Crop Availability of Sulphur From Elemental-S

Kent Martin, Ph.D.

Alberta Update

Martin Agronomic and Environmental Consulting, LLC

Background

- Sulphur is taken up by plants as $SO_4^{=}$
- Mobile in the soil, immobile in the plant
- Fertilizer recommendations tied to yield goals
  - Due to mobility in soil and activity in the plants

- Deep soil sampling increases accuracy and predicted crop response
- Deficiency typically seen with coarse soil texture, low S testing soil, low organic matter, or eroded areas
  - In crops with high demand – alfalfa, canola, corn

Survey

- Survey conducted to Researchers, University, and Consultants
- 100% of respondents recognized the need for S and that farmers focus on S is increasing
  - Perceived need for Sulfate – 73%
  - Perceived need for ES – 27%
  - What are the drivers?
    - Availability of S to the crop
    - Able to be blended
    - Free of dust and fines
- Recognized need for high analysis S product that is readily available

Role of S in Plants (Canola)

- Key nutrient for structural plant parts
- Part of enzymes
- Amino acids responsible for protein synthesis
- Chlorophyll synthesis

Biochemical

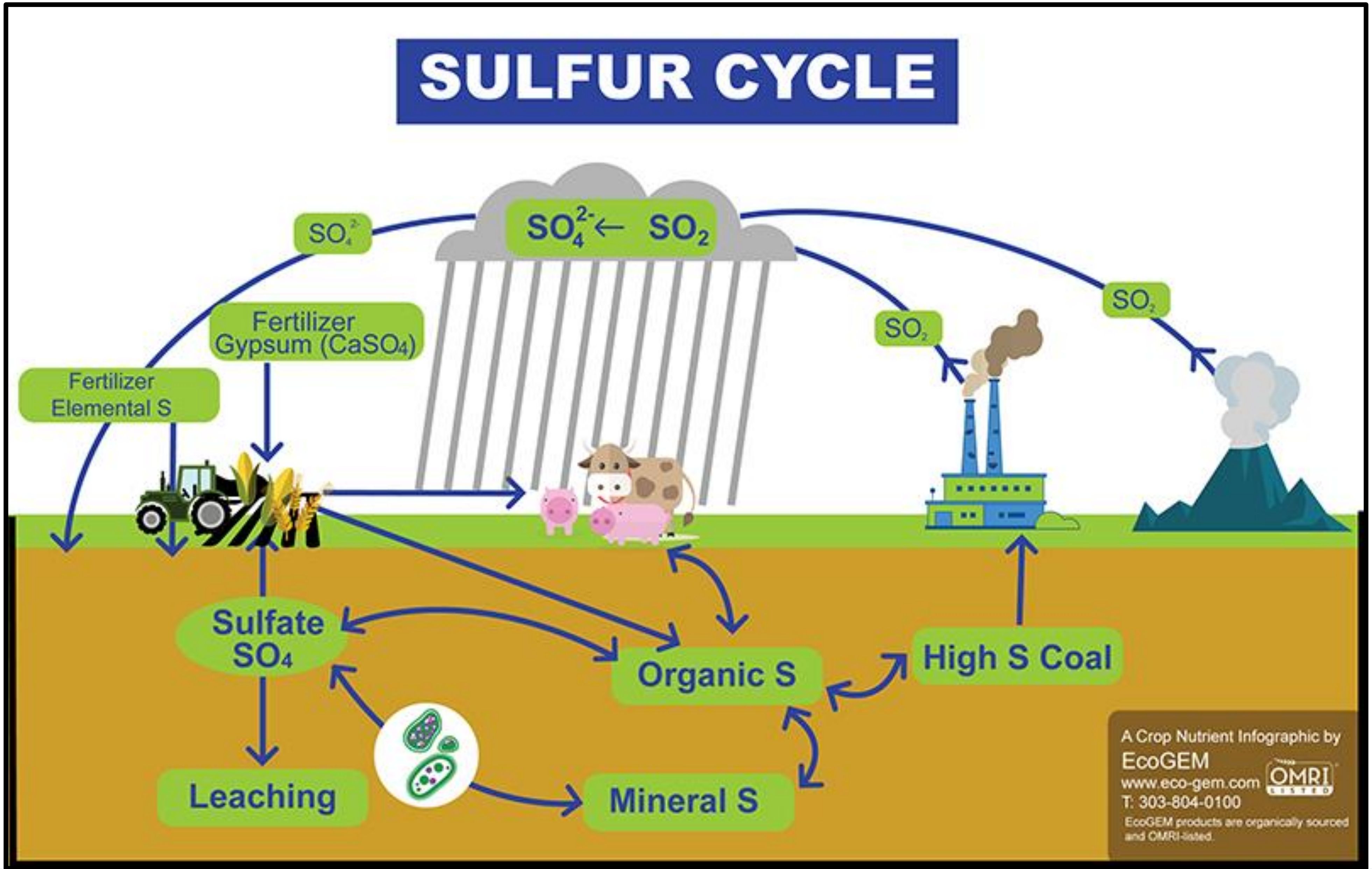
- Rapid crop growth
- Earlier maturity
- Yield

Yield

- Protein content
- Oil content

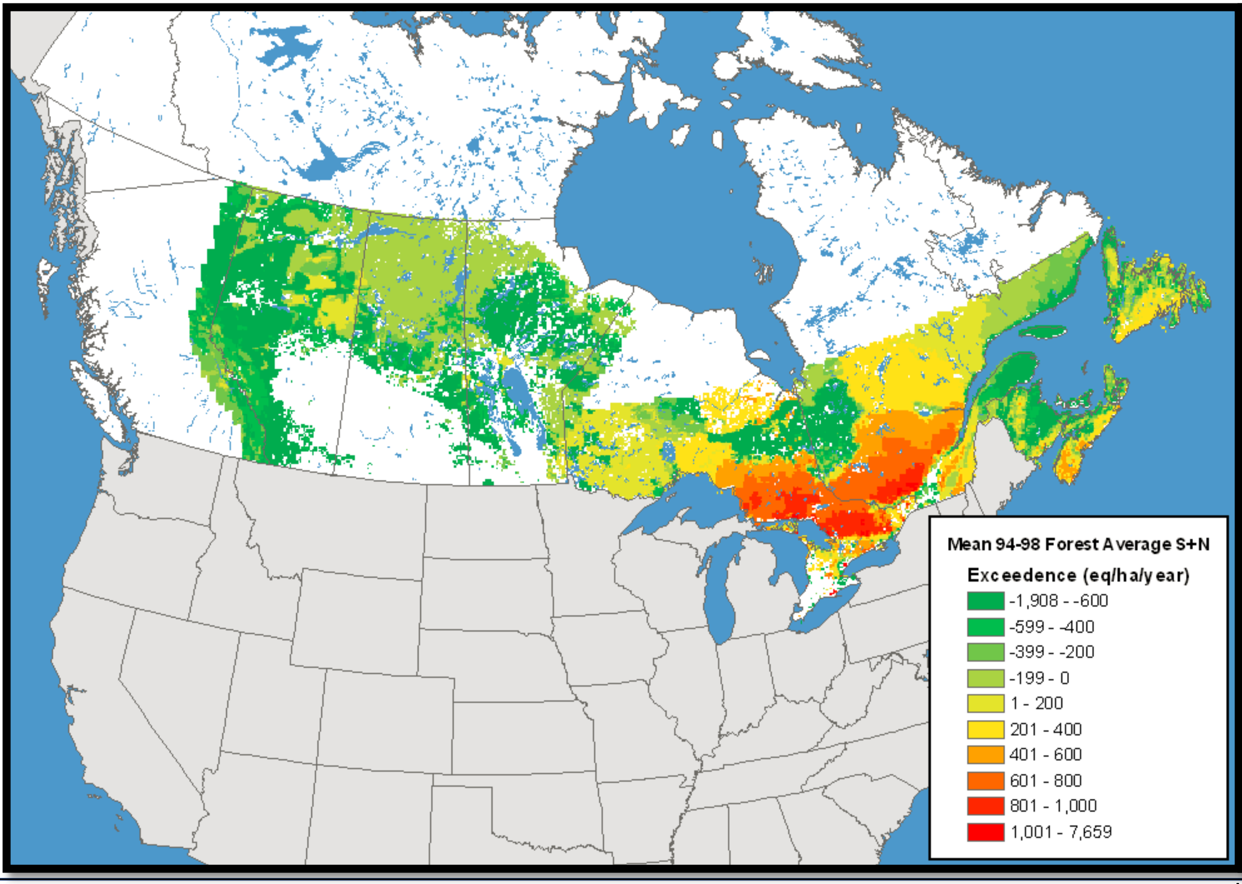
Quality

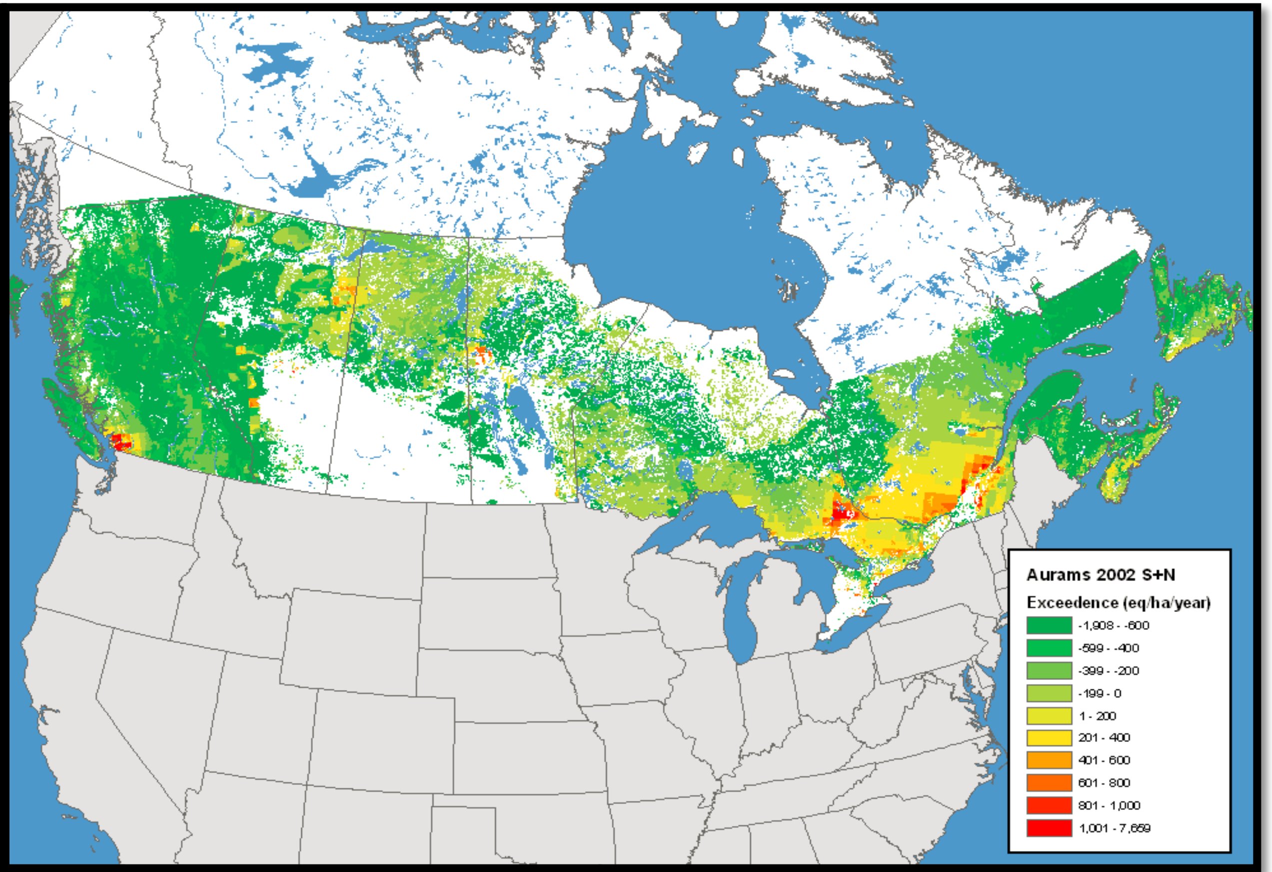
Sulphur Deficiency Symptoms


SULFUR CYCLE
SO_4^{2-} ← SO_2
SO_4^{2-}
Fertilizer
Gypsum ($CaSO_4$)
Fertilizer
Elemental S
SO_2
SO_2
Sulfate
SO_4
Organic S
High S Coal
Leaching
Mineral S
A Crop Nutrient Infographic by
EcoGEM
www.eco-gem.com
T: 303-804-0100
OMRI LISTED
EcoGEM products are organically sourced and OMRI-listed.

Atmospheric Deposition of S

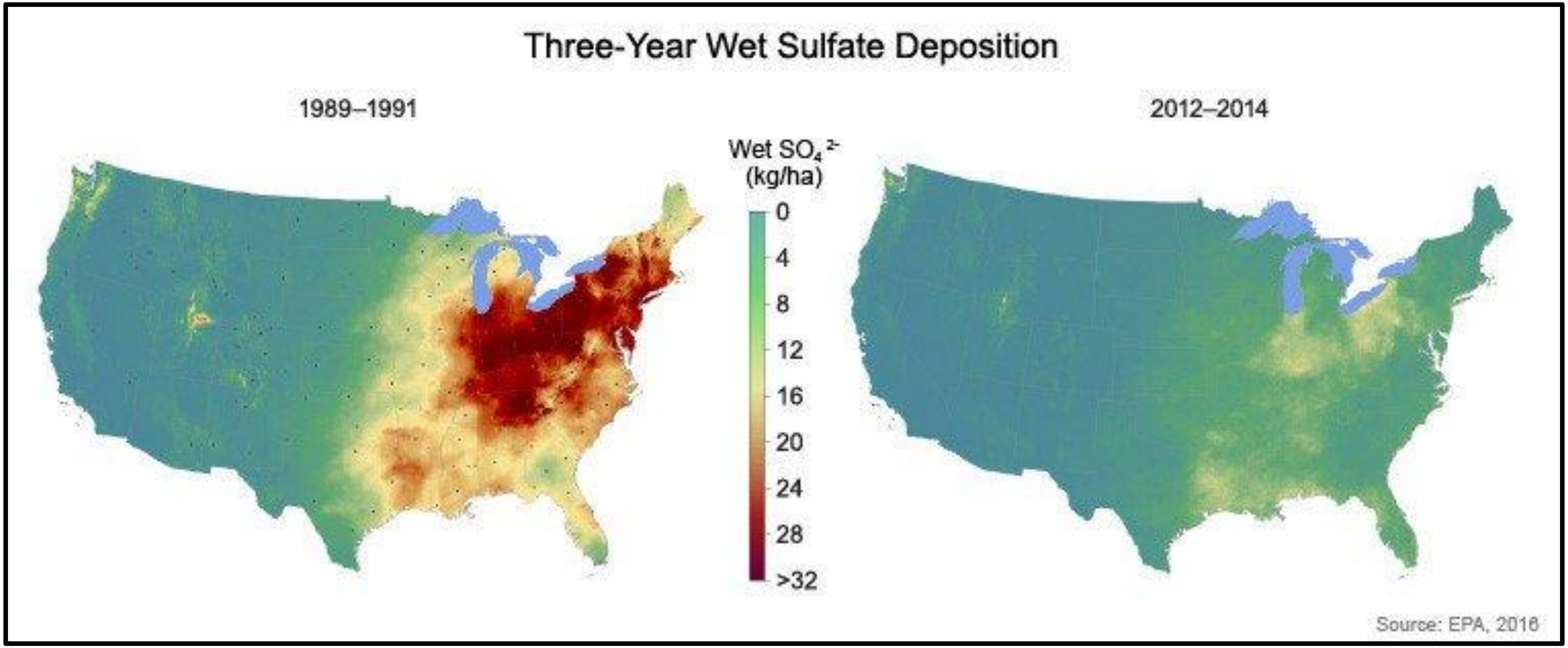
One of the greatest reasons for decrease in S deposition is clean air





https://www.ccme.ca/files/Resources/air/acid_rain/national_picture_acid_deposition_pn1412.pdf

Atmospheric Deposition of S



Sulphur Sources

- Soil S Pool:
  - Organic (95%) ------- Inorganic (5%)
  - Balance depends on the balance of immobilization and mineralization
    - Immobilization – microbial conversion of inorganic S to organic S (not available to plants)
    - Mineralization – Breakdown of organic S into inorganic compounds that results in plant available S
- S Fertilizer
  - Sulfate
    - Ammonium Sulfate (21-0-0-24)
    - Gypsum ($CaSO_4$, 15% S, 19% Ca)
  - Elemental
    - Sulphur Bentonite (0-0-0-90)
    - Co-granulated S

Fertilizer Source	Formula	Analysis
Ammonium Sulfate	$(NH_4)_2SO_4$	21-0-0-24
Ammonium Thiosulfate (ATS)	$(NH_4)_2S_2O_3$	12-0-0-26
Gypsum	$CaSO_4 \bullet 2H_2O$	0-0-0.5-17
Epsom Salt	$MgSO_4 \bullet 7H_2O$	0-0-0-14
Potassium Magnesium Sulfate	$K_4SO_4 \bullet 2MgSO_4$	0-0-22-23
Potassium Sulfate	K_4SO_4	0-0-50-18
Elemental S	S + Bentonite	0-0-0-90
Co-granulated Elemental S	S + Co-granulated Product	variable

Advantages and Disadvantages

Sulfate

Advantages	Disadvantages
Immediately Available	Leachable
Fast Concentration of Sulfate	Only Takes One Large Rainfall for Loss
Water Soluble	Water Soluble

Elemental S

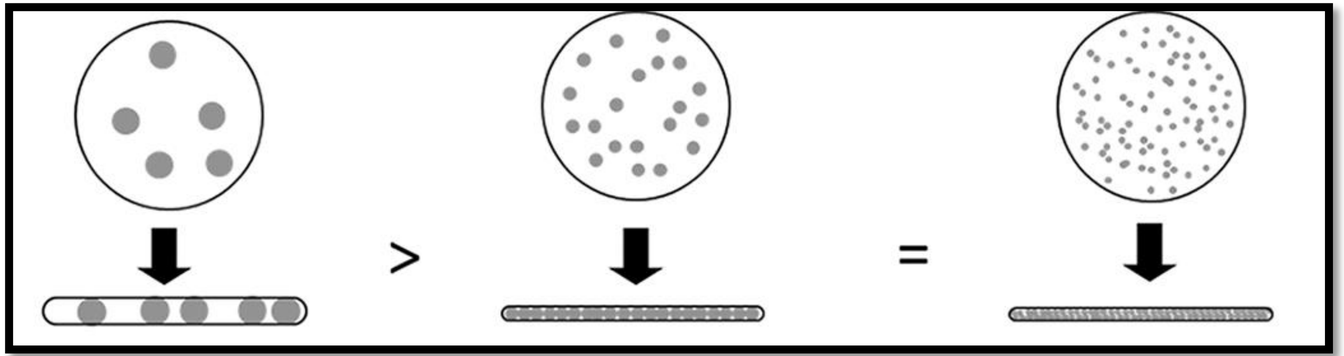
Advantages	Disadvantages
Sustained Release	Slower to Become Available
Less Risk of Loss by Leaching	Not Able to Immediately Correct Deficiency
Can Build Soil S Levels	Need to Understand Products

Microbial Oxidation of Elemental S

- Elemental S must be oxidized to be available to plants
  - $S^0 + O_2 + H_2O \xrightarrow{\text{Microbes}} H_2SO_3 + ½\ O_2 \longrightarrow H_2SO_4$
- *Thiobacillius* is most recognized microbe involved in S oxidation
  - Others are also important
- Conditions favorable for microbial growth are favorable for oxidation
  - Adequate temperature
  - Moisture
  - Air

Importance of Particle Size of Elemental S

- Range in days to reach 50% oxidation from 17 to 210 days
  - Fastest occurs with smaller particle size when it was co-granulated



Degryse et al. 2016

Particle Size	% S Oxidized	
(microns)	2 Weeks	4 Weeks
> 2,000	1	2
840 – 2,000	2	5
420 – 840	5	14
180 – 420	15	36
125 – 180	36	68
90 – 125	61	81
60	80	82

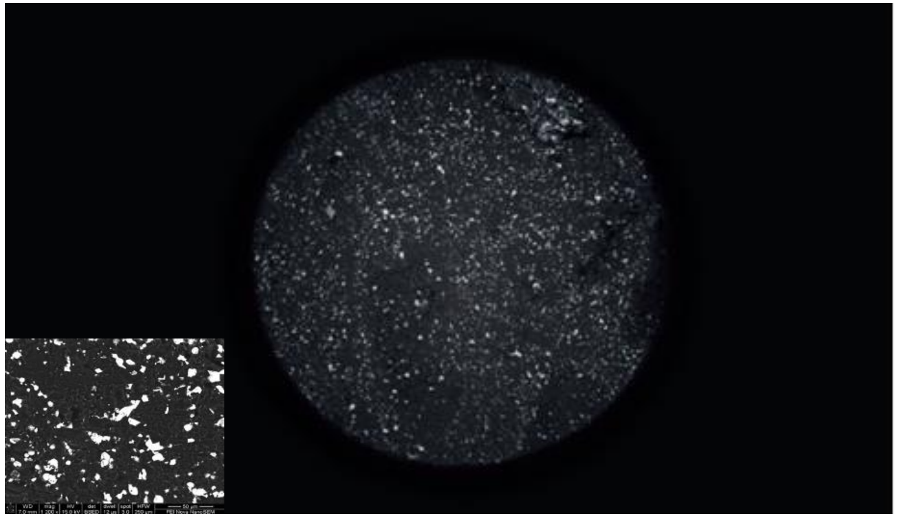
Canola.okstate.edu

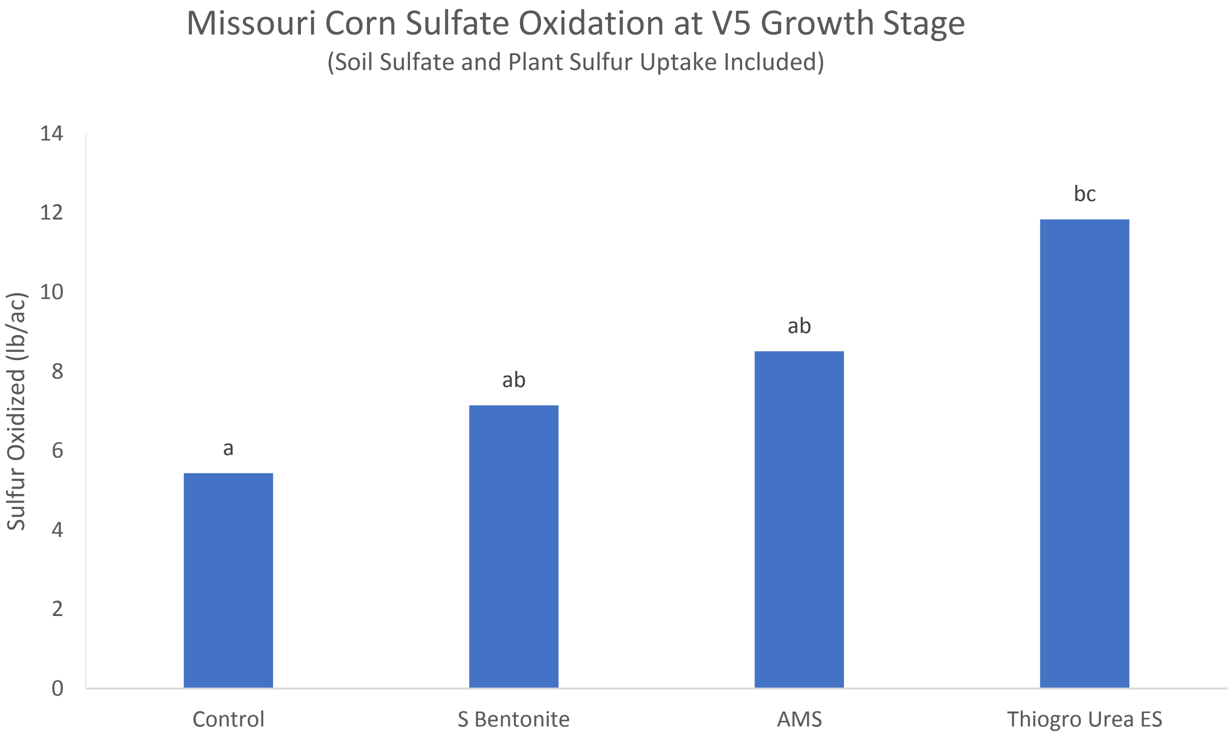
Shell Thiogro Technologies

- Has been in the S fertilizer technology business since 1960's
- Technology allows fertilizer producer to incorporate micronized elemental S into existing product streams
- Phosphate technology developed in mid-2,000's
  - MAP, DAP, TSP with 4-15% S
  - Currently being commercially produced in India, Australia, and soon in Morocco (by OCP)
- Urea ES developed 2013
  - 10 – 30% ES
  - Average particle size less than 40 µm
- Special S developed 2017
  - ~ 75% ES
  - Average particle size less than 50 µm

Urea-ES

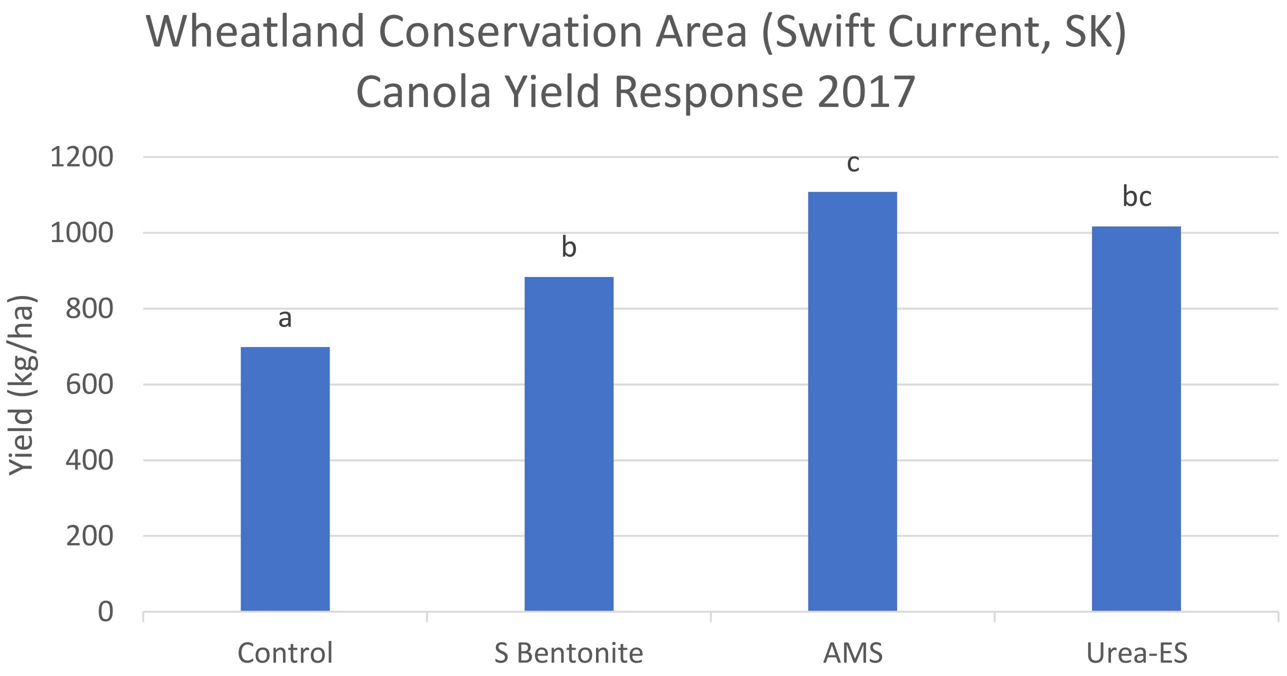
- Various formulations evaluated
- Co-granulated urea and sulphur





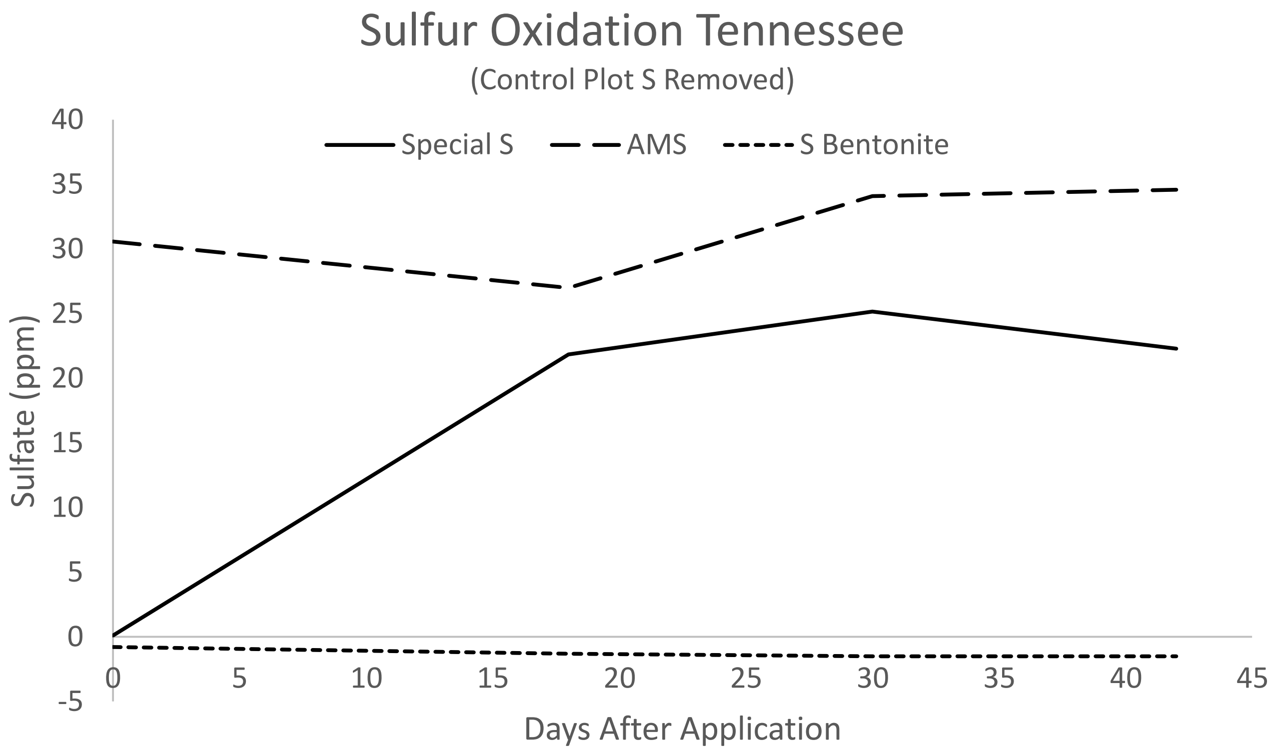
Urea-ES


S Bentonite
AMS
Urea-ES (13%)


Wheatland Conservation Area (Swift Current, SK)
Canola Yield Response 2017
Yield (kg/ha)
0
200
400
600
800
1000
1200
a
b
c
bc
Control
S Bentonite
AMS
Urea-ES

Special-S vs Bentonite Properties

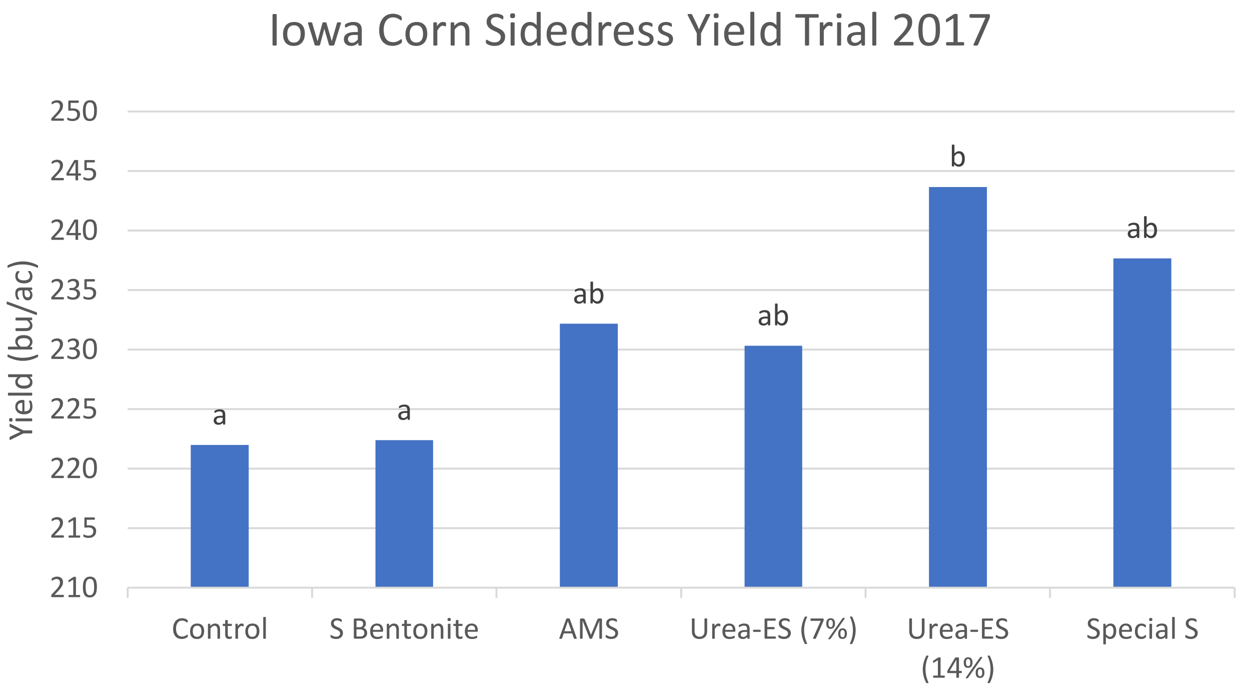
SPECIAL-S DISOLUTION/DISPERSION	SULPHUR BENTONITE SWELLING/DISPERSION
Dispersion mechanism involves urea dissolving in water leaving clusters of sulphur particles which then ‘crumble’ Timeframe: minutes (3-5)	Dispersion mechanism consist of the swelling clay expand, breaking the solid elemental sulphur matrix in small pieces Timeframe: hours (24-48)



Martin Agronomic and Environmental Consulting, LLC

Special S


Urea Plus (13%)
Control


Iowa Corn Sidedress Yield Trial 2017
Yield (bu/ac)
250
245
240
235
230
225
220
215
210
a
a
ab
ab
b
ab
Control
S Bentonite
AMS
Urea-ES (7%)
Urea-ES (14%)
Special S

Summary

- S deficiency is getting more common
- S is mobile in the soil and immobile in the plant
- S Sources
    - Sulfate (Readily available, Leaches)
    - Elemental (Must be oxidized, Less prone to loss)
- New Technologies for Elemental S
    - Small particle size is better
    - Availability is better than traditionally thought
    - Nice mix of availability and minimizing loss risk

Kent Martin, Ph.D.

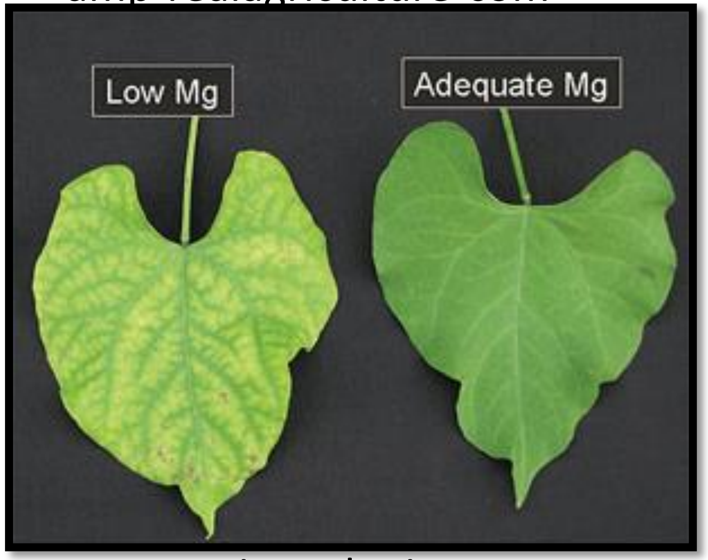
martinagconsulting@gmail.com

580-430-9196

Calcium and Magnesium

- Calcium – Functions in plant growth and structural support for cell walls
  - Deficiency rarely occurs with adequate pH
  - Acid soil < 500 lb/ac deficient for legumes
  - Mobile in soil
  - Most common source is lime, gypsum
- Magnesium – Central in chlorophyll molecule used for photosynthesis
  - Deficiency in coarse sands with low pH
  - Immobile in soil
  - Common sources – dolomitic lime, magnesium sulfate, K-Mag

amp-realagriculture-com

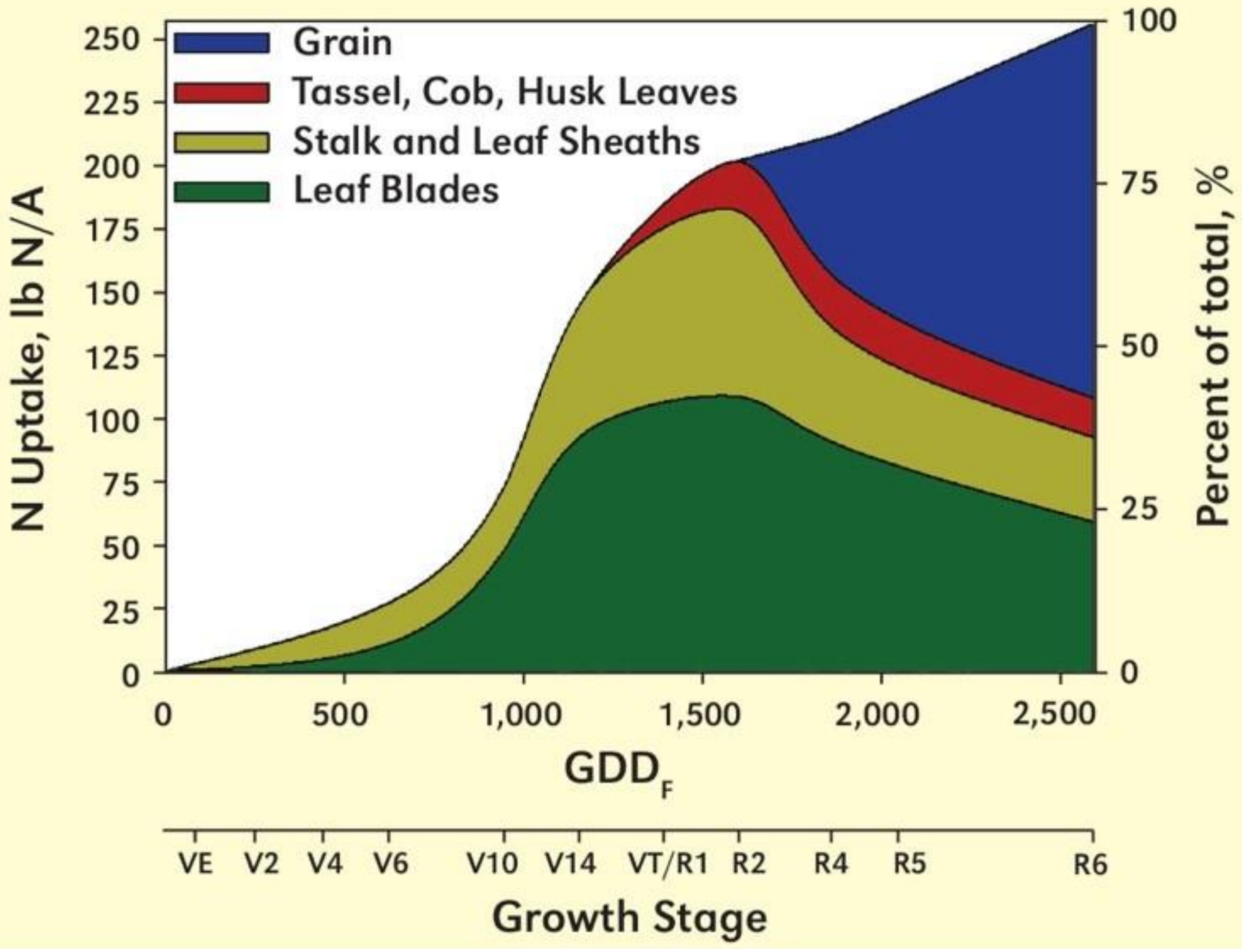


www.epicgardening.com

History

- The first reported ES use was in South Carolina in 1877 (Charles Panknin)
  - Recommendation: 95 parts bone or ground phosphate with 5 parts elemental S to aid in P availability
  - Knew ES was oxidized to SO_4 , but didn't know it was a microbial process
- 2008 Estimates of global S supplies estimated ~ 5 billion tons
  - Contained in natural gas, oil, metal sulfides, salt domes and volcanic deposits
- 2008 Production of S worldwide reached 69 million tons
  - Canada (13.5%), US (13%), China (12%), Russia (10%), Japan (4.5%) …
- Of all S consumed in the world, 55% was used in production of fertilizers

S Uptake and Partitioning in Corn



Better Crops, Vol. 97, (2013, No. 1), International Plant Nutrition Institute