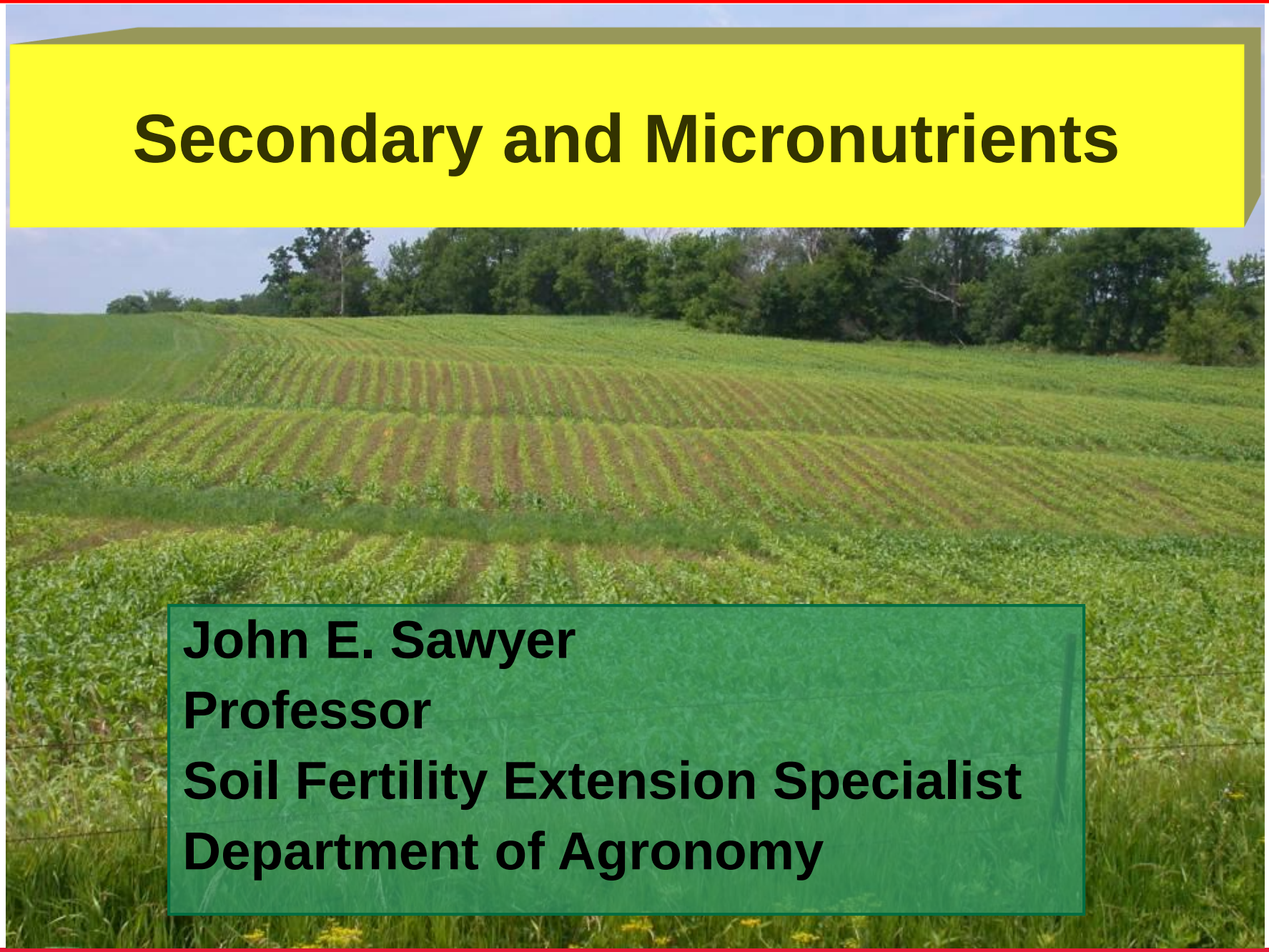
Secondary and Micronutrients



John E. Sawyer
Professor
Soil Fertility Extension Specialist
Department of Agronomy

Plant Essential Element Sulfur (S)

- Movement in plant
  - Relatively non-mobile
- Functions
  - Proteins, chlorophyll and photosynthesis
- Deficiency symptoms
  - Yellowing/chlorosis stripping of younger leaves
  - Plant yellowing, stunting, and spindly plants with severe deficiency
  - Easily mistaken with nitrogen
- Plant available form: sulfate (SO_4^{2-})

Sulfur Sources

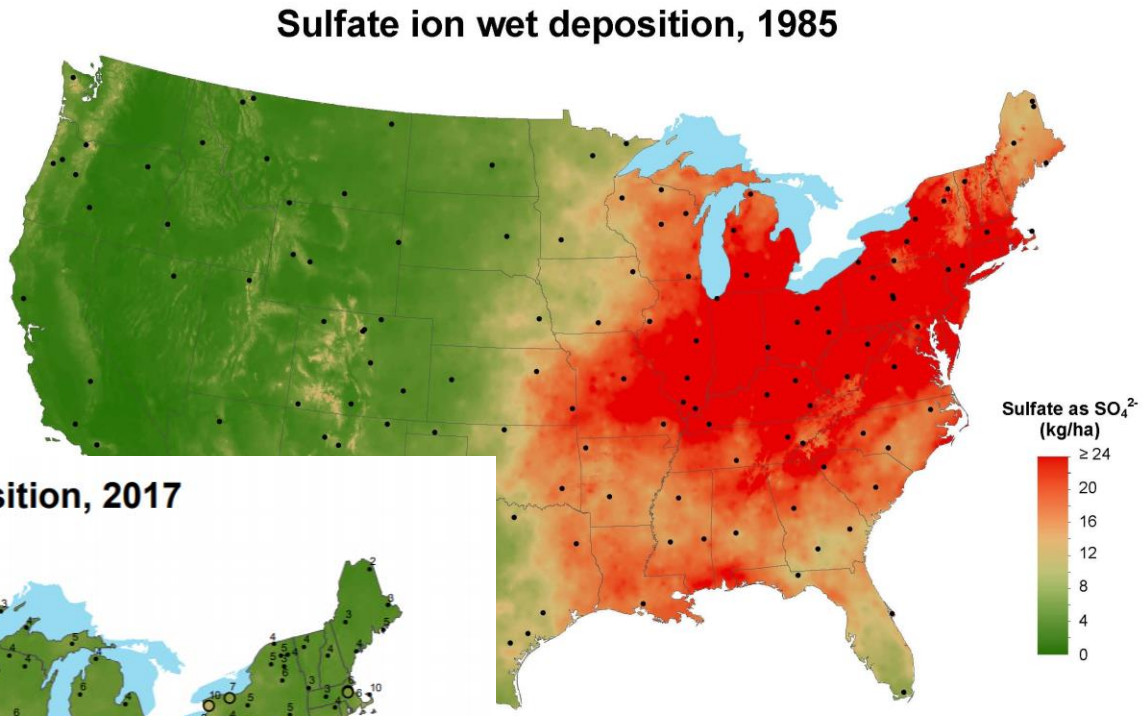
- Where does crop-available sulfur come from?
  - Soil organic matter
    - Large pool of sulfur in most soils
  - Subsoil sulfate
  - Rock degradation/accumulated gypsum
  - Atmospheric deposition
    - Volcanic emission
    - Marine gases
    - *Coal/diesel burning*
  - Manure
  - Fertilizers/byproducts containing sulfur
  - Irrigation water

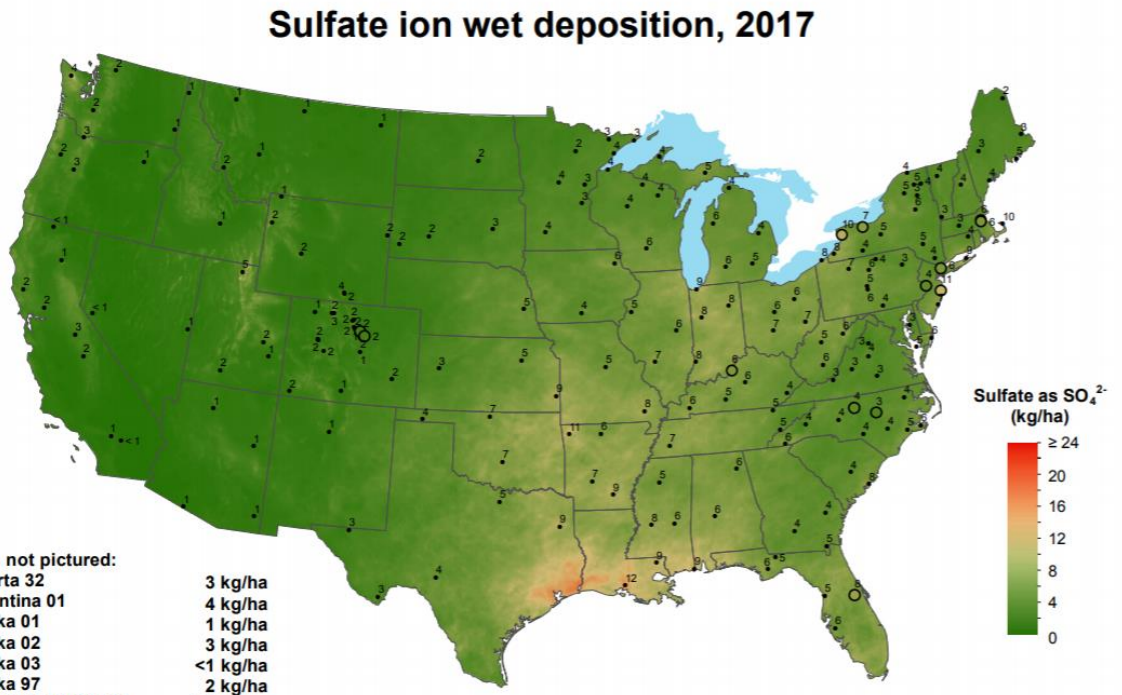
Crop Sulfur Uptake

- Corn at 200 bu/acre (Iowa trials)
  - 8 lb S/acre grain (0.04 lb S/bu)
  - 5 lb S/acre vegetation (1.3 lb S/ton d.m.)
  - 14 lb S total
- Alfalfa (Iowa trials)
  - 5-6 lb S/ton d.m.

- Modern Corn and Soybean
  - Corn – 0.07 lb S/bu
  - Soybean – 0.10 lb S/bu
  - Alfalfa – 5 lb S/ton

Sulfate Deposition 1985 – 2017





Sites not pictured:

Alberta 32	3 kg/ha
Argentina 01	4 kg/ha
Alaska 01	1 kg/ha
Alaska 02	3 kg/ha
Alaska 03	<1 kg/ha
Alaska 97	2 kg/ha
British Columbia 22	34 kg/ha
British Columbia 23	4 kg/ha
British Columbia 24	5 kg/ha
Saskatchewan 21	1 kg/ha
Saskatchewan 31	1 kg/ha

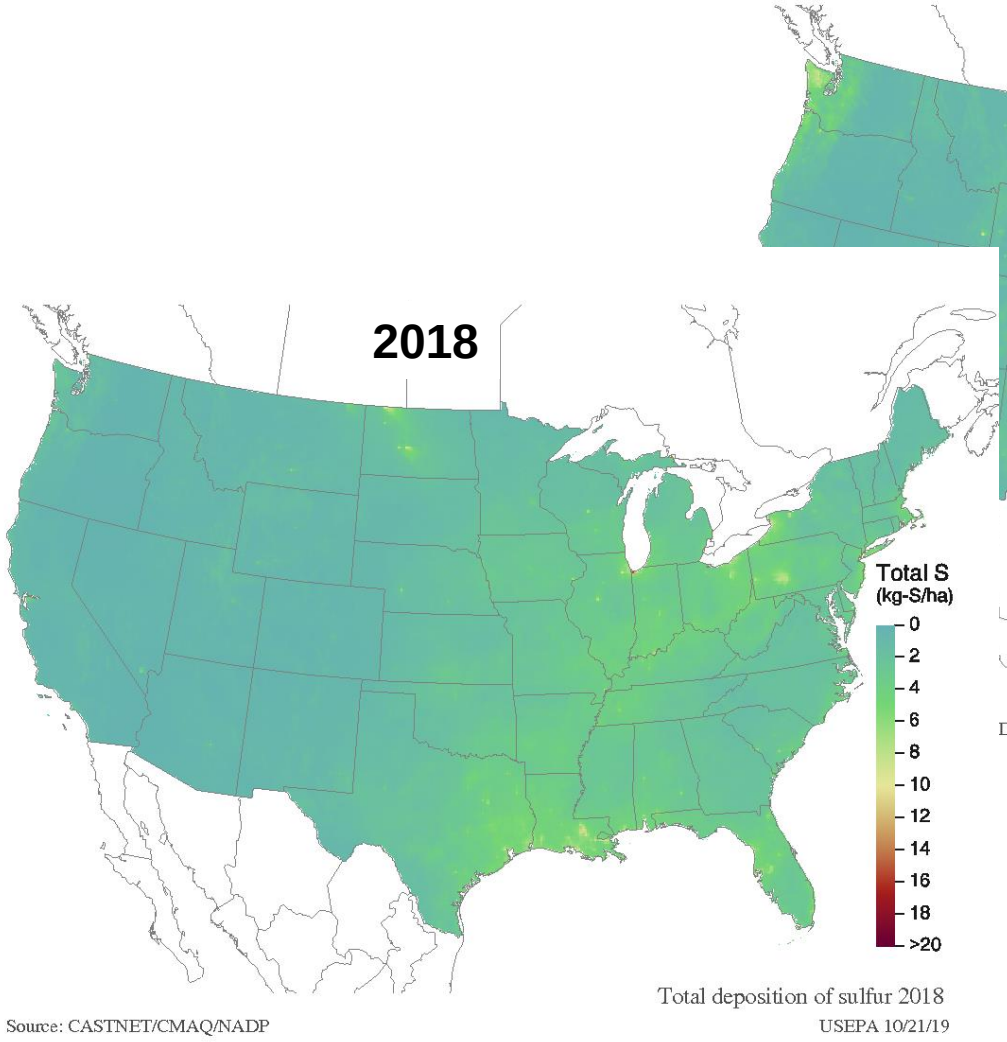
National Atmospheric Deposition Program/National Trends Network
http://nadp.slh.wisc.edu

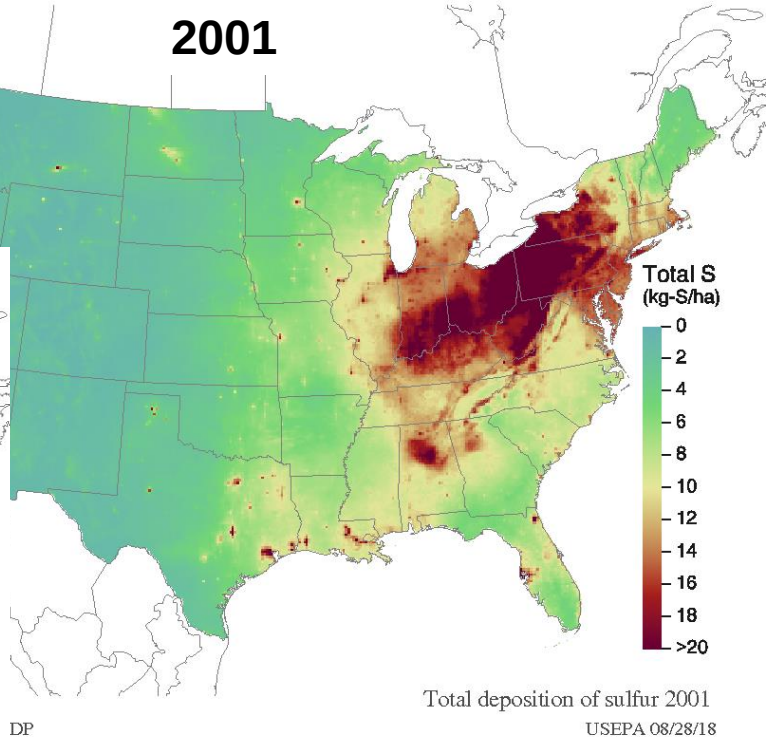
National Atmospheric Deposition Program (NADP)

10 kg SO_4/ha = 3 lb S/acre

Total Sulfur Deposition (wet+dry)

National Atmospheric Deposition Program





1 kg S/ha = 0.9 lb S/acre

Sulfur Supply to Crops Changed

Observation of poor alfalfa growth in Northeast Iowa

Alfalfa Response to S Application in Field Areas with Poor and Good Coloration of Alfalfa, 2005-2006

Sulfur	2005				2006	
	Cuts 2+3 DM Yield		Cut 2 Plant Top S		Cut 1 DM Yield	
	Observed Growth Area					
Treatment	Poor	Good	Poor	Good	Poor	Good
	- - ton/acre - -		- - - % S - - -		- - ton/acre - -	
None	1.18a	2.99b	0.14a	0.22b	1.10a	2.04b
Am. sulfate	2.76b	3.26b	0.40d	0.35c	2.18b	2.22b
Ca. sulfate	2.49b	3.21b	0.41d	0.37c	2.14b	2.19b
	6.6	7.4	Soil Sulfate-S (ppm)			

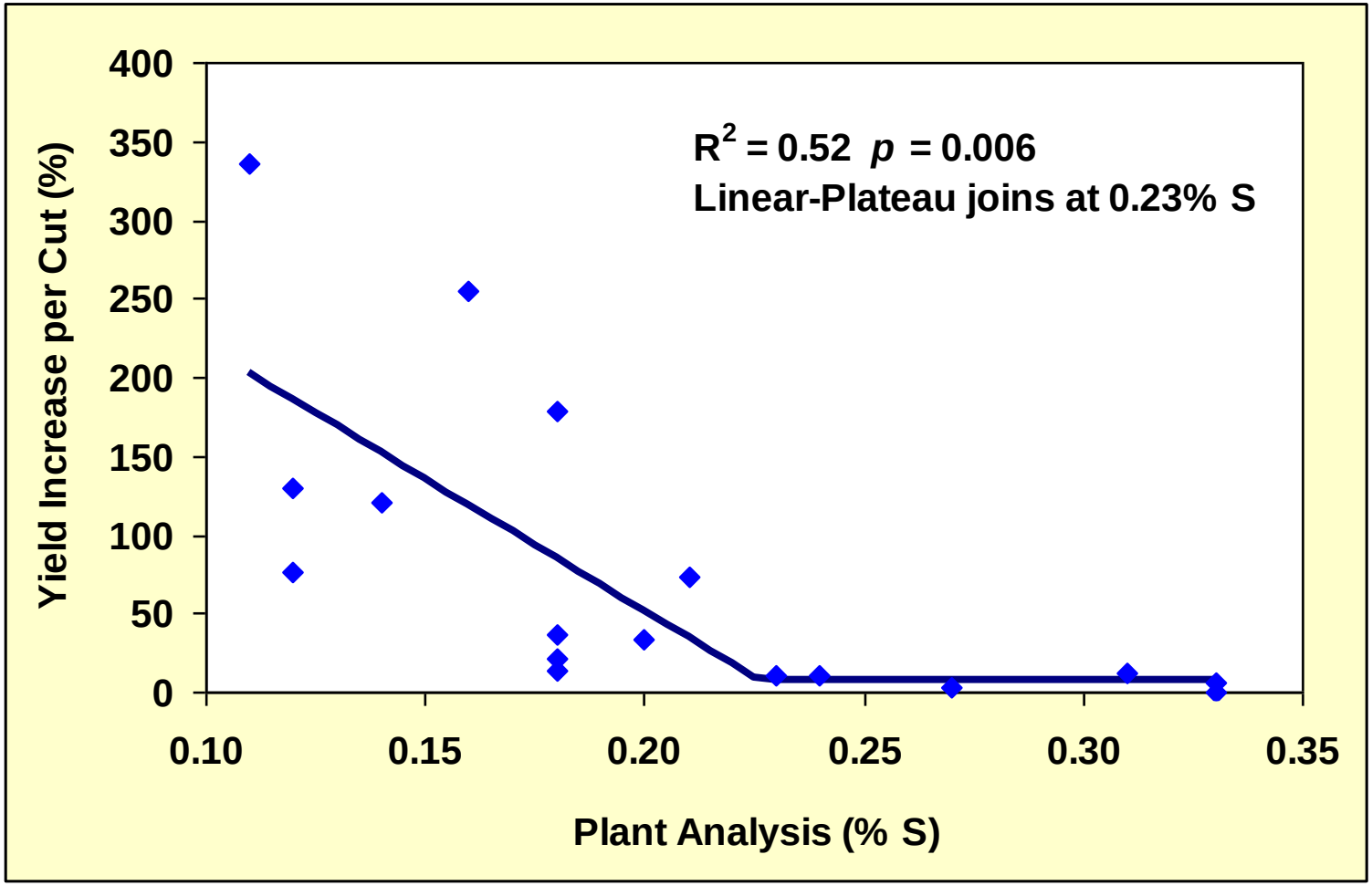
Three field sites in 2005, Elgin, Gunder and West Union, IA (Fayette & Downs sil soils).

Two field sites in 2006, Elgin and Gunder, IA.

Sulfur materials were applied at 40 lb S/acre after first cut in in 2005.

Treatment means followed by the same letter are not significantly different ($p \leq 0.10$).

Alfalfa Yield Increase to Applied S vs. Plant S Concentration (six-inch plant top)



Sulfur Supply to Crops Changed

Response in Corn to Sulfur Application

S Check S Check S Check

Slide from B. Lang, ISU

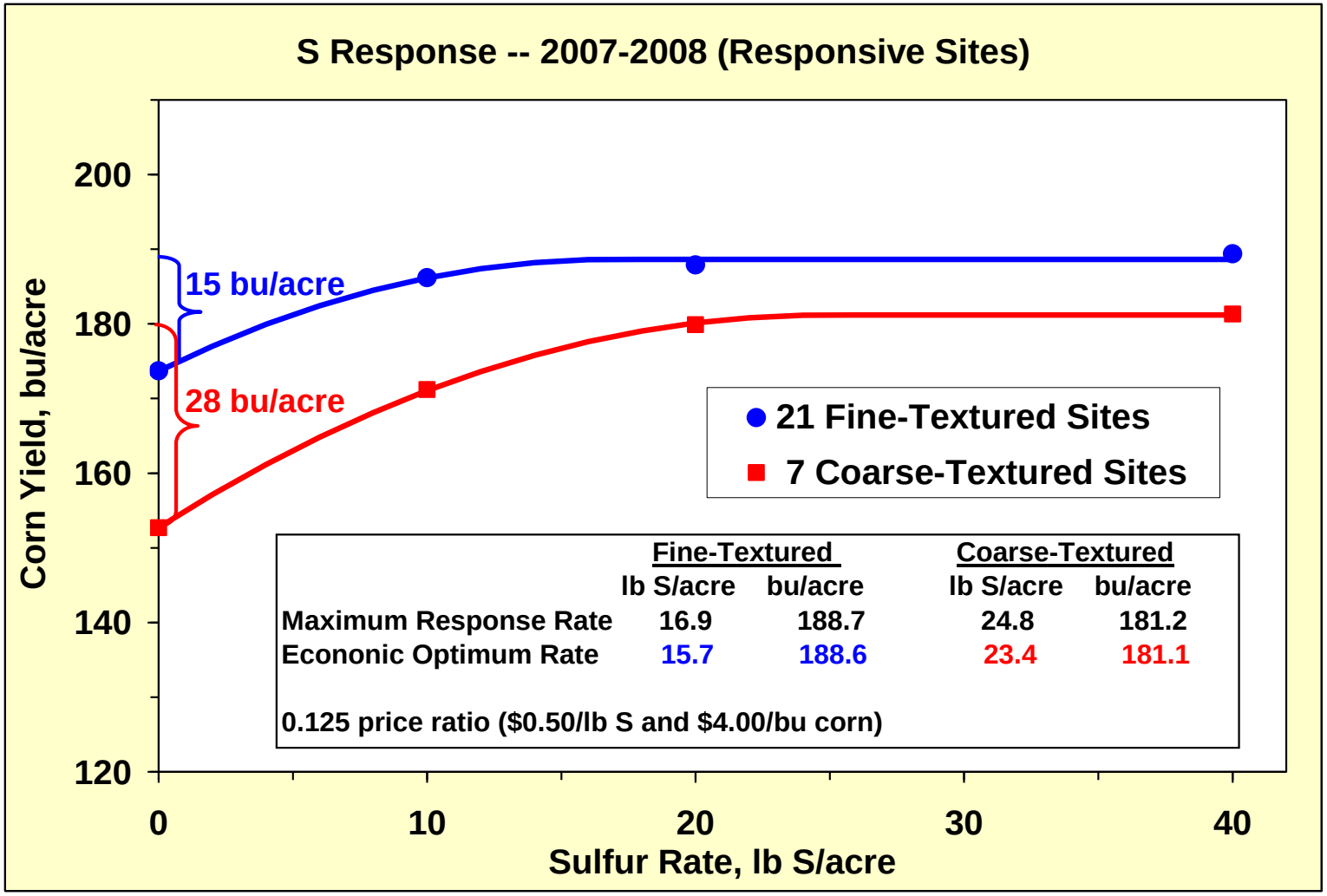
Forty-Seven Corn S Rate Sites in 2007-2009 Northeast – North Central Iowa

- Sulfur (gypsum) at 0, 10, 20 and 40 lb S/acre
- 2007
  - 17 of 20 sites responded to S application
    - 18 bu/acre average yield increase across all sites
- 2008
  - 11 of 25 sites responded to S application
    - 7 bu/acre average yield increase across all sites
- 2009
  - 2 sites with no response to S application

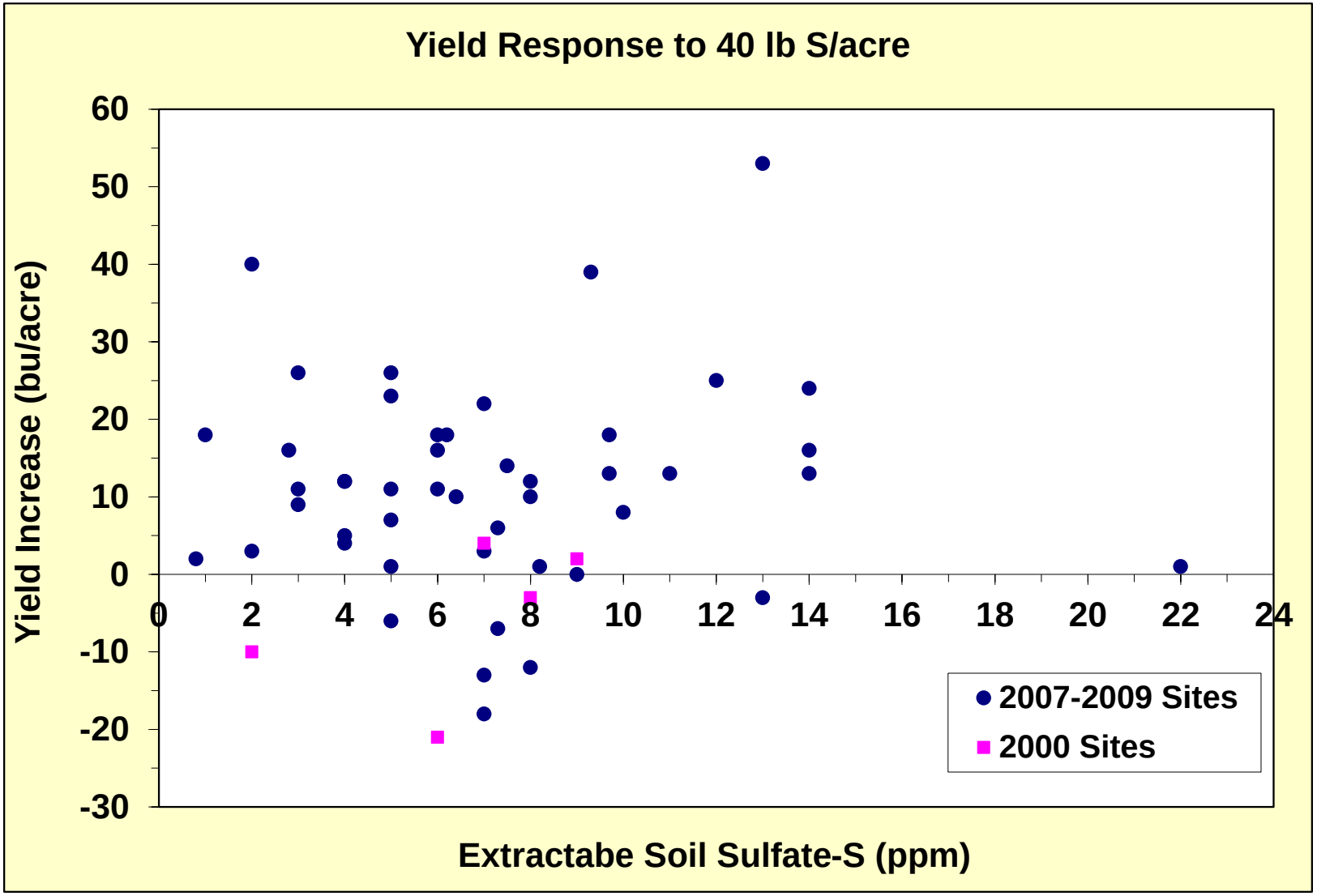
Twenty-Eight Responsive S Rate Sites

2007-2009 North Central - Northeast Iowa

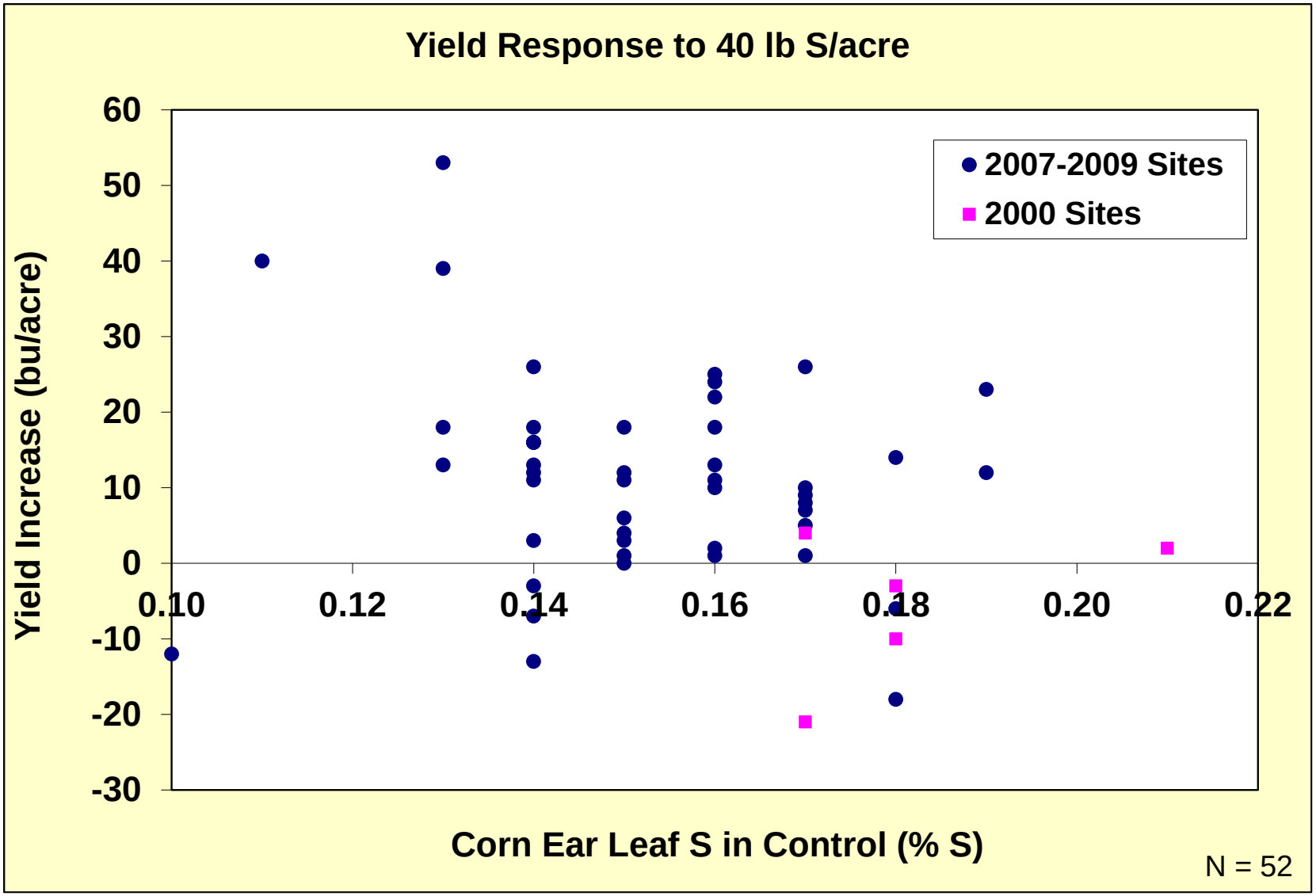
Soils: 21 fine texture (cl, sicl, sil, l); 7 coarse texture (fsl, lfs, sl)



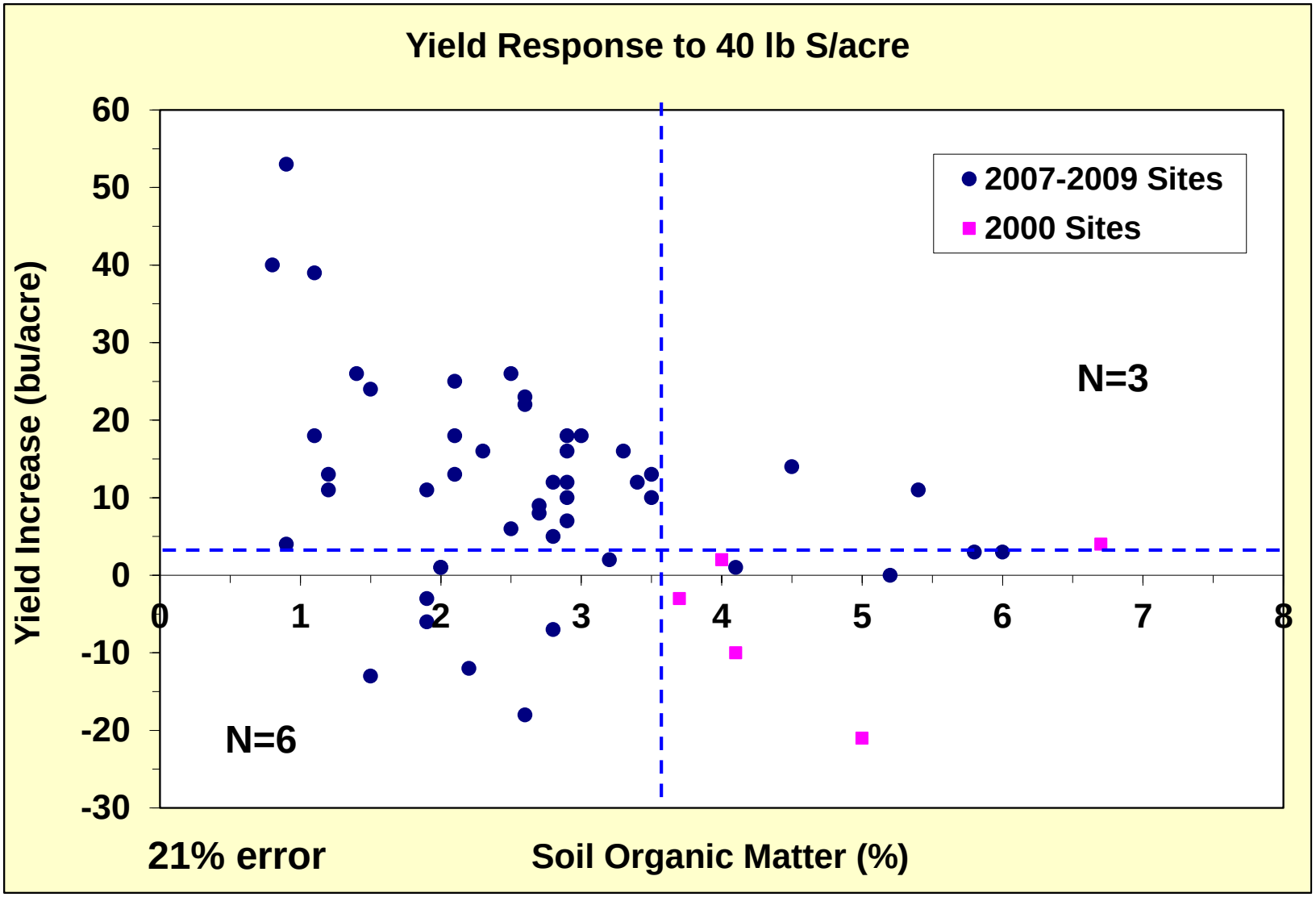
Extractable Soil Sulfate-S



Corn Ear Leaf S Concentration



Soil Organic Matter



76 bu/acre Response
Site WK 2006
Alfalfa Previous Crop
Fayette sil

20 bu/acre Response
Site T1 2006
Soybean Previous Crop
Chelsea lfs

Zero bu/acre Response
Site Mason City 2008
Soybean Previous Crop
Readlyn loam

Zero bu/acre Response
Ames Site 2001
Soybean Previous Crop
Clarion loam

Sulfur Rate Trials – Northern Research Farm

	Higher OM Site (5.8%)				Lower OM Site (4.1%)		
	2011	2012	2013		2011	2012	2013
S Rate	SC	SCC	SCCC		SC	SCC	SCCC
lb S/acre	- - - - - bu/acre - - - - -				- - - - - bu/acre - - - - -		
0	192	82	152		187	80	174
5	184	100	171		188	99	192
10	190	105	180		187	109	191
20	191	105	179		191	113	179
40	187	111	181		183	104	185
Sign. (0.10)	NS	*	*		NS	*	*

Higher OM site Webster clay loam; lower OM site Clarion loam.
S rates (as gypsum) applied in spring 2011 and 2013 before corn.
No S applied before corn in 2012.
Significance either rate, linear, quadratic, cubic, or +S vs. –S.
Dave Rueber, ISU Northern Research Farm, Kanawha, IA

Summary

- Sulfur deficiency an issue in Iowa
  - 60% corn S rate sites responsive to S application
  - Especially coarse textured, sideslope landscape, low organic matter, eroded soils; no-tillage, reduced-tillage, alfalfa prior crop, no manure application, no S applied in fertilizers or irrigation
- Approximately 50% S response frequency in corn for trials statewide from 2006 – 2018

Summary

- Sulfur application rate when needed
  - Alfalfa: topdress 20 to 30 lb S/acre
  - Corn/Soybean:
    - 15 lb S/acre fine textured soils
    - 25 lb S/acre coarse textured soils
    - Apply every-other year to corn
- Tools to indicate S deficiency
  - Alfalfa – top six-inch plant growth at early bud
  - General field/soil characteristics
  - Visual coloration and growth response
  - Replicated strip trials +/- S for multiple years

Sulfur Fertilizers

- Ammonium Sulfate (21-0-0-24S)
- Ammonium Thiosulfate (12-0-0-26S)
- Gypsum (Calcium Sulfate) (0-0-0-17S)
- Elemental Sulfur (0-0-0-90S)
- Magnesium Sulfate (0-0-0-14S)
- Potassium Magnesium Sulfate (0-0-22-23S)
- Potassium Sulfate (0-0-50-18S)
- N-P-S products (ex. 13-33-0-15S)
- Polysufate (0-0-14-19S)
- By-Products
  - Lysine manufacturing
  - Soybean soapstock refining process water
  - Wallboard (gypsum)
- Sulfur in MAP, DAP, TSP

Sulfur Fertilizers

- Incidental S applied in MAP and DAP applications?
- Analysis of 65 MAP, 46 DAP and 7 TSP samples by the Office of the Indiana State Chemist (data provided by Dr. Jim Camberato, Purdue Univ.)
- MAP: 1.8% mean (1.3 - 2.4%S)
- DAP: 1.9% mean (1.4 - 3.3% S)
- TSP: 1.6% mean (1.4 – 1.9% S)
- At 75 lb P_2O_5/acre
  - MAP 2.0 - 3.6 lb S/acre
  - DAP 2.3 – 5.4 lb S/acre
  - TSP 2.3 – 3.1 lb S/acre

Managing Ca and Mg on Iowa Soils

- Critical soil test level (sufficiency)
  - No Ca or Mg soil test interpretation for Iowa soils
  - Neither generally deficiency in Iowa soils
    - Maybe Mg – K – NH_4 grass tetany concern in some soils
- Ca and Mg managed by limestone application from local quarry to acidic soils

Zinc Deficiencies

- Sensitive crops
  - Corn, sorghum
- Soil Situation
  - Low organic matter, high pH (>7.4), eroded soil
  - Coarse texture, restricted rooting
  - High P application in conjunction with borderline or low zinc availability
    - High soil P alone does not create deficiency
  - Organic soils
- Climatic Conditions
  - Cool and wet soil

Iowa State University
Zn Recommendations for Corn and Sorghum

	Zinc Soil Test (ppm)		
Soil Test Category:	**Low**	**Marginal**	**Adequate**
DTPA Extractable Zn:			
	0-0.4	0.5-0.8	0.9+
	Zn to apply broadcast (lb/acre)		
	10	**5**	**0**
	Zn to apply in band (lb/acre)		
	2	**1**	**0**

ISU Extension Publication PM 1688

Previous Zn Research With Corn

- Webb 1970s-1980s four long-term trials
  - Continuous corn, broadcast Zn, 2 sources
  - Isolated responses when DTPA Zn was < 1.0
- Webb & Mallarino 1965-1990 long-term trial
  - Zn broadcast and several P treatments very low to extremely high
  - No yield increase, but DTPA Zn was >1 ppm
- Bickel & Killorn 2007, 12 strip trials in NC Iowa
  - Planter-band Zn sulfate, soil Zn low to high
  - 61 yield comparisons, 2 increases and 7 decreases; no relationship with soil Zn or pH

Iron Deficiencies

- Sensitive Crops
  - Soybean
- Complicated-Interrelated Soil Conditions
  - High pH (usually >7.4 in Iowa) with free calcium carbonates in surface soil
  - Carbonates and Bicarbonates (CO_3^{2-}, HCO_3^-)
  - High salt level
  - Poorly aerated soils
  - High soil nitrate
- Wet Conditions


J.E. Sawyer, ISU Agronomy Extension


J.E. Sawyer, ISU Agronomy Extension

Management of Iron Deficiencies

- Soybean variety choice
- Not soil applied fertilizer treatments
  - Not iron or sulfur or gypsum
- Not seed coated iron treatments
  - Expensive and limited yield response
- Maybe in-furrow chelated (ortho-ortho FeEDDHA) iron fertilizer
- Maybe reduced soil nitrate-N
  - Soybean inter-seeded into cover crop

Management of Iron Deficiencies

- Maybe foliar applied chelated iron
  - (FeEDDHA – Sequestrene 138, ortho-ortho)
  - Early - when plants have two fully developed trifoliolate leaves
  - Application within 7 days after chlorosis symptoms expressed
  - 0.15 lb Fe plus surfactant in 15 to 30 gal water over plants
  - May require multiple applications

J.E. Sawyer, ISU Agronomy Extension

Recent Micronutrient Research Resurgence in Interest for Micronutrient Applications

Research in 2012 – 2014
Antonio Mallarino and His Research Group

Micronutrients Applied Foliar

- 46 soybean trials, 35 on farmers' fields
- 10 corn trials at ISU research farms
- B, Cu, Mn, Zn, and a mixture; 4 replications
- Sources:
  - Boric acid (Max-In B, 8% B)
  - EDTA Cu (Max-In Cu, 5% Cu)
  - EDTA Zn (MicroBolt Zn, 9% Zn)
  - EDTA Mn (MicroBolt Mn, 6% Mn)
- Sprayed twice: at V6 for both crops; V10 in corn, R2-R3 in soybean; with total amount applied:
  - 0.16 lb B /ac
  - 0.08 lb Cu /ac
  - 0.33 lb Mn/ac
  - 0.50 lb Zn/ac

Foliar Research in 2012 & 2014

- ISU field specialists on-farm project
- 26 corn and soybean strip trials
  - North, NW, and SW Iowa
  - 9 with corn
  - 17 with soybean
  - 3 to 5 replications
- Sprayed a mixture of B, Mn, and Zn
  - One application at V6 to V8 stage
  - 1 pint/acre Max-In Boron (8% B, boric acid)
  - 1 quart/acre Max-In B ZMB (0.1% B, 3%Mn, 4% Zn, 3.6% S)

Micronutrients Applied to Soil, 2012-2014

- 8 trials, 3 years each, 4 began with corn and 4 with soybean
- Treatments
  - B, Mn, Zn planter band with MAP
  - Mixture band or broadcast with MAP
- Solid granulated fertilizers
  - Boron: NuBor 10 (boric acid, 1.5% S):
    - banded, 0.5 lb B/ac
    - broadcast, 2 lb B/ac
  - Mn: Broadman20 (12% S), 5 lb Mn/ac
  - Zn: EZ20 (14% S), 5 lb Zn/acre

Yield Response to Micronutrients

- Foliar fertilization plot trials (56 fields)
  - No grain yield increase at any trial
  - Yield decrease at one soybean trial from Cu, Zn, and the mixture
  - Yield decrease from the mixture each year
- Foliar fertilization strip trials (26 fields)
  - One soybean yield increase
  - One corn yield decrease
- Fertilization to soil (8 fields, 3 years each)
  - No yield increase or decrease at any trial

Micronutrient Research Conclusions

- Very unlikely corn and soybean yield response to micronutrients in Iowa
- Published sufficiency levels for soil or tissue tests are too high
- Little or no agreement between soil and tissue tests
- Couldn't develop interpretations due to no response

Micronutrient Research Conclusions

- Yield level is not a good indication of micronutrient need
- Don't trust published soil or tissue test interpretations, maybe use the lowest suggested sufficiency values
- Lime acid soils and watch sandy, badly eroded, or calcareous soils

Questions?