# Sulfur Fertility – The Future

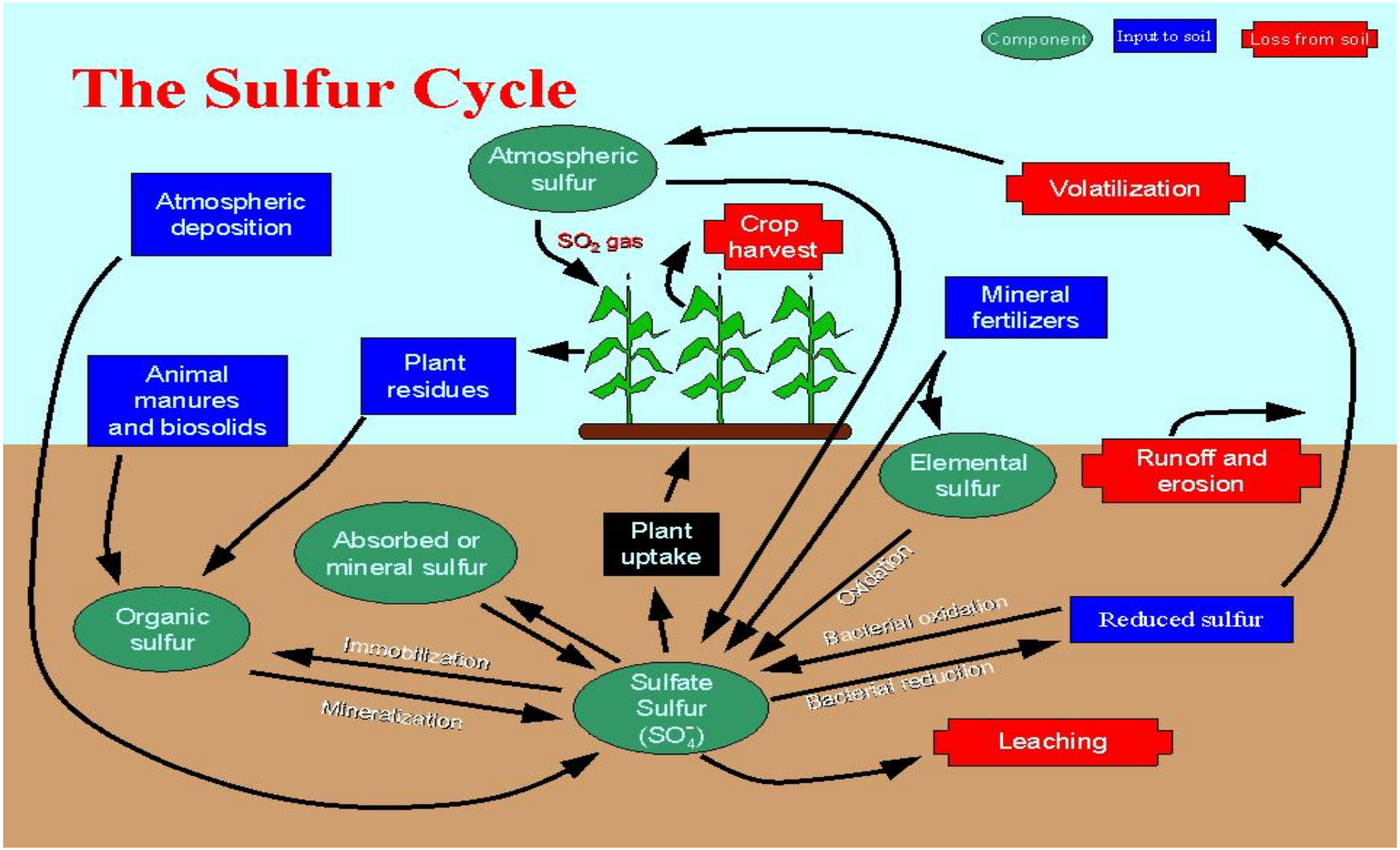
Dr. Kent Martin – December 2019

# Sulfur Background

- An essential element for plant growth (recognized in the mid 1800's)
  - Considered a secondary macronutrient
    - 4th – N,P,K,S
    - Used in quantities similar to P
  - Important for structural plant parts
  - Part of enzymes
  - Part of amino acids responsible for protein synthesis
  - Chlorophyll synthesis
  - Rapid crop growth
  - Key component in crop yield generation
  - Generation of proteins and oils

# Sulfur Background

- Sulfur has very dynamic processes in soil
  - The S cycle helps visualize the fate of S in the soil
    - Total S varies greatly in soil
    - S supply increases with increasing organic matter
    - Soil parent material plays a role
    - Increases from fertilizer additions
    - Additions from plant residues
    - Chemical reactions in soil (oxidation-reduction, adsorption-desorption)
    - Transitions between inorganic and organic forms
    - Atmospheric deposition

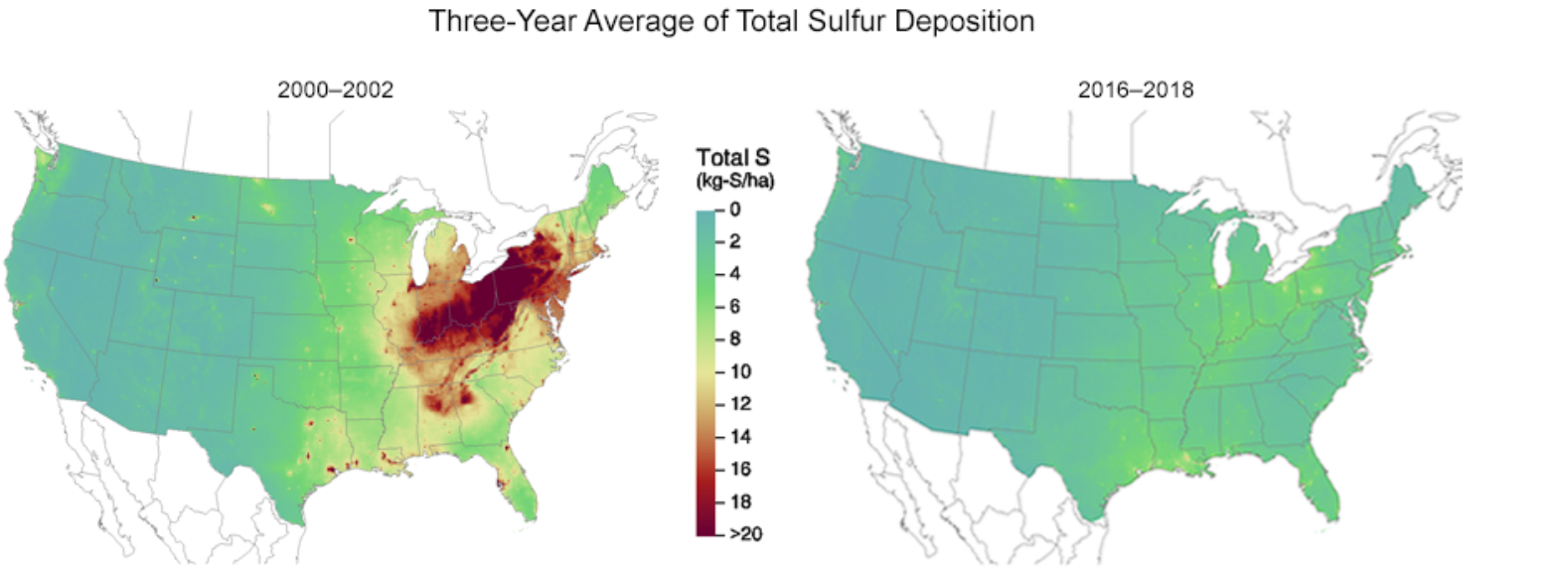



Shell Thiogro Technologies

Source: biology.Kenyon.edu

# Sulfur Background

- Clean Air Initiatives




Source: CASTNET/CMAQ/NADP
USEPA, 2019

# Sulfur Background

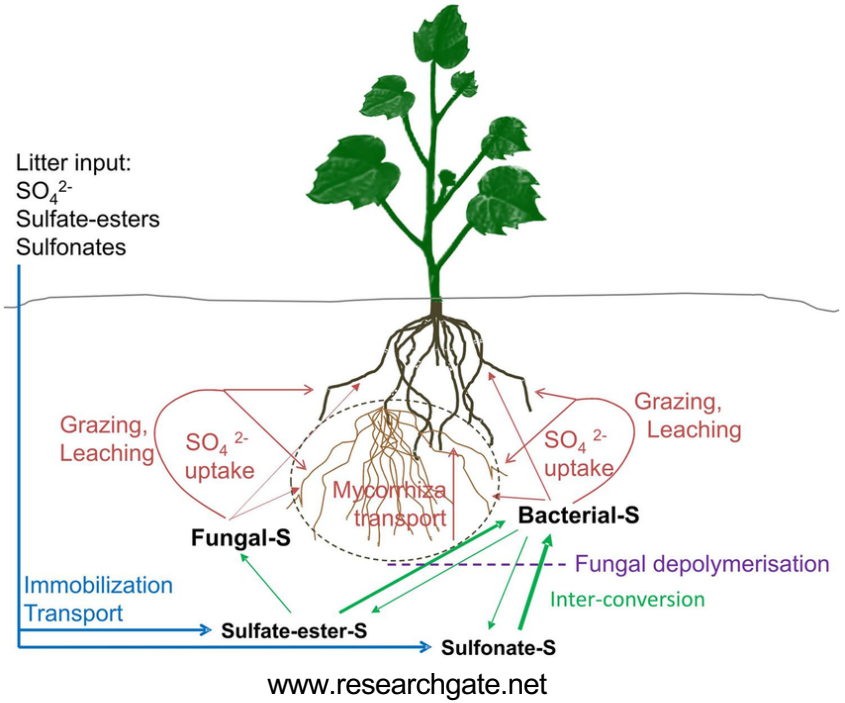
- High Yielding Crops
  - Continual increases in crop yields have increased S removal
    - S is strongly related to yield
  - S has a role in N fixation
    - Removed at higher levels in legumes

| Crop | Yield/acre | S Removal (lb/acre) |
|---|---|---|
| Alfalfa | 8 tons | 26 |
| Corn Grain | 180 bu | 14 |
| Stover | 8,000 lb | 16 |
| Potato (White) | 30,000 lb | 7 |
| Soybean Grain | 50 bu | 23 |
| Leaves, Stems | 6,100 lb | 12 |
| Wheat Grain | 80 bu | 5 |
| Straw | 6,000 lb | 15 |

Source: The Fertilizer Institute, International Plant Nutrition Institute

# Sulfur In Soil

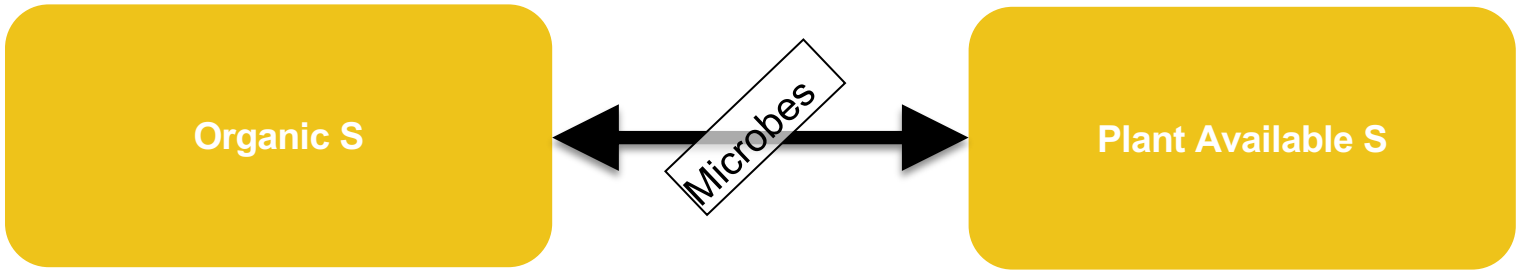
- Sulfur Cycle – Organic Sulfur
  - This is the largest pool of S in the soil
    - 95% or more of the total S
  - Usually exists from:
    - Plant residue
    - Animal residue
    - Microbial biomass
    - Humus
    - Metabolic products
  - The same organic matter is high in C and N
    - S is usually highly correlated with both C and N




www.researchgate.net

# Sulfur In Soil

- Sulfur Cycle – Organic Sulphur – Immobilization and Mineralization




Without Atmospheric deposition or fertilizer addition, this is the primary way S is plant available

# Sulfur In Soil

- Sulfur Cycle – Inorganic Sulfur
  - This is the form that is available to plants
    - Absorbed by plant roots
    - Less then 5% of total S in soil
  - Where do we find sulfate:
    - Soil solution
    - Adsorbed on soil or mineral surfaces
    - Can be precipitated with other elements
      - Ca
      - Mg

$SO_4^{=}$

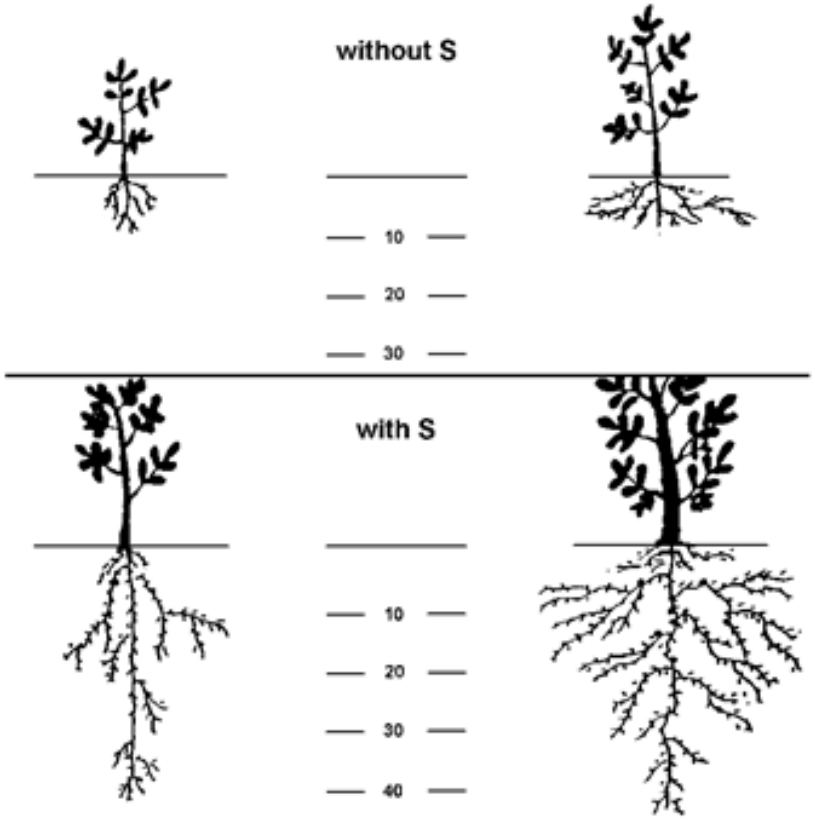
# Sulfur In Soil

- Sulfur Cycle – Inorganic Sulfur - S Availability
  - Neutral and High pH – Soluble sulphate is available
  - Low pH – Adsorbed sulphate can contribute to plant S needs
  - Influenced by competing anions
    - Phosphate – held less strong than ortho-phosphate. Application of P fertilizer increases availability of sulfate
    - Nitrate
    - Chloride

# Sulfur In Soil

- Sulfur Relationships With Other Nutrients – Secondary Benefits
- Increase in rooting depth
- Result of increased P availability

- Case for blending Special S+MAP or
- SRx + Forty Rock
- Have noted increased interest in this!




Source: volkerkleinhenz.com

# Sulfur – Fertilizer

- Elemental Sources – Risks vs Rewards

| Risk | Reward |
|---|---|
| Understanding product | Does not leach |
| Requires oxidation | Oxidation increases with time |
| Particle size influences oxidation | Match plant uptake curve |
| Pastille degradation | Decrease runoff potential |
| Differences within products | Stimulate soil microbes |

# Sulfur – Fertilizer

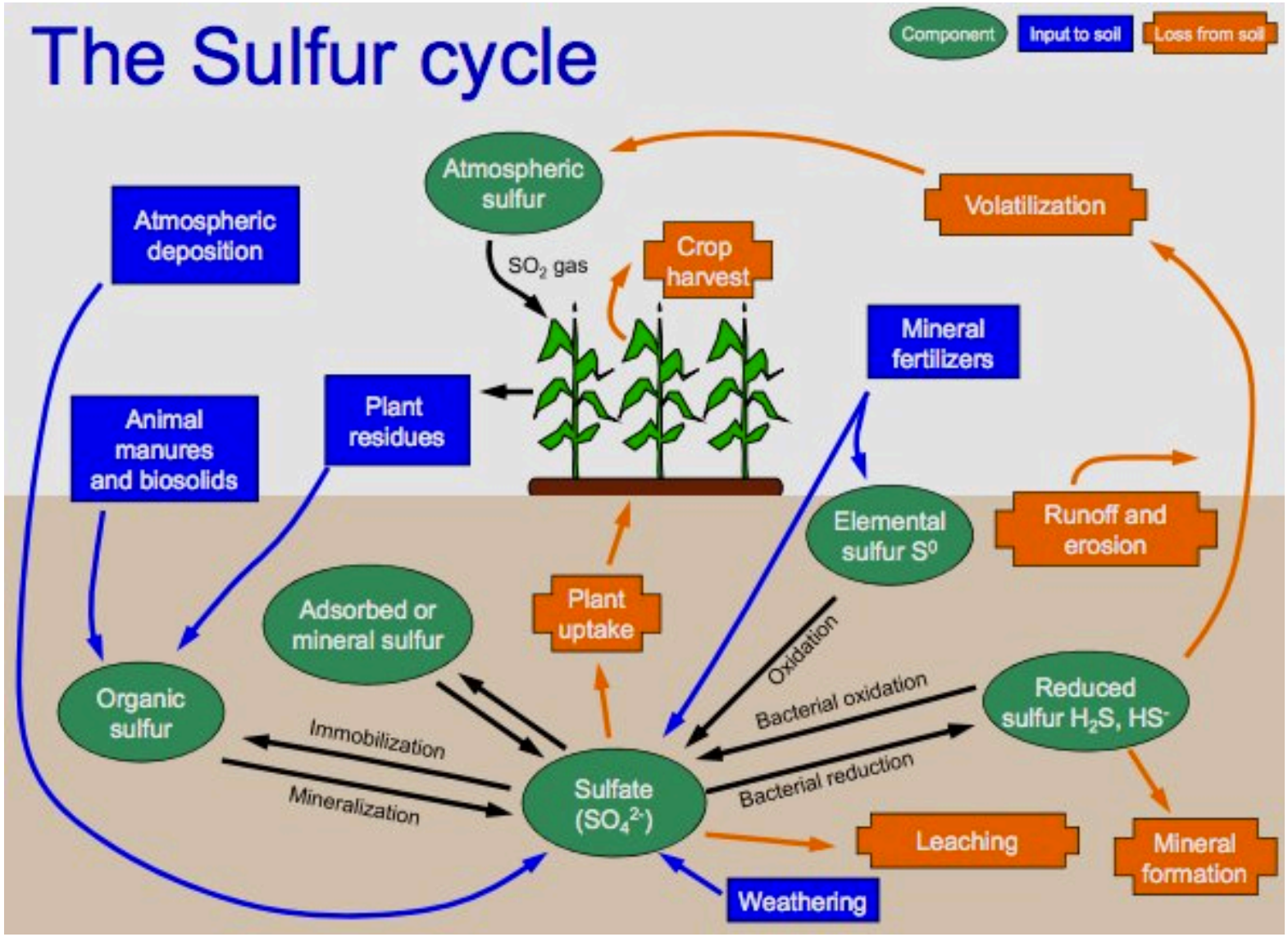
- Elemental Sources – Microbial Oxidation - S Particle Size
  - Small S particles increases oxidation rate
    - Knowing this will determine potential oxidation with all other factors equal
      - Soil
      - Moisture
      - Temperature
      - Aeration

| 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 |

Source: canola.okstate.edu

# Sulphur – Fertilizer

- Elemental Sources – Microbial Oxidation – Other Factors
  - Microbes need:
    - Air
      - Proper aeration in soil
    - Moisture
      - Adequate moisture for growth
        - Consider microbes have adapted to different moisture conditions
    - Favorable temperature
      - Warm temperature speeds oxidation and microbial activity
      - Too hot will slow activity
    - Energy
      - Access to energy source – e.g. sulphur



# Improving Fertilizer Efficiencies

- Sulfur
  - Where are Sulfur Levels today
  - Why do we need to include Sulfur in our blends
  - Understanding different Sulfur Types
  - Options for Increasing Efficiencies
- Open Discussion

# Why is sulfur a bigger agronomic issue?

- Less atmospheric pollution
  - Regulations
  - Plant efficiencies
- Higher crop yields
- Purer fertilizer products e.g. phosphates

# Two Options in the Past

- The two main forms of Sulfur Fertilizers
  - Soluble Sulfate (SO4-S), Commonly sold as Ammonium Sulfate 20.5-0-0-24 or 21-0-0-24
  - Degradable Elemental S Fertilizers – sulfur bentonite

# Factors to Consider

## AMS

PRO's

- Quick Response
- Immediately Available
- Can be uses for correcting in crop deficiencies

CON's

- High Salt Index
- Very Bulky
- Extremely Leachable

## Elemental Sulfur

PRO's

- Long Term Building Block
- Season Long Release
- Low Salt Index
- Higher Analysis (Less Bulk
- Non-Leachable
- Very Effective Fall Application

CON's

- Conversion takes place over a period of time (Pro and a Con)
- Needs to be Managed Accordingly to be Effective

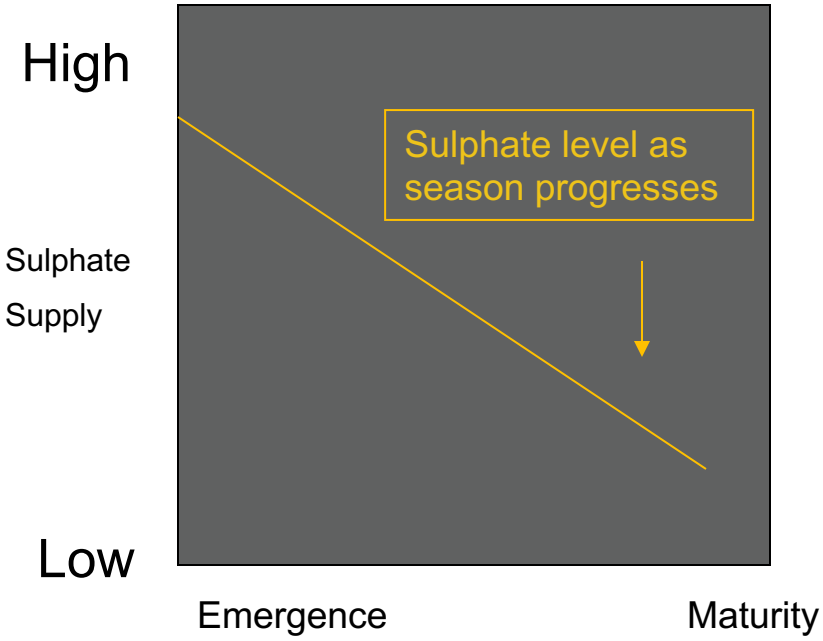
## SALT INDEX (SI)

| FERTILIZER PRODUCT | NUTRIENT CONCENTRATION | SALT INDEX |
|---|---|---|
| SRx Thrive | S 75%, N 11% (11-0-0-75) | 17.8 |
| SRx 85 | S 85% | 3.7 |
| SRx 90 | S 90% | 3.7 |
| Gypsum | Ca 23%, S 17% | 8.1 |
| Triple superphosphate | $P_2O_5$ 45% | 10.1 |
| Ammonium Polyphosphate | N 10%, $P_2O_5$ 34% | 20.0 |
| Monoammonium Phosphate | $P_2O_5$ 52%, N 11% | 26.7 |
| Diammonium Phosphate | $P_2O_5$ 46%, N 18% | 29.2 |
| Potassium Sulfate | $K_2O$ 50%, S 18% | 42.6 |
| Sulfate of Potash – Magnesia | $K_2O$ 22%, Mg 11%, S 22% | 43.4 |
| Magnesium sulfate | Mg 10%, S 14% | 44.0 |
| Anhydrous Ammonia | N 82% | 47.1 |
| Urea-Ammonium Nitrate Solution | N 28% | 63.0 |
| Potassium thiosulfate | $K_2O$ 25%, S 17% | 68.0 |
| Urea-Ammonium Nitrate Solution | N 32% | 71.1 |
| Potassium Nitrate | $K_2O$ 46.5%, N 13% | 73.6 |
| Urea | N 46% | 74.4 |
| Ammonium Sulfate | N 21%, S 24% | 88.3 |
| Ammonium thiosulfate | N 12%, S 26% | 90.4 |
| Sodium Nitrate ($NaNO_3$) | N 16.5% | 100.0 |
| Ammonium Nitrate | N 34% | 104.0 |
| Potassium Chloride | $K_2O$ 60% | 116.3 |

# Sulfate Fertility

Season Long Sulfur Fertility: Immediate and over the growing season

## Ammonium Sulfate

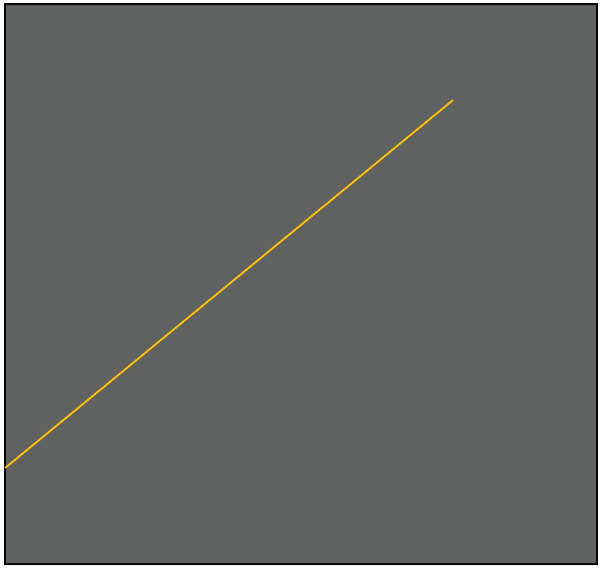



- Crops take up sulfur in the sulfate form.
- Ammonium sulfate is entirely in the sulphate form.
- Sulfate levels are drawn down due to:
    1) Leaching – high rainfall events.
    2) Plant removal – I.E. Canola S demand.
    3) S application rate & initial soil S level.
- Plants cannot transfer Sulfur from older leaves to newer leaves. I.E. Canola's demand for sulfate is critical during flowering and pod fill.

# Season Long Sulfur Fertility

Season Long Sulfur Fertility: Immediate and over the growing season

## Plant Nutrient Elemental Sulfur

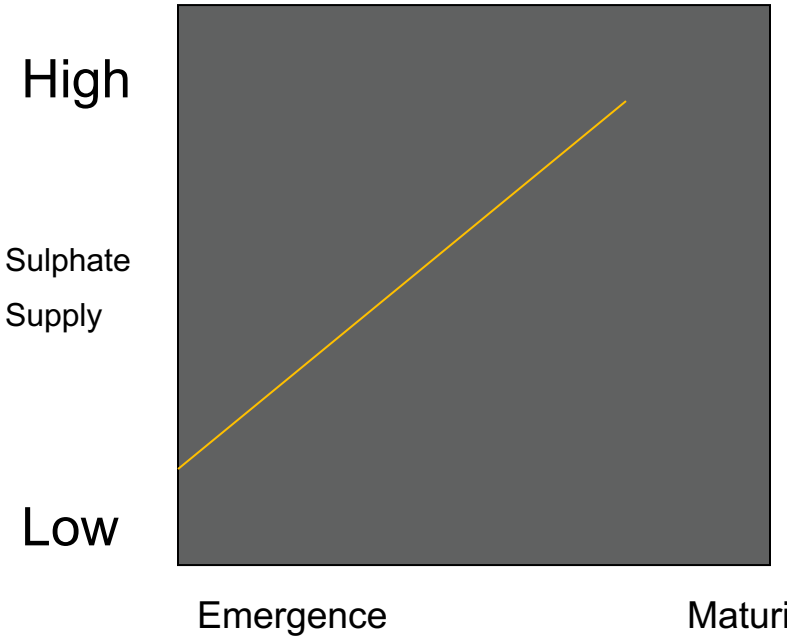


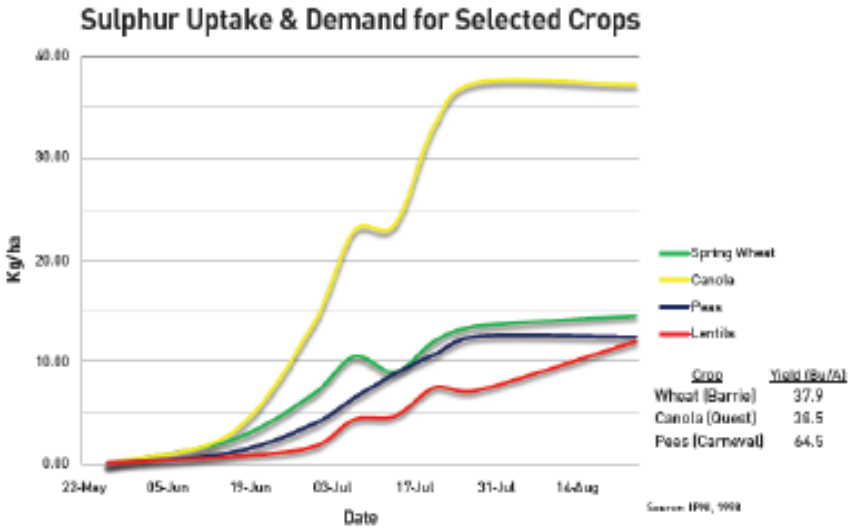

- PNES is degradable Sulfur, and is rapidly oxidized by soil microbes and converted into sulfate for plant uptake.
- Early season Sulfate supply is critical to seedling development, and overall plant yield.
- Annual applications builds S levels and supplies crops with adequate early season S.
- Will not leach

# Season Long Sulfur Fertility

Season Long Sulfur Fertility: Immediate and over the growing season

## Plant Nutrient Elemental Sulfur



## Five Factors that Influence Conversion

1. Microbial Activity – Repeat Elemental Sulfur applications increase Thiobacillus populations
2. Particle Size - Sulfur needs to be broken down in fine particles to increase surface are for Thiobacillus
3. Soil Temperature – Oxidization begins above 40f, increases at 60f and maxes out at around 90f
4. Soil Moisture – Moist soils promote Oxidization. Dry or flooded soils slow Oxidization
5. Oxygen – Needs to be present for conversion. Placing Sulfur deep into the soil reduces SO4 production

# Micro Site Study