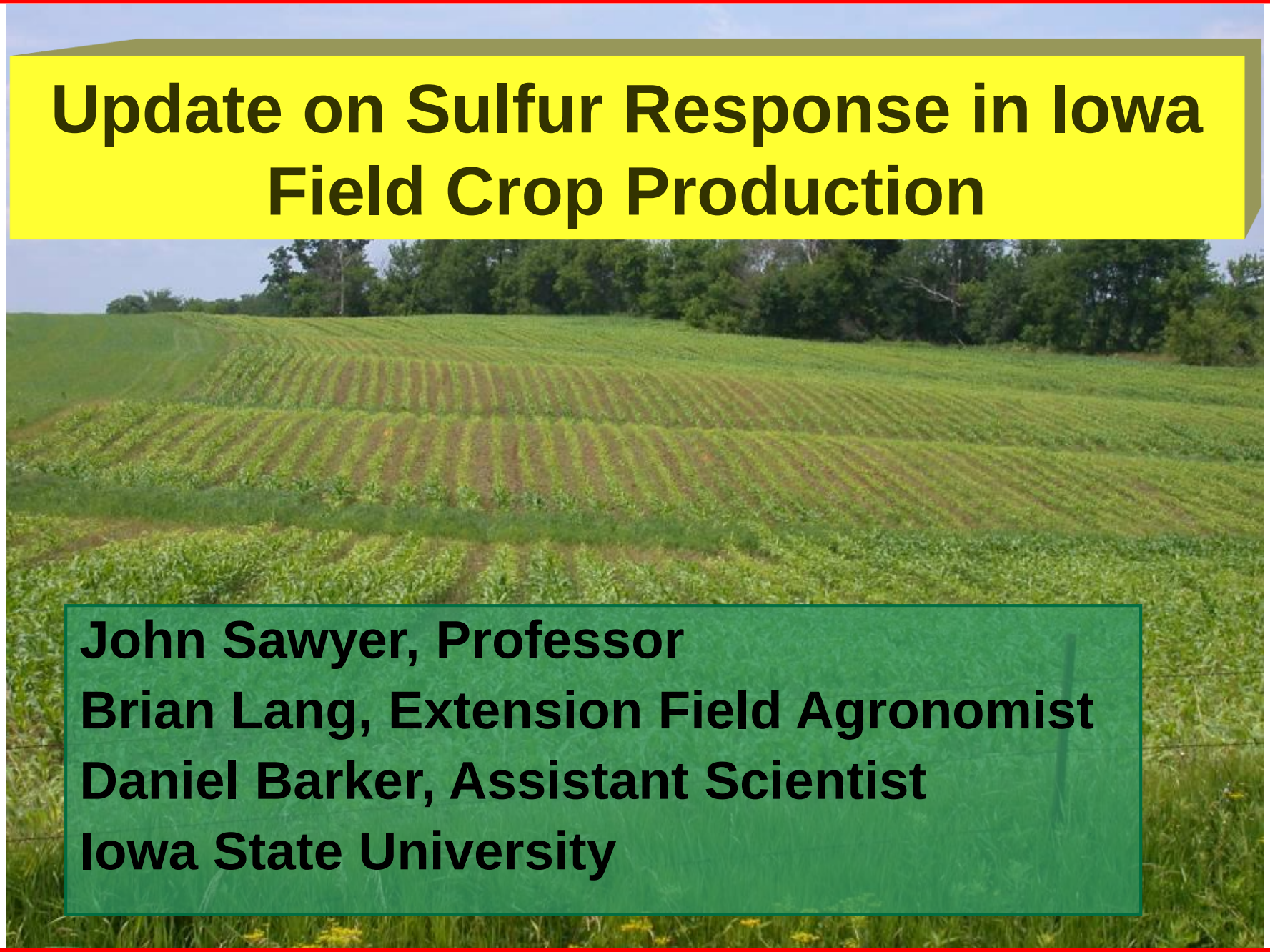
# Update on Sulfur Response in Iowa Field Crop Production

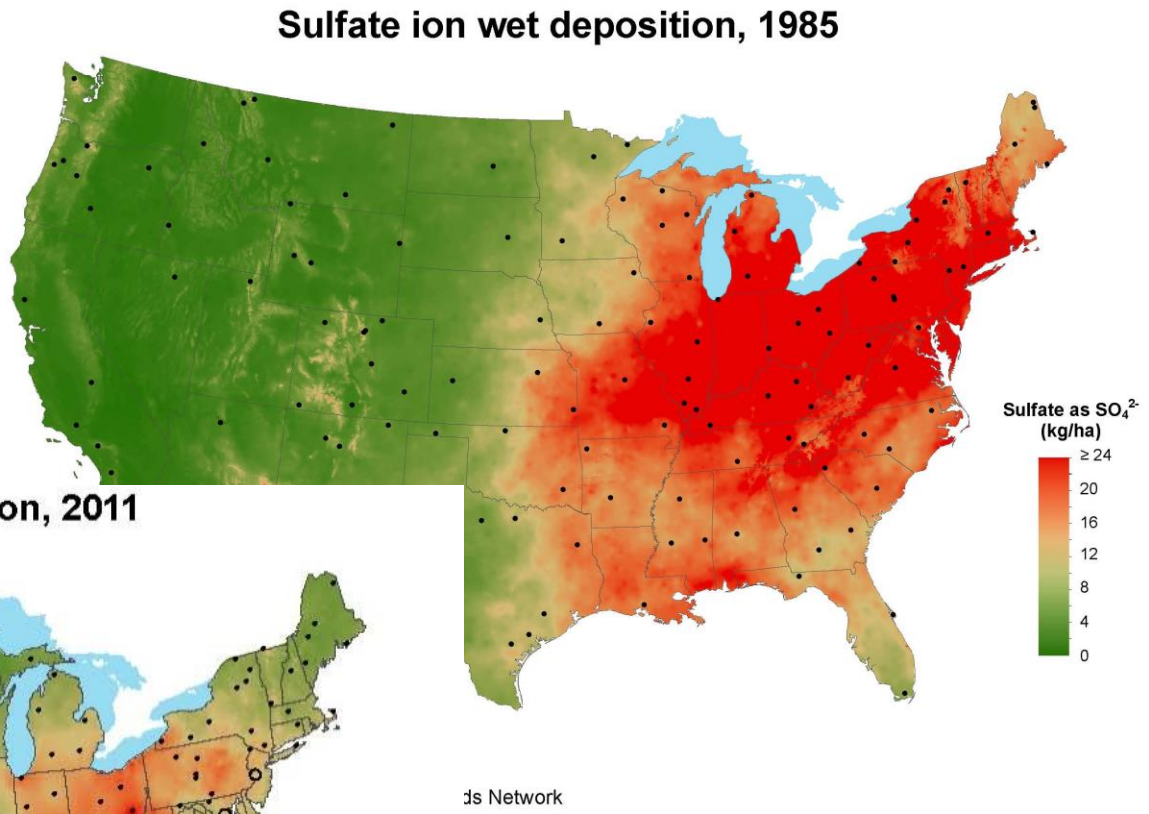


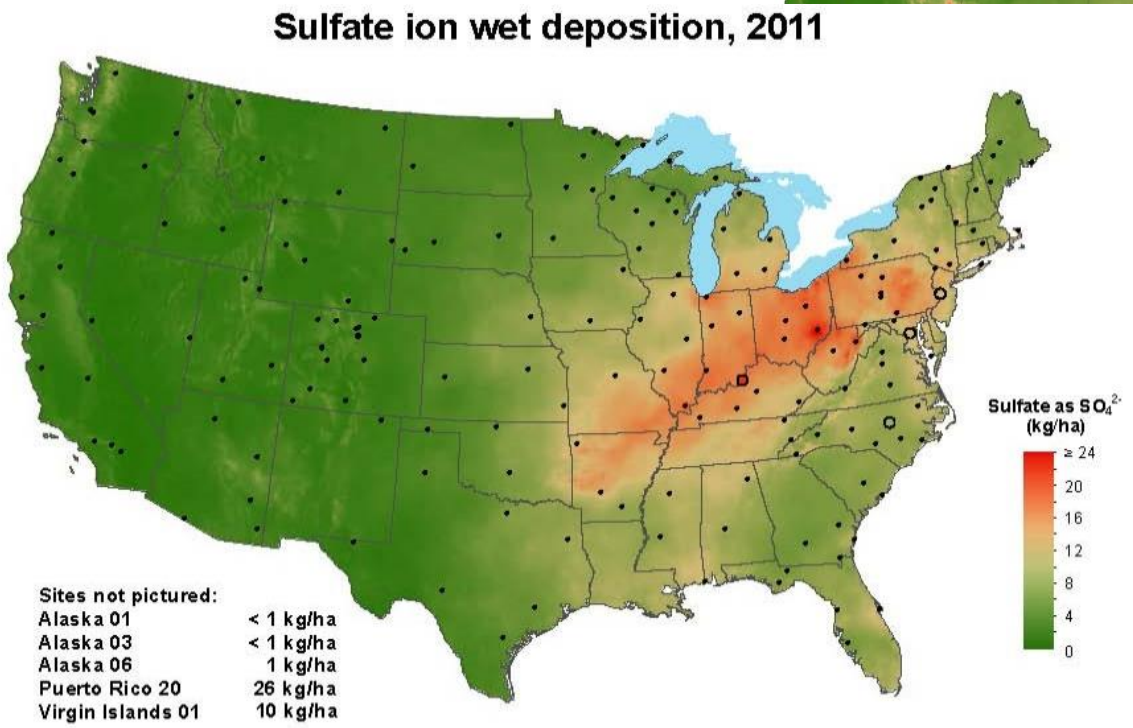
John Sawyer, Professor
Brian Lang, Extension Field Agronomist
Daniel Barker, Assistant Scientist
Iowa State University

# Sulfur Research History in Iowa

- 40+ years (before 2005 ) of research across Iowa (approximately 200 site-years)
  - Three times statistically significant yield increase
  - One study with multi-year average yield decrease
- Why no response to sulfur?
  - High soil organic matter
  - High subsoil sulfate
  - Atmospheric deposition
  - Manure application
  - Low S demanding crops
  - Fertilizers containing sulfur

# Sulfate Deposition 1985 – 2011




**National Atmospheric Deposition Program (NADP)**

National Atmospheric Deposition Program/National Trends Network
http://nadp.isws.illinois.edu

**10 kg $SO_4$/ha = 3 lb S/acre**

# Things Changed

## Observation of poor alfalfa growth in Northeast Iowa

# Visual Response in Alfalfa to S Application

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

| Sulfur Treatment | 2005 Cuts 2+3 DM Yield | | 2005 Cut 2 Plant Top S | | 2006 Cut 1 DM Yield | |
|---|---|---|---|---|---|---|
| | Observed Growth Area | | | | | |
| | 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) | | | |

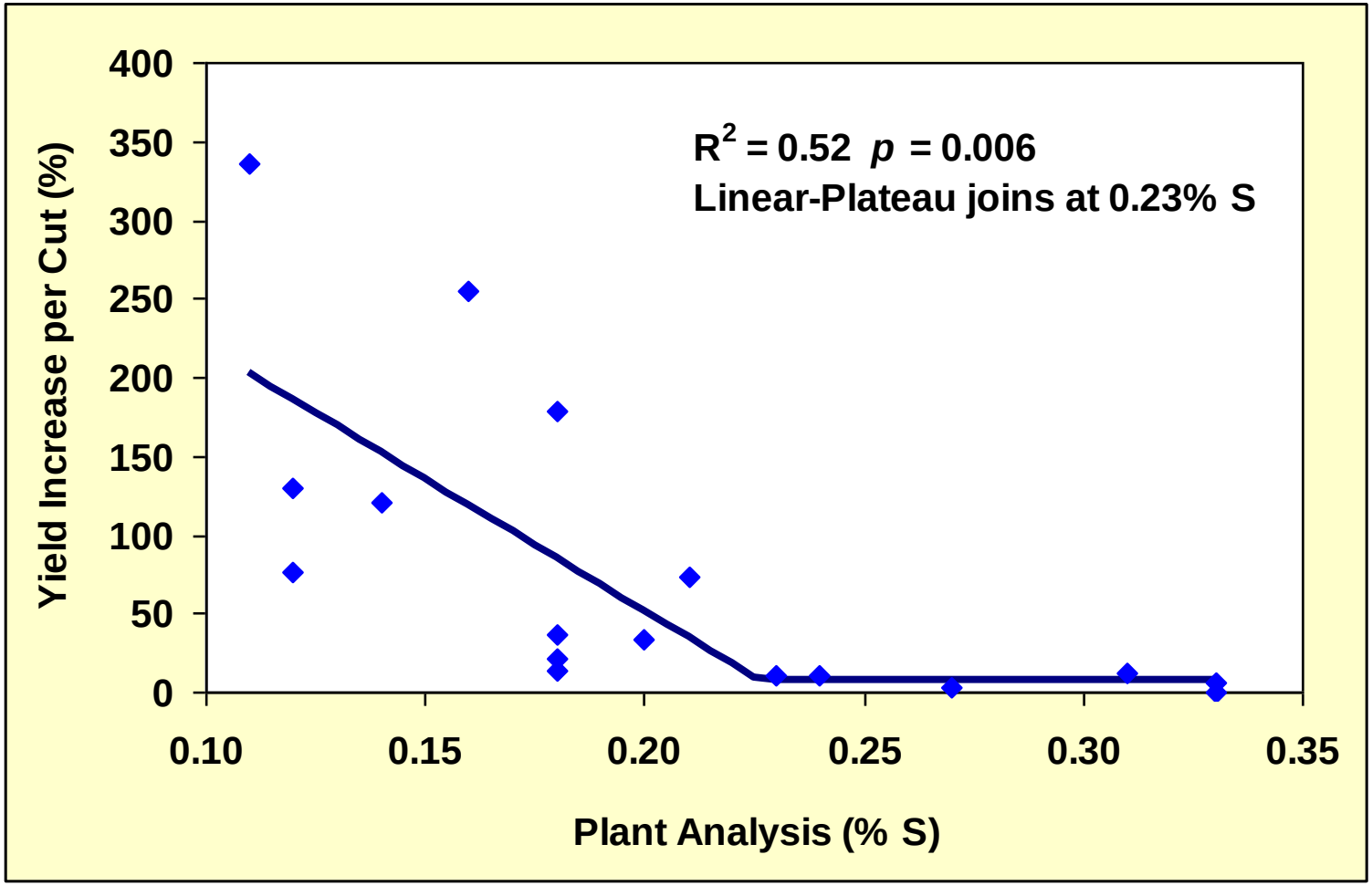
Three field sites in 2005, Elgin, Gunder and West Union, IA (Fayette & Downs sil soils).

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)



# 2010-2011 Alfalfa Sulfur Trial
# Nashua Research Farm

| Trt | Forage Yield | | | Soil S Test | | Plant Analysis | |
|---|---|---|---|---|---|---|---|
| | 2010 | 2011 | Mean | 2010 | 2011 | 2010 | 2011 |
| | - - - - - ton DM/acre - - - - - | | | - - - ppm - - - | | - - - - % S - - - - | |
| None | 6.15a | 6.44a | 6.30a | 7.8 | 7.5 | 0.22 | 0.19 |
| B | 6.10a | 6.68a | 6.39a | 6.9 | 5.8 | 0.17 | 0.20 |
| S | 6.91b | 7.85b | 7.38b | 7.4 | 6.7 | 0.39 | 0.47 |
| B + S | 6.67ab | 8.07b | 7.37b | 7.0 | 6.7 | 0.36 | 0.43 |

Means followed by the same letter are not different, $p \leq 0.05$.
S applied at 40 lb S/acre as gypsum (calcium sulfate).
B applied at 2 lb B/acre as Borate-48.
Fertilizers applied for each year.
Readlyn loam, 3.3% organic matter.
Three harvests in 2010 and four harvests in 2011.

B. Lang and K. Pecinovsky, ISU

# Things Changed

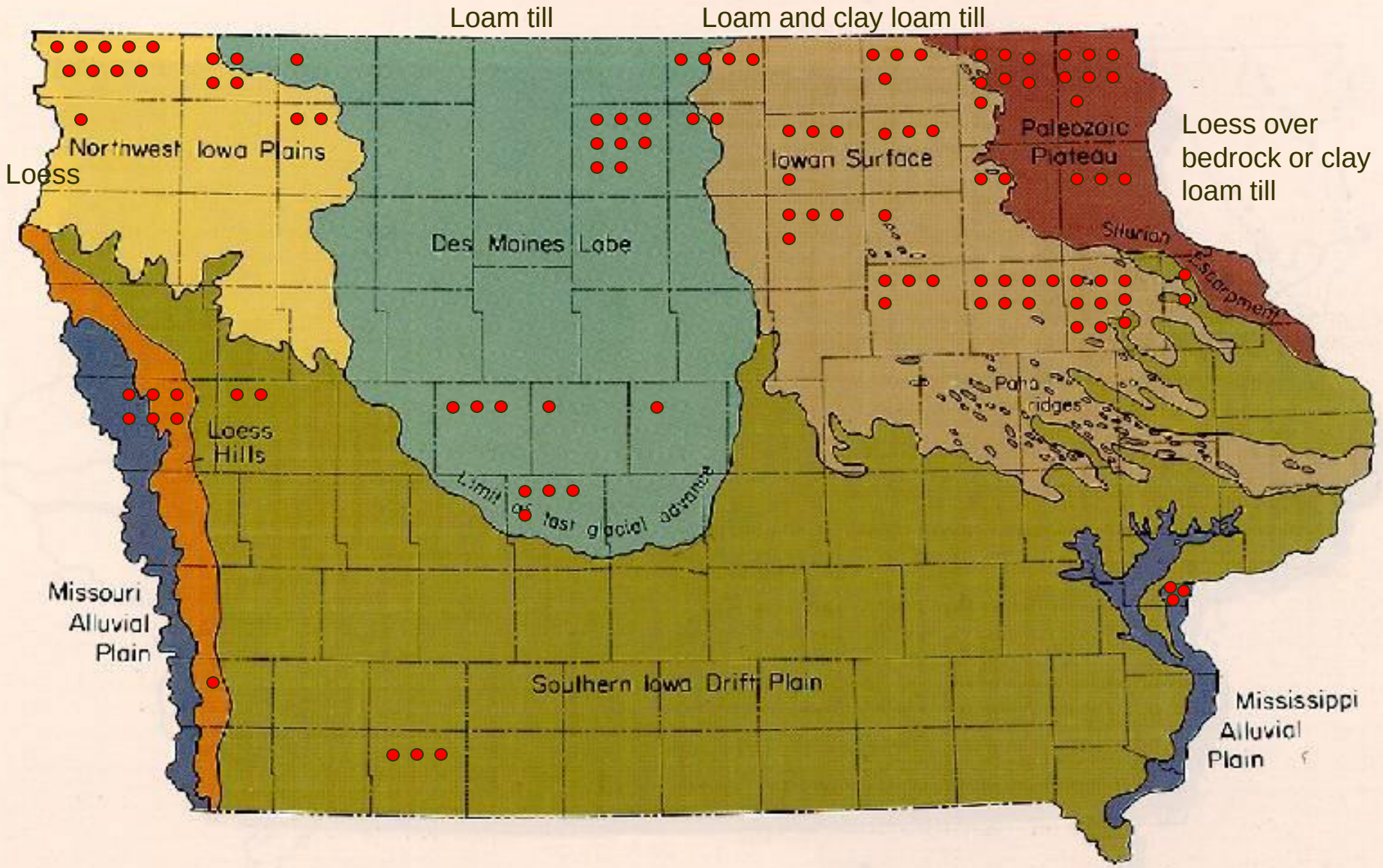
Slide from B. Lang, ISU

# Things Changed

## Visual Response in Corn to Sulfur Application

S Check S Check S Check

Slide from B. Lang, ISU




**Corn and soybean S trial sites, 2006-2013**

# Sulfur Fertilizer Trials on Corn in Problem Field Areas, Northeast Iowa, 2006

| Location | Soil type | Sulfur | Yield |
|---|---|---|---|
| | | | bu/acre |
| Lamont 1 | Sparta lfs | No | 123 a |
| | | Yes | 151 b |
| Lamont 2 | Sparta lfs | No | 154 a |
| | | Yes | 198 b |
| Thorpe 1 | Chelsa lfs | No | 88 a |
| | | Yes | 108 b |
| Thorpe 2 | Kenyon l | No | 196 a |
| | | Yes | 204 a |
| Waukon | Fayette sl | No | 96 a |
| | | Yes | 172 b |
| Waterville | Fayette sl | No | 118 a |
| | | Yes | 171 b |

Sulfur applied as calcium sulfate at 40 lb S/acre.



J.E. Sawyer, Iowa State Univ.

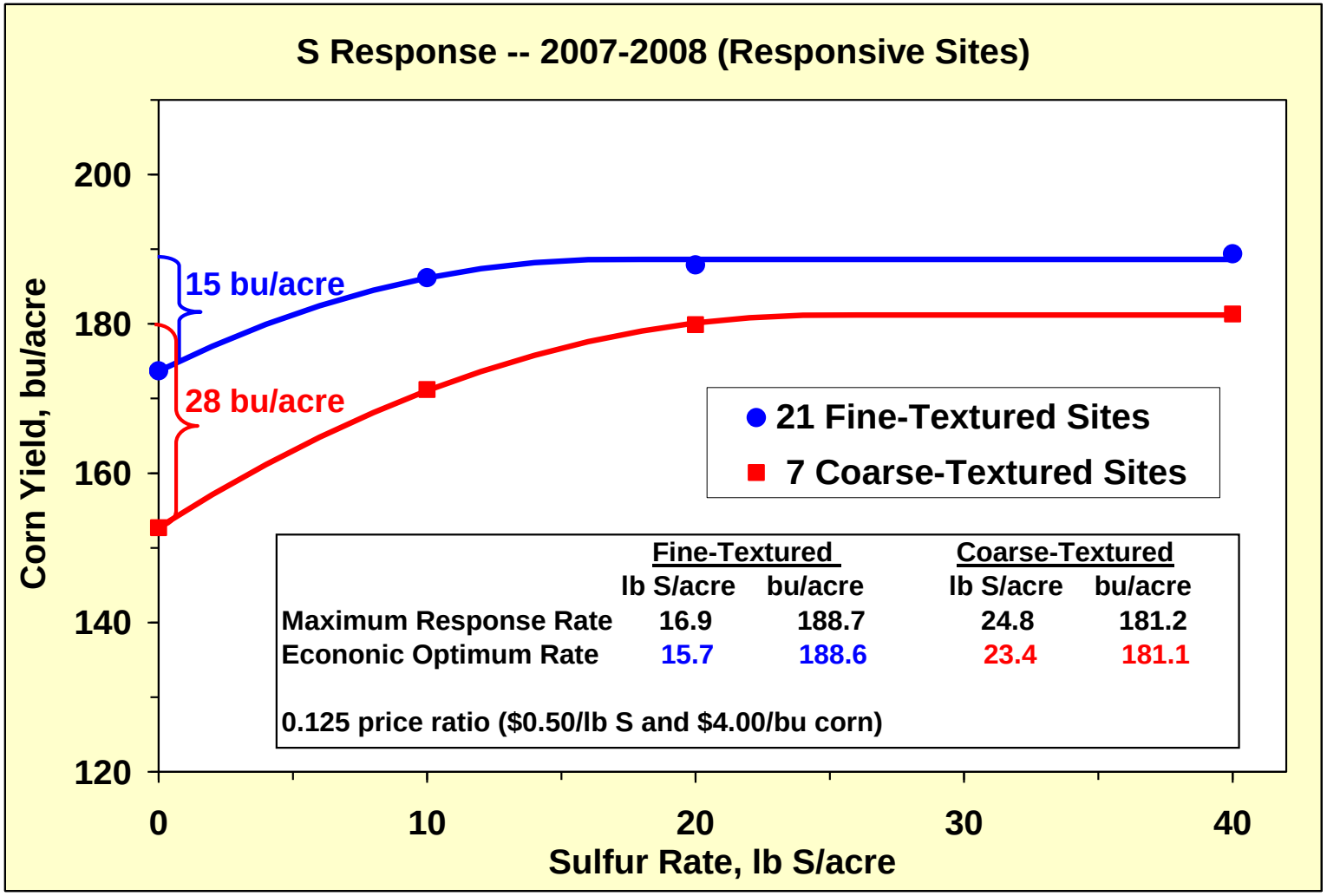
# Forty-Seven Corn S Rate Sites in 2007-2009
## Northeast – North Central Iowa

- 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
- Soils: l, sil, fsl, lfs, sl, sicl, cl

# Twenty-Eight Responsive S Rate Sites

## 2007-2008 North Central - Northeast Iowa

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



# Phosphorus and Sulfur Product Evaluation

- Two sites in northeast Iowa
  - 2006 (silt loam and loam soils)
  - Simplot 13-33-0-15S (SEF)
- Five sites in central to north-central Iowa
  - 2008 – 2010 (four loam and one loamy fine sand soils)
  - Mosaic 13-33-0-15S (MES15)
  - Mosaic 12-40-0-10S (MES10)
- Compared to AMS and MAP
- Sulfur applied at 10 and 30 lb S/acre
  - N and P equalized at rate with highest S rate

# Phosphorus and Sulfur Product Evaluation

- Sulfur response at two 2006 sites

| Treatment | Ear Leaf S | Grain Yield |
|---|---|---|
| | % | bu/acre |
| S-CON | 0.15a | 196a |
| SEF-10 | 0.18b | 211b |
| AMS-10 | 0.18b | 211b |

Mean response across both sites, 2006.

- No S yield response at five 2008 – 2010 sites
  - Leaf S concentration increased with all products
- Across all sites (2006 – 2010)
  - Yield response to P with all products (17 bu/acre)
  - Leaf P concentration increase with all products

# On-Farm Strip Trials
## Central and Northeast Iowa, 2009

| Site | County | Previous Crop | Sulfur Rate | Corn Yield - S | Corn Yield + S | Resp. |
|---|---|---|---|---|---|---|
| | | | lb S/acre | - - - - bu/acre - - - - | | |
| 3 | Greene | corn | 40 | 225 | 229 | |
| 4 | Greene | corn | 40 | 210 | 215† | 5 |
| 5 | Greene | corn | 40 | 217 | 228† | 11 |
| 6 | Dallas | soybean | 40 | 201 | 200 | |
| 9 | Dallas | corn | 40 | 147 | 152† | 5 |
| 10 | Dallas | corn | 40 | 135 | 134 | |
| 1 | Fayette | soybean | 15 | 224 | 236† | 12 |
| 2 | Howard | soybean | 20 | 186 | 192† | 6 |
| 7 | Dubuque | soybean | 30 | 216 | 229† | 13 |
| 8 | Floyd | --- | 20 | 199 | 203 | |
| 11 | Winneshiek | soybean | 30 | 215 | 212 | |

† Significantly different, P ≤ 0.10.

Sulfur applied as gypsum.



55% site response

# ISU FARM On-Farm Strip Trials
## Northwest Iowa, 2011-2012

ISU FARM On-Farm Strip Trials, 2011 and 2012 Residual Year

| County | Soil Texture | Previous Crop | Sulfur Rate | 2011 Yield | | 2012 Yield | |
|---|---|---|---|---|---|---|---|
| | | | | - S | + S | - S | + S |
| | | | lb S/acre | - - - - - - bu/acre - - - - - - - | | | |
| Osceola | scl | corn | 23 | 70.9 | 68.8 | 188 | 185 |
| Lyon | scl | corn | 23 | 60.4 | 60.9 | -- | -- |
| Lyon | scl | corn | 23 | 60.8 | 59.3 | 203 | 199 |
| Sioux | scl | corn | 23 | 74.3 | 73.6 | 173 | 175 |
| Lyon | scl | soybean | 23 | 209 | 203 | -- | -- |

* Indicates statistical difference at P ≤ 0.10.

Sulfur applied in spring as gypsum.

# ISU FARM Strip Trials
## NW-W-SW Iowa, 2012-2013

ISU FARM On-Farm Strip Trials, 2012, 2013, and 2013 Residual Year

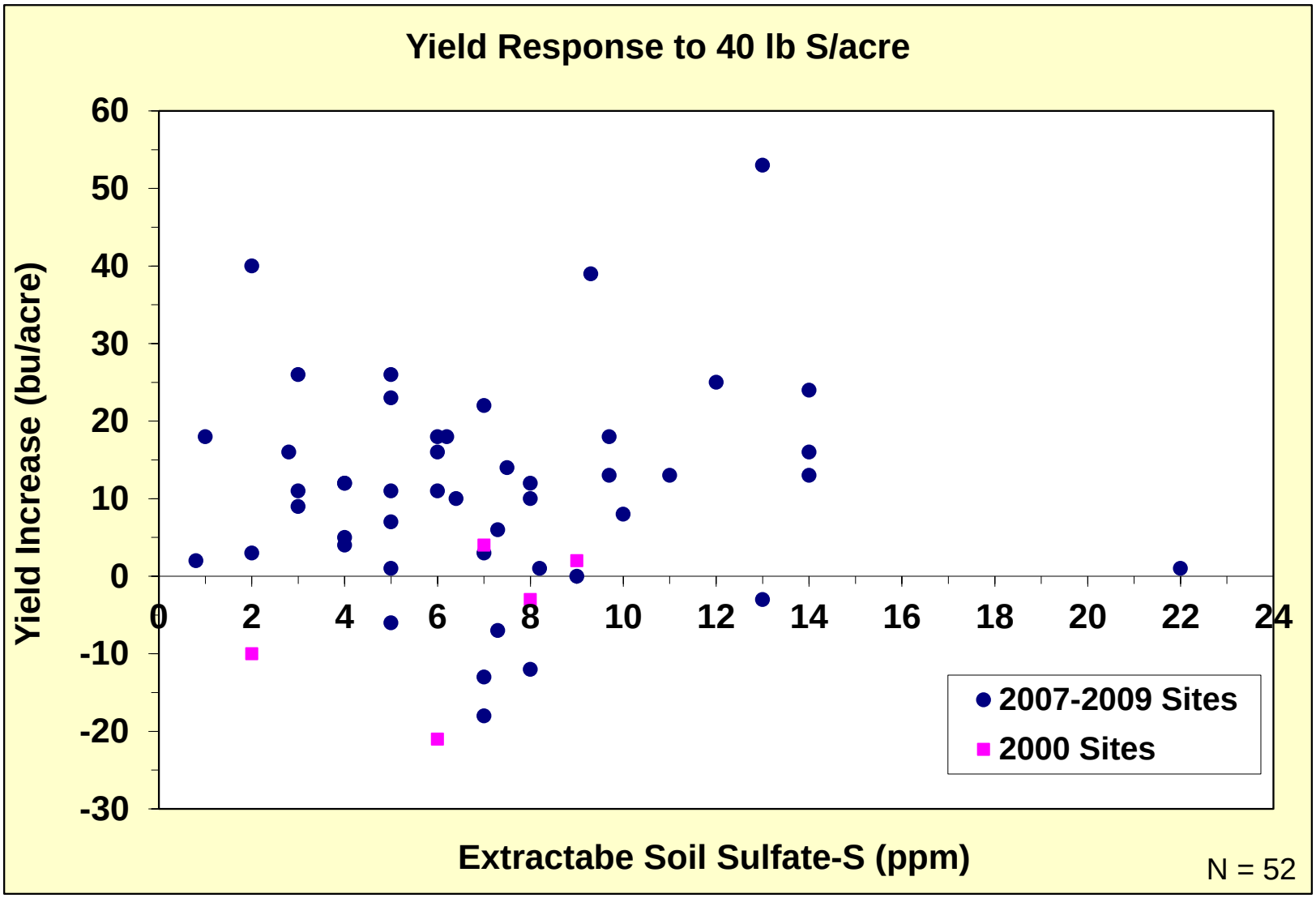
| Site | County | Previous Crop Yr 1 | Sulfur Rate | 2012 Yield - S | 2012 Yield + S | 2013 Yield - S | 2013 Yield + S | Response '12 | Response '13 |
|---|---|---|---|---|---|---|---|---|---|
| | | | lb S/acre | bu/acre | | | | | |
| 1c | Mills | soybean | 17 | 217 | 218 | -- | -- | | |
| 2c | Taylor | soybean | 17 | 99 | 106* | -- | -- | 7 | |
| 3c | Lyon | soybean | 15 | 157 | 160 | 40.5 | 44.3* | | 3.8 |
| 4c | Osceola | soybean | 15 | 198 | 197 | -- | -- | | |
| 5c | Dickinson | soybean | 15 | 213 | 214 | -- | -- | | |
| 6c | Lyon | soybean | 15 | 140 | 134* | 43.7 | 42.7 | -6 | |
| 7c | Lyon | soybean | 15 | 88 | 79 | 55.5 | 53.6 | | |
| 8c | Crawford | soybean | 15 | 100 | 132* | 45.0 | 49.1* | 32 | 4.1 |
| 9c | Monona | soybean | 15 | 190 | 195 | 228 | 240 | | |
| 10c | Monona | soybean | 15 | 232 | 228 | 69.3 | 69.5 | | |
| 11c | Clay | soybean | 15 | 231 | 235 * | 54.8 | 55.2 | 4 | |
| 1s | Osceola | corn | 15 | 50.2 | 52.4 | 201 | 205 | | |
| 2s | Monona | corn | 15 | 64.3 | 63.3 | 230 | 236* | | 6 |
| 1n | Taylor | soybean | 17 | -- | -- | 172 | 181* | | 9 |
| 1n | Taylor | corn | 17 | -- | -- | 45.3 | 44.1 | | |

* Significant difference at P ≤ 0.10. Sulfur applied in spring as gypsum.

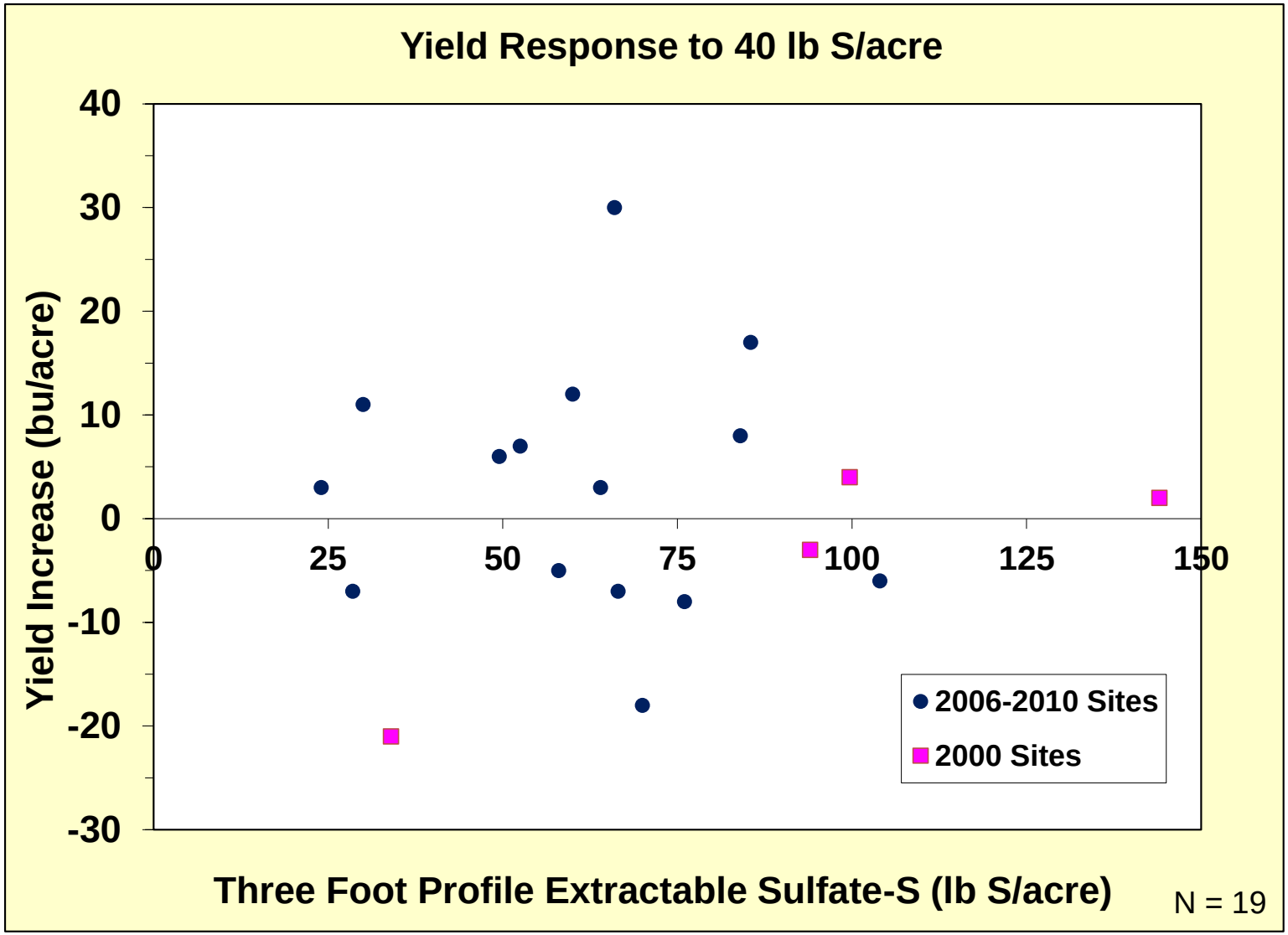


29% site positive response

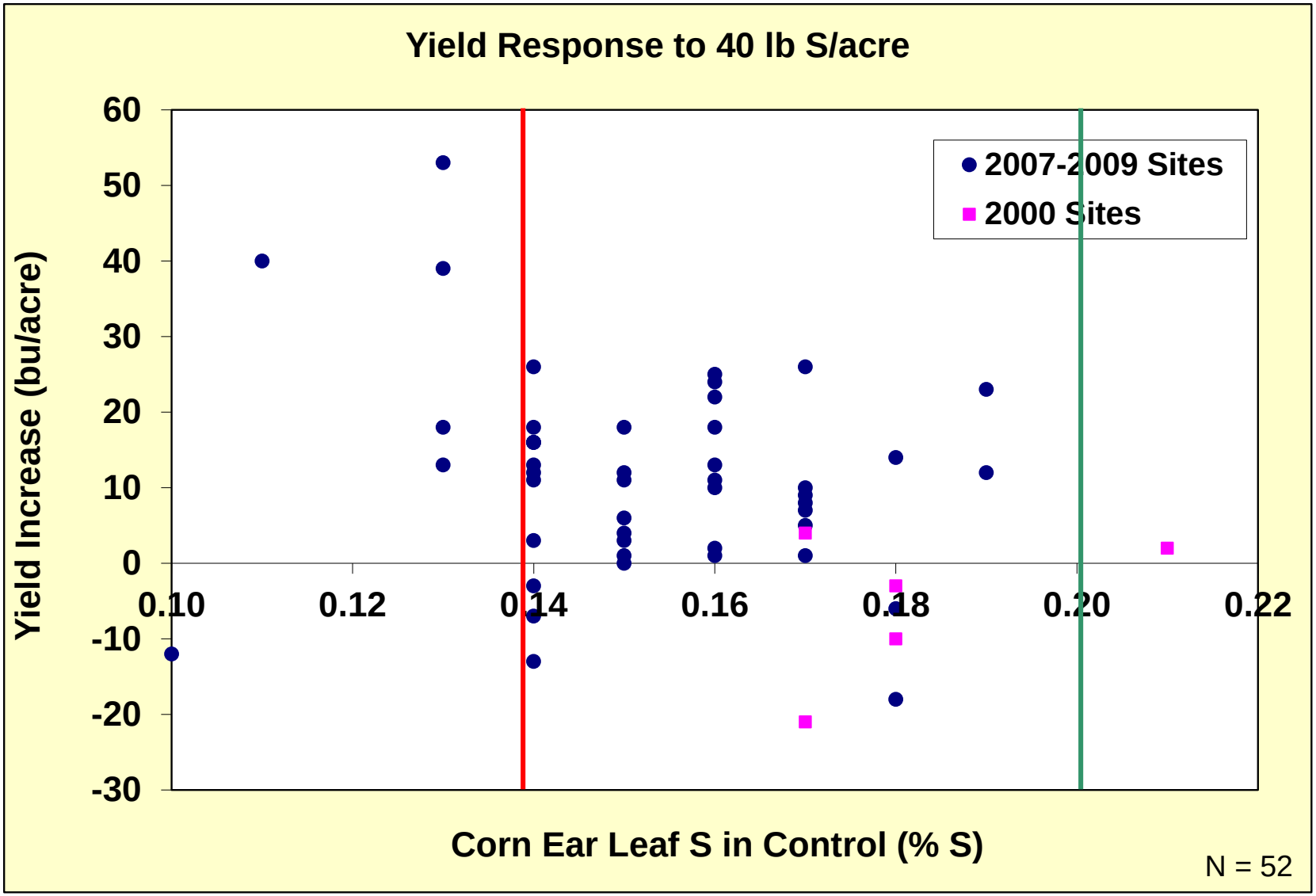
# Extractable Soil Sulfate-S (0-6 inch depth)



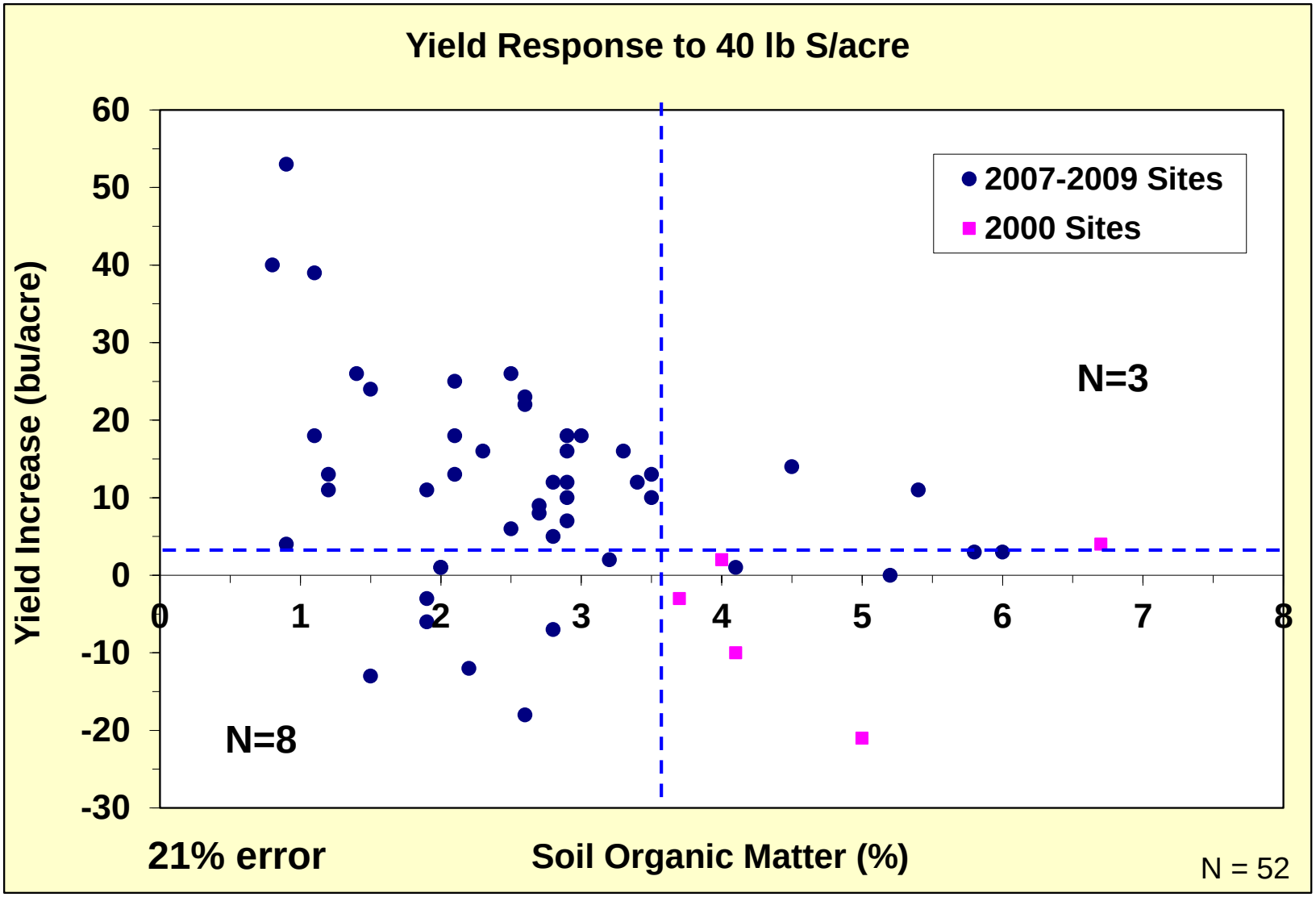
# Soil Profile Extractable Sulfate-S



# Corn Ear Leaf S Concentration (R1 Stage)



# Soil Organic Matter (0-6 inch depth)

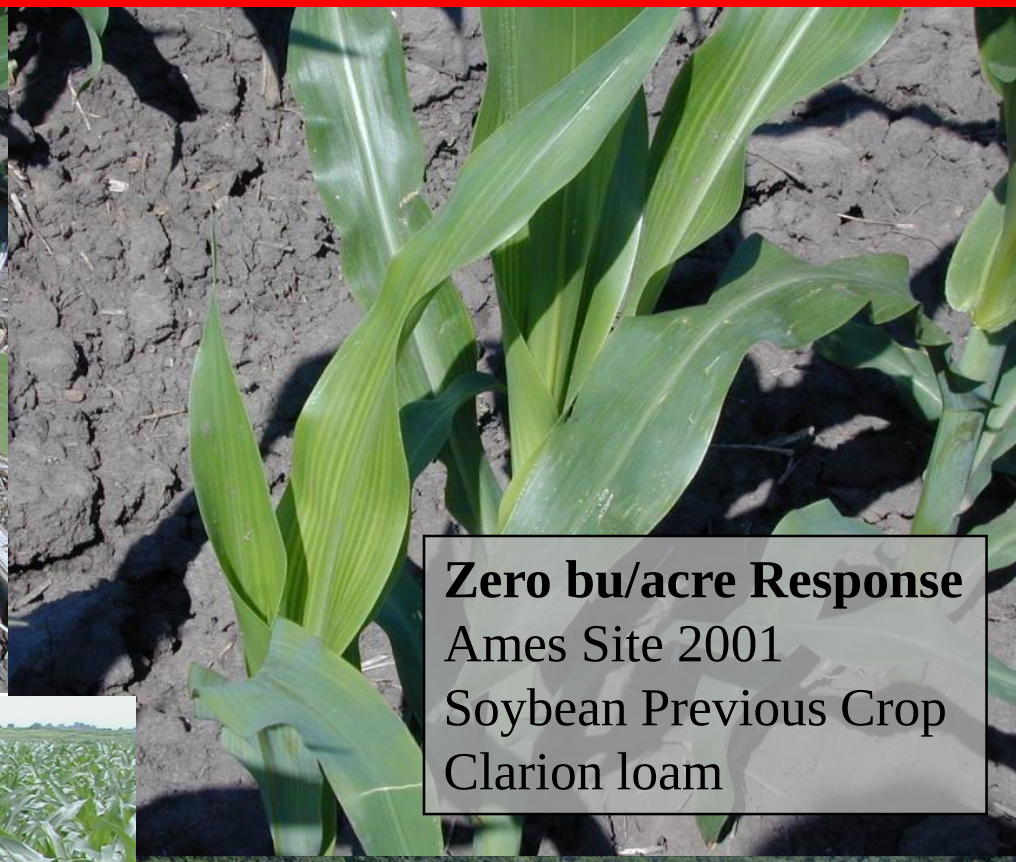


**76 bu/acre Response**
Site WK 2006
Alfalfa Previous Crop
Fayette sil

**42 bu/acre Response**
Site D 2007
Soybean Previous Crop
Sparta lfs

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

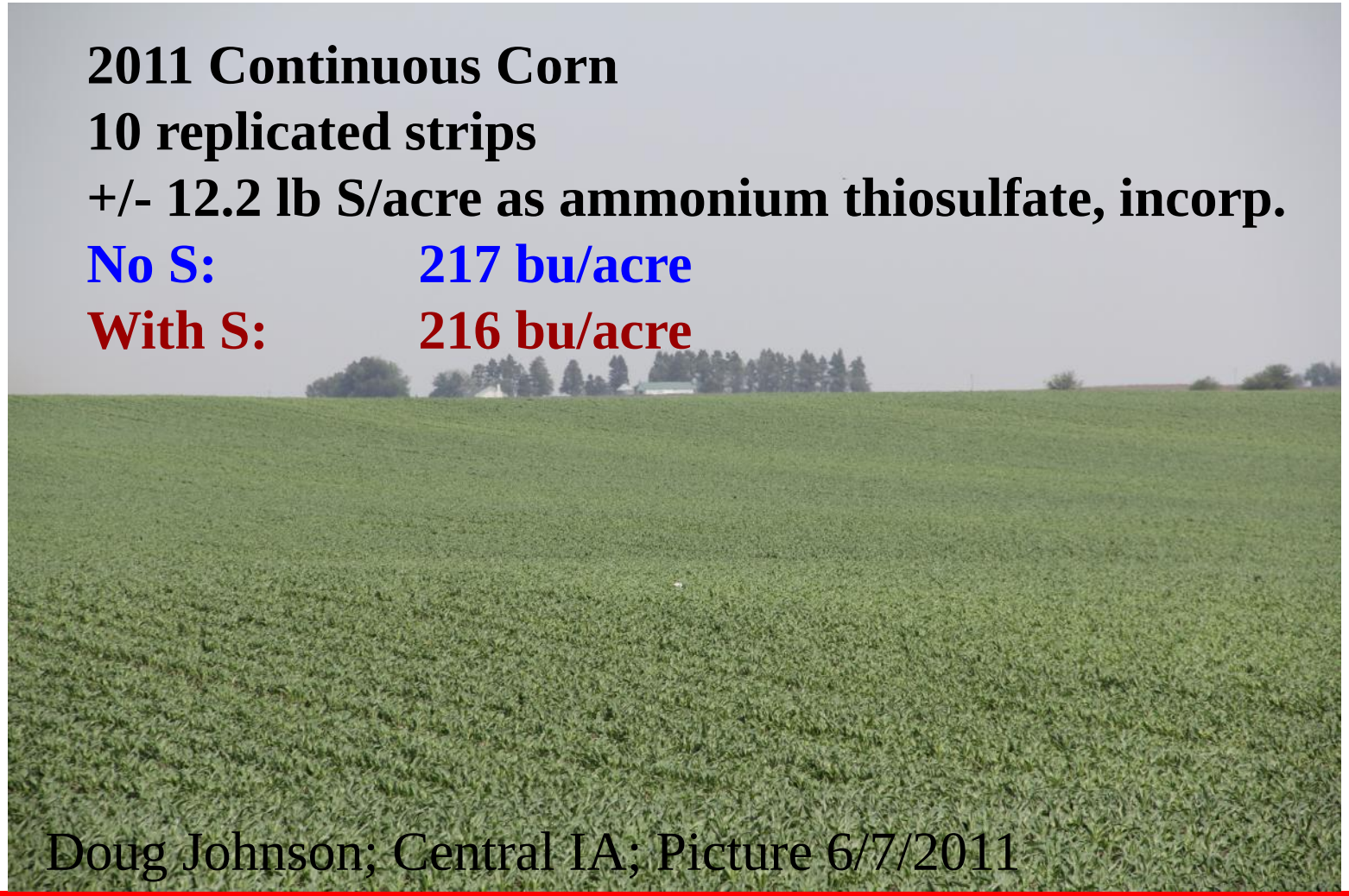
**Zero bu/acre Response**
Site Mason City 2008
Soybean Previous Crop
Readlyn loam



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

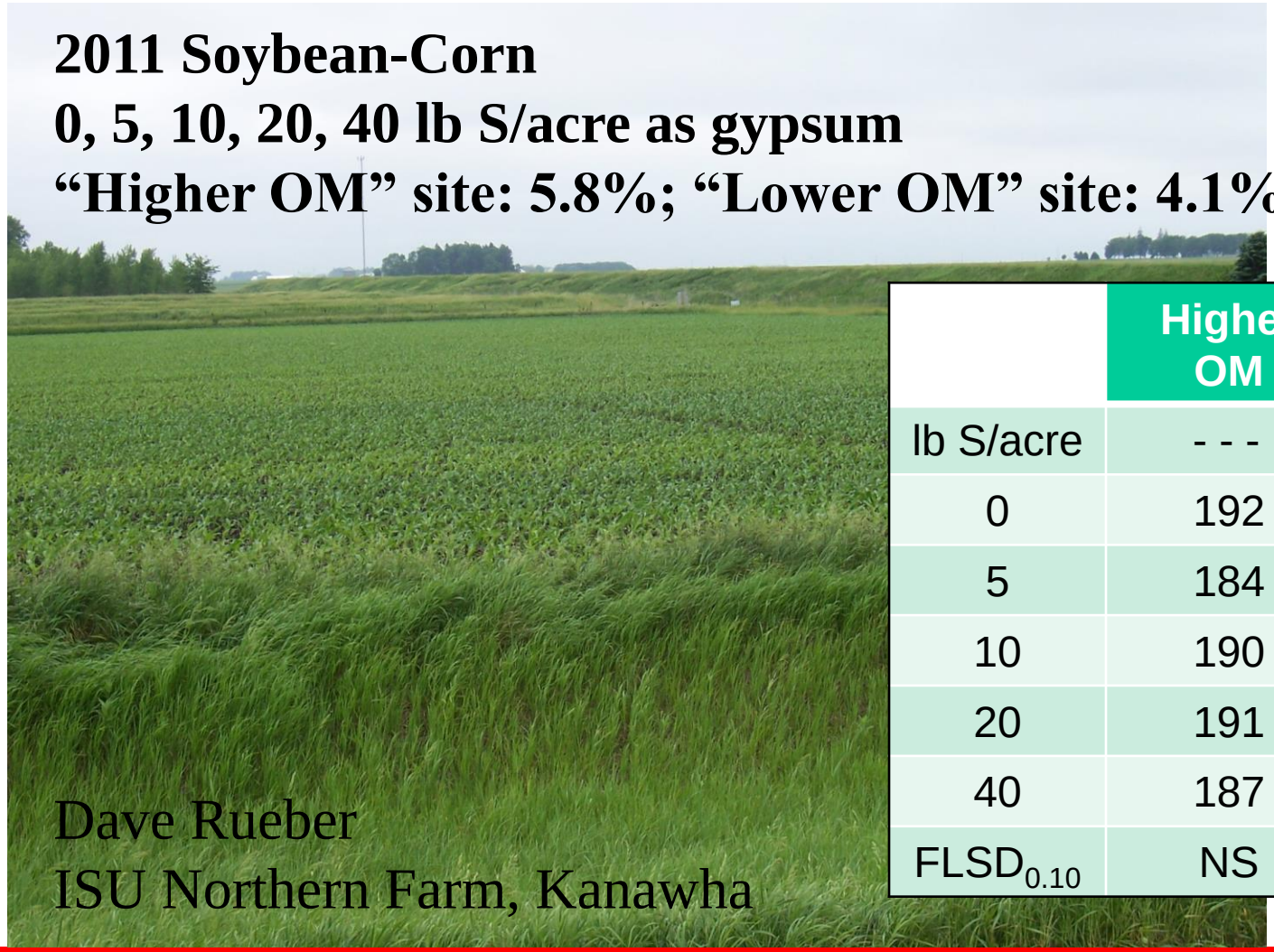
**No Response or Small Response**

# Early Season Sulfur Deficiency Symptoms Can Disappear



# Early Season Sulfur Deficiency Symptoms Can Disappear

**2011 Soybean-Corn**
**0, 5, 10, 20, 40 lb S/acre as gypsum**
**“Higher OM” site: 5.8%; “Lower OM” site: 4.1%**



Dave Rueber
ISU Northern Farm, Kanawha

| | Higher OM | Lower OM |
|---|---|---|
| lb S/acre | - - - bu/acre - - - | |
| 0 | 192 | 187 |
| 5 | 184 | 188 |
| 10 | 190 | 187 |
| 20 | 191 | 191 |
| 40 | 187 | 183 |
| $FLSD_{0.10}$ | NS | NS |

# 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 - - - - | | | NDVI | | - - - - bu/acre - - - - | | | NDVI | |
| 0 | 192 | 82 | 152 | 0.557 | | 187 | 80 | 174 | 0.577 | |
| 5 | 184 | 100 | 171 | 0.591 | | 188 | 99 | 192 | 0.619 | |
| 10 | 190 | 105 | 180 | 0.657 | | 187 | 109 | 191 | 0.649 | |
| 20 | 191 | 105 | 179 | 0.629 | | 191 | 113 | 179 | 0.663 | |
| 40 | 187 | 111 | 181 | 0.638 | | 183 | 104 | 185 | 0.671 | |
| 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.
Significance either rate, linear, quadratic, cubic, or +S vs. –S.
Dave Rueber, ISU Northern Research Farm, Kanawha, IA.
NDVI from Crop Circle at V10 corn growth stage.

# Sulfur Rate Trials – Northern Research Farm

| | Next to Lower OM Site | | |
|---|---|---|---|
| | 2012 | 2013 | |
| S Rate | CS | SC | |
| lb S/acre | - - - bu/acre - - - | | NDVI |
| 0 | 35 | 149 | 0.620 |
| 5 | 35 | 154 | 0.636 |
| 10 | 34 | 150 | 0.637 |
| 20 | 34 | 152 | 0.635 |
| 40 | 36 | 154 | 0.645 |
| Sign. (0.10) | NS | NS | NS |

Clarion silt loam.
S rates (gypsum) in spring 2012 before soybean.
Significance: rate, linear, quadratic, cubic, or +S vs. –S.
Dave Rueber, ISU Northern Research Farm, Kanawha.
NDVI from Crop Circle at V10 corn growth stage.

# Sulfur Rate Trials
# Muscatine Island Research Farm

| S Rate | 2011 | 2012 | 2013 |
|---|---|---|---|
| lb S/acre | bu/acre | | |
| 0 | 72.4 | 211 | 259 |
| 10 | 74.4 | 207 | 258 |
| 20 | 69.6 | 214 | 254 |
| 40 | 72.2 | 210 | 262 |
| Sign. (0.05) | NS | NS | NS |

Fruitfield coarse sand (1 to 1.5% OM), irrigated.
S rates (gypsum) applied post-emergence.
Leaf S concentrations increased each year with S application.
2013: 1.7 lb $SO_4$-S/acre-inch irrigation (27 lb S/acre in 16 inches).
Vince Lawson, ISU Muscatine Island Research Farm, Fruitland.

# Summary

- Sulfur deficiencies 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
    - 68% sites responsive with l, sil, fsl, lfs, sl soils
    - 14% sites responsive with sicl, cl soils
- 47% S response frequency for 110 trials statewide from 2006 – 2013
  - 33% S response frequency for 2009 – 2013

# Summary

- Sulfur application rate when needed
  - Alfalfa: topdress 20 to 30 lb S/acre
  - Corn: 15 lb S/acre fine textured soils
    25 lb S/acre coarse textured soils
- Tools to indicate S deficiency
  - Alfalfa – top six-inch plant growth at early bud
  - Corn and soybean – ??
    - General field/soil characteristics
    - Visual coloration and growth response

# Sulfur Fertilizers

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

# Research Support

- Honeywell International, Inc.
- J.R. Simplot Company
- Mosaic Fertilizer, LLC
- Foundation for Agronomic Research
- Calcium Products, Inc.
- Iowa State University Extension
- Iowa State University Research Farms
- Iowa State University FARM

Slide from B. Lang, ISU