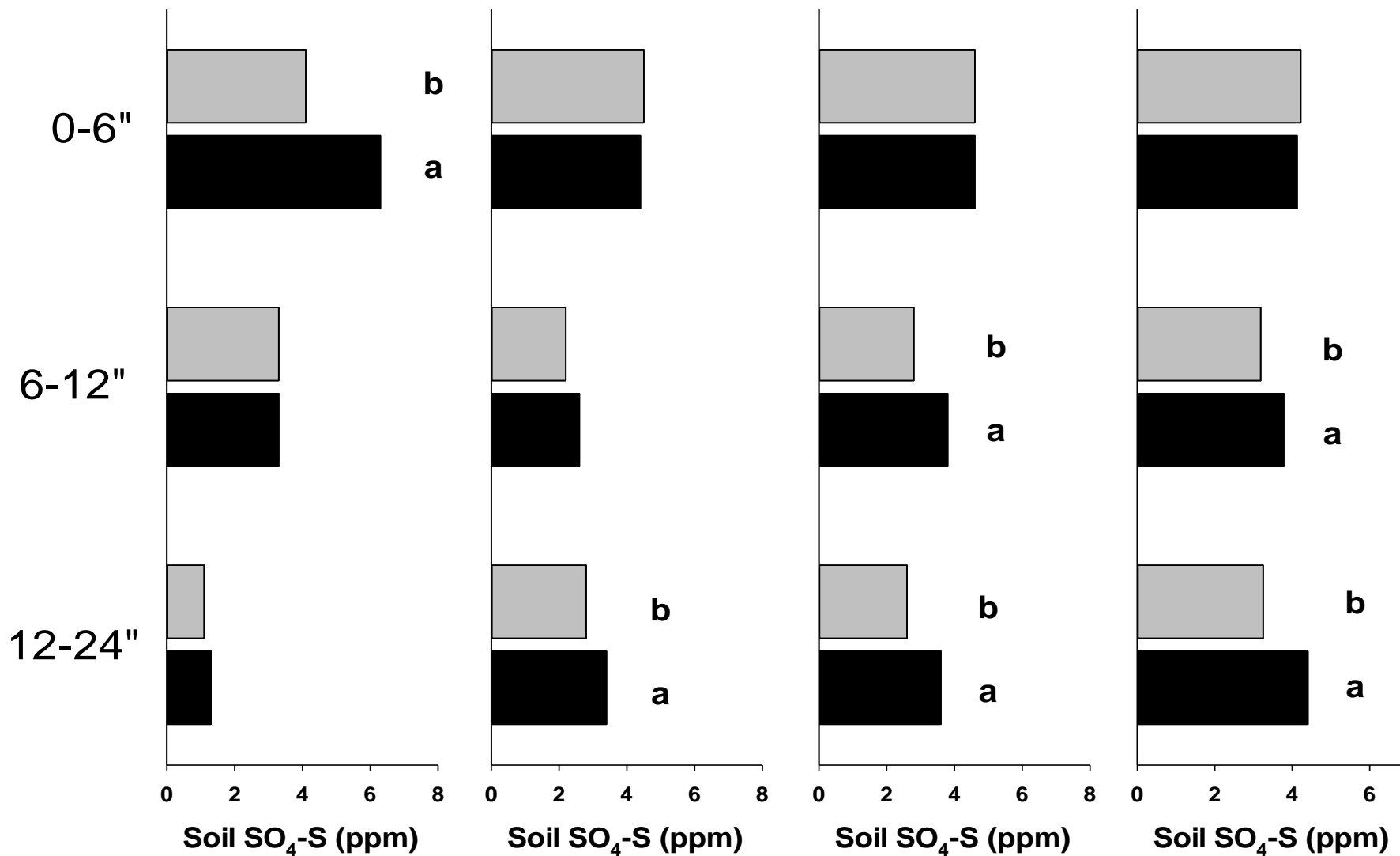
Red Wing, MN

Fall 2011

Fall 2012

Fall 2013

Fall 2014



□ No S ■ + 25 lb S

Leaching of Sulfur

- The rate of S leaching depends on soil texture
 - Sandy soils are more likely to require annual applications
- Sulfate-S can remain in the upper soil profile for 1 or more years
 - Fall application of sulfate may be okay in high clay soils
- Leaching of sulfate-S is not fast enough to warrant split application of S



C:S Ratio of Corn Stover

Year	Location	No Sulfur	+ Sulfur
2011	Red Wing	580:1	500:1
	Rochester	691:1	630:1
2012	Becker	560:1	524:1
	Lamberton	531:1	495:1
2013	Red Wing	572:1a	490:1b
	Rochester	590:1a	497:1b
2014	Becker	794:1	853:1
	Lamberton	1340:1a	666:1b

Immobilization occurs when $> 400:1$; mineralization occurs when $< 200:1$



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Fe Deficient Corn??

SOM > 5.0%

Renville, MN

June 2014

2014

- No S No Fe
 - 155 bu/ac
- + S No Fe
 - 168 bu/ac
- + S + Foliar Fe
 - 171 bu/ac

2015

- No Fe
 - 223 bu/ac
- + 3-6 GPA Redline
 - 221 bu/ac



Becker, MN 2014



Red Wing, MN 2015



Red Wing, MN 2015



2-Year Average Yield

Fall vs Spring: Elemental & Sulfate-S

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Sulfur Response Scenarios

1: Low S supply capacity

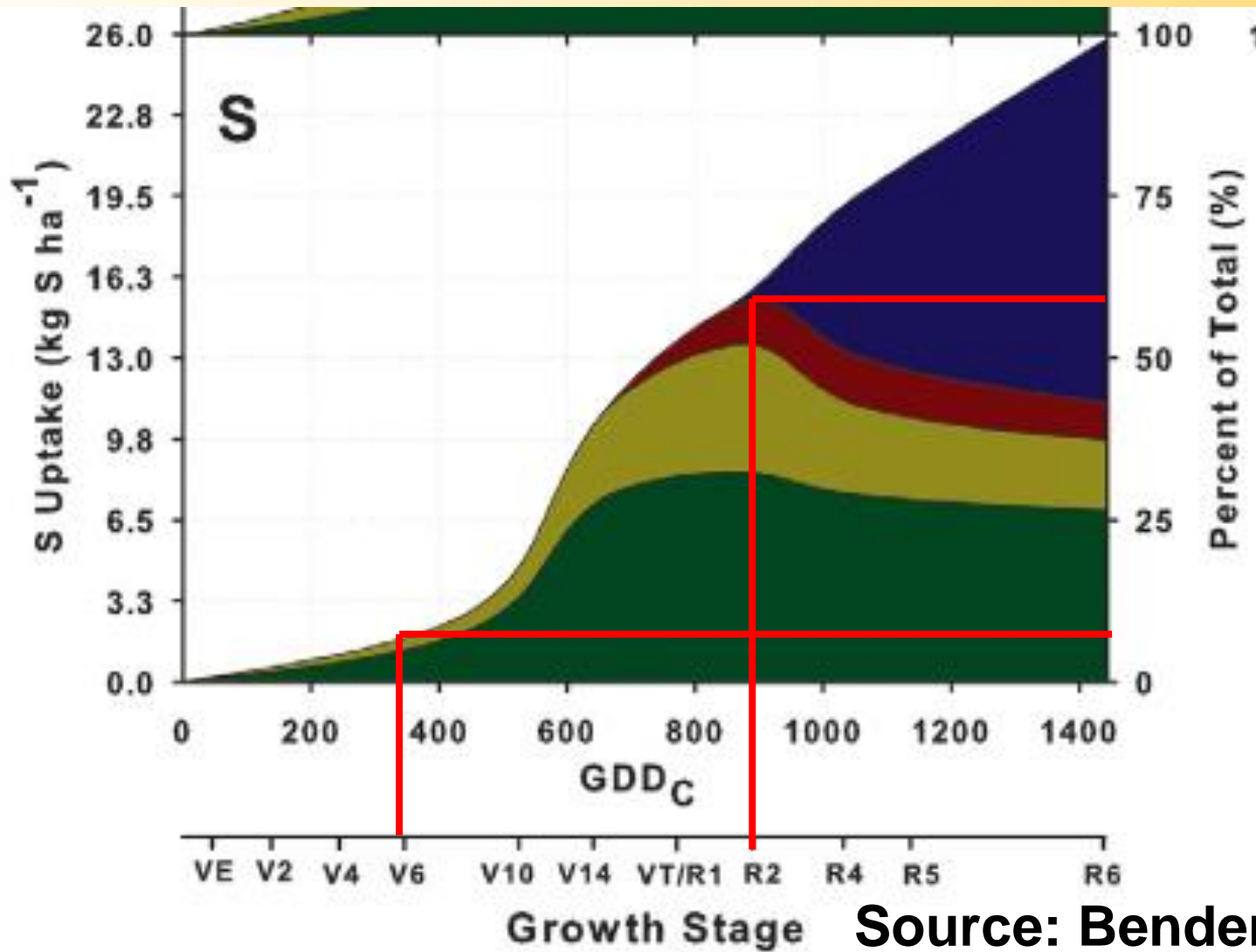
- Response is dictated by supply capacity of soil
 - i.e. organic matter
- Temp. and moisture are still factors
- If deficient, S uptake will be limited throughout the growing season
- Plant analysis should provide useful data

2: Temporary deficiency

- Response is dictated by availability of S at key growth stages
- Greater impact of temp. and moisture
 - Start and end of season
- Plant may green up if S supply increases
 - Plant tissue analysis would be less reliable



Key Growth Stages for Sulfur Uptake in Corn



~40%
Of total
uptake

~50%
Of total
uptake

~10%
Of total
uptake

Sulfur Studies 2014-2015

Corn Grain Yield – Red River Valley

Sulfur Rate	Marshall 2014	Norman 2014	Norman 2015	Polk 2015	2yr-Avg.
-lb S/ac-	-----Bushels/acre-----				
0	153	132	232	211b	181
10	155	127	234	219ab	183
20	152	128	235	221ab	185
30	156	133	240	226a	189
Statistical Significance					
$P > F$	ns	ns	ns	0.09	ns



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Wrap Up

- I don't think sulfate leaching is a serious issue to warrant only applying elemental S
- Timing of S application was not discussed but data indicates that S application can be delayed up through V5 with no yield penalty for corn
- Soil and plant tissue tests for S are not reliable for determining where a response will occur
- Some striping can occur on plants early in the growing season which may not affect grain yield



Are Responses to S Increasing?

- The answer depends on early season rainfall and soil temperature
- Atmospheric S has decreased but the relative impact in an individual year is low
 - May compound over a number of years
- Mineralization of S from soil organic matter is still an important source of S
 - Rate depends on soil temp and moisture
- Drainage may also impact S availability



When to Apply S

- Sulfate can carry over in soils so the question of Fall versus Spring application is less important
- Should you apply sulfur across all acres?
 - Probably not needed in all circumstances but a low rate may be warranted
 - No justification to apply over 20 lbs on medium to fine textured soils
- Apply to low organic matter or highly leached soils
- Poorly drained soils may also warrant application – Soil test for S???
- Responses may be limited to highly alkali areas
- Source of sulfur applied is important



Thank You Questions?



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