The Roles of Sulfur in Nutrient - Disease Interactions

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The Roles of Sulfur in Nutrient-Disease Interactions

- Background on nutrient associations
- Interactions of Sulfur and Disease
- Use of Sulfur in Disease Management

Implications of Nutrition in Disease

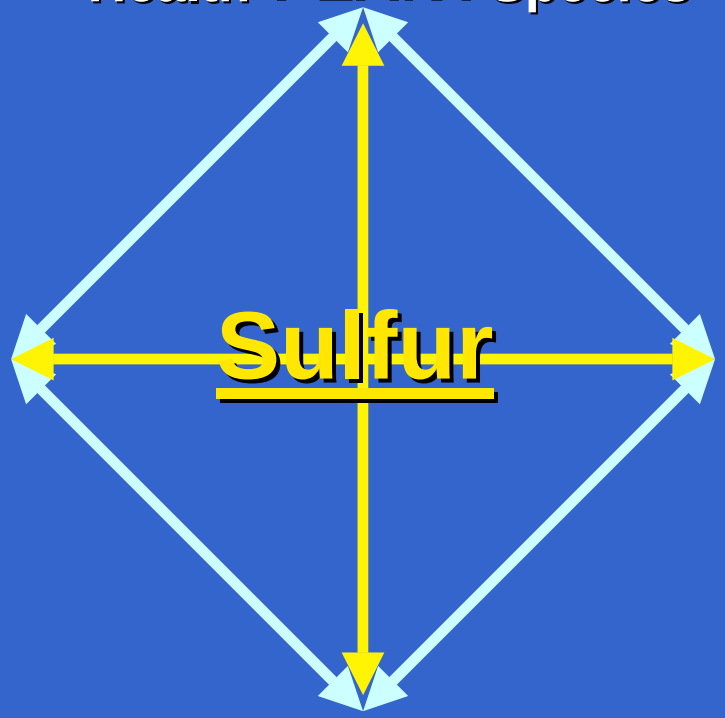
Rhizoctonia winter-kill of wheat

- Observed effects of mineral amendment on disease severity
- Comparison of plant tissue levels of resistant and susceptible plants or diseased and non-diseased plants
- Association of conditions affecting a specific nutrient with differences in disease
- A combination of the above

Some Diseases Reduced by Sulfur

Host Plant	Disease	Effect of S
Cotton, tomato	Fusarium wilt, Verticillium wilt	Decrease
Crucifers	Club root	Decrease
Grape	Downy mildew, powdery mildew	Decrease
Maize	Leaf blight, Stewarts wilt	Decrease
Nicotiana glutinosa	Tobaco Mosaic Virus	Decrease
Peach	Armillaria root rot	Decrease
Peanut	Cercospora leaf spot	Decrease
Pine	Needle blight	Decrease
Potato	Common scab, late blight, stem canker	Decrease
Rape	Black spot, black leg, late leaf spot, Sclerotinia stem rot, Verticilium wilt	Decrease
Rhododendron	Bud Death	Decrease
Soybeans	Rhizoctonia root rot	Decrease
Sugarbeets	Ramularia leaf spot	Decrease
Turfgrass	Fusarium patch	Decrease
Wheat	Powdery mildew, sharp eye-spot	Decrease

Interacting Roles of Sulfur on Disease



PATHOGENS
Population
Virulence
Activity

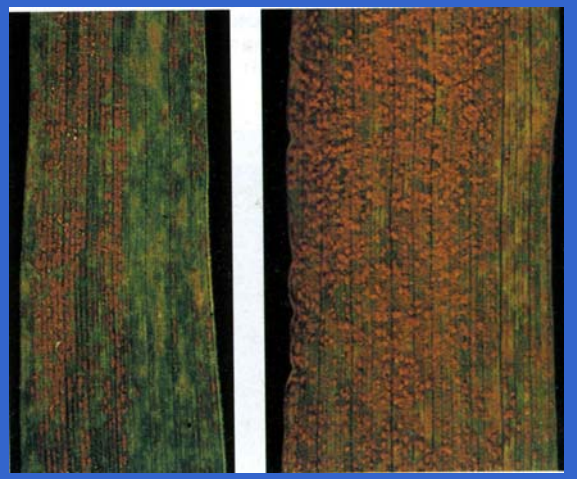
ABIOTIC ENVIRONMENT
Moisture
Temperature
pH, gases
Density,
Interacting nutrients
Organic matter (sinks)
Herbicides

RHIZOSPHERE ENVIRONMENT
Oxidizers, Reducers
Competitors, Mineralizers
Biological controls
Other diseases

The Effect of Sulfur on the PATHOGEN May be Direct or Indirect

- **Direct toxicity**
  - Pesticides
- **Inhibition of growth**
  - Preservatives
- **Inhibited virulence**
  - Pesticides

Powdery mildews



Stripe rust on Wheat

• Direct Effect of Sulfur on the PATHOGEN

➢ Sulfur Compounds are Applied:

- **Preplant** - seed or soil treatments
- **During plant growth** - foliage and fruit sprays
- **Post harvest** - dips, sprays, fumigants

➢ Some Sulfur compounds used

- Inorganic sulfur compounds

Sulfur, sulfur oxides
Bordeaux mixture
Copper sulfate
Sulfides (NH_4S_x, CS_2, K_2S, H_2S, P_2S_5)
Thiosulfates ($NH_4S_2O_3$)

- Organic sulfur compounds

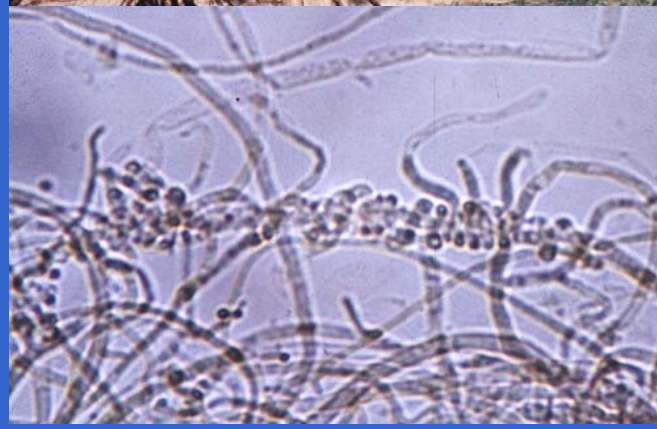
Dithiocarbamates

Downy mildew of grape
Plasmopara viticola

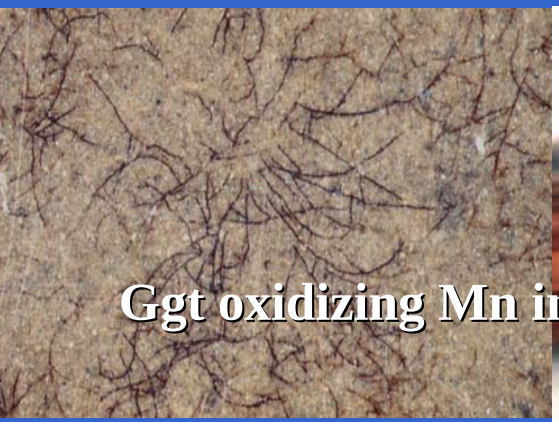
• Some Indirect Effects of Sulfur on the PATHOGEN

- **Indirect effects** are mediated through changes in the abiotic or biotic environments:
  - Inhibit virulence mechanisms
  - Stimulate biological control
  - Enhance microbial competition
- **Some sulfur compounds involved:**
  - Sulfides, thiosulfates, thiocyanates
  - Organic sulfur compounds

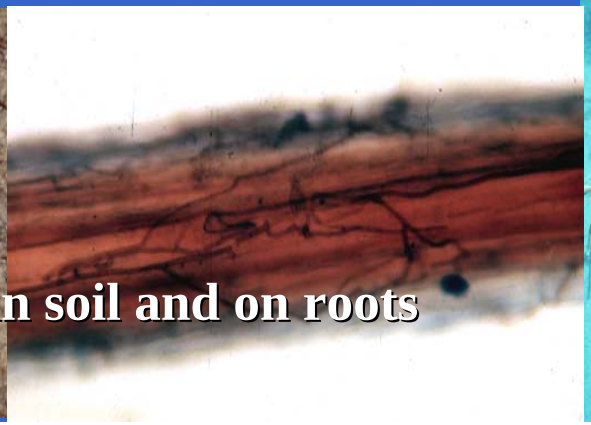
Armillaria root rot of peach

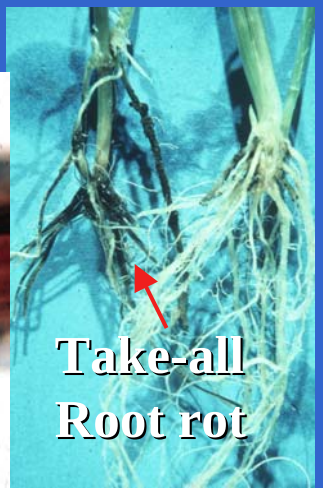


Biological control of *Amillaria* by *Trichoderma* after CS_2 fumigation of soil



Ggt oxidizing Mn in soil and on roots

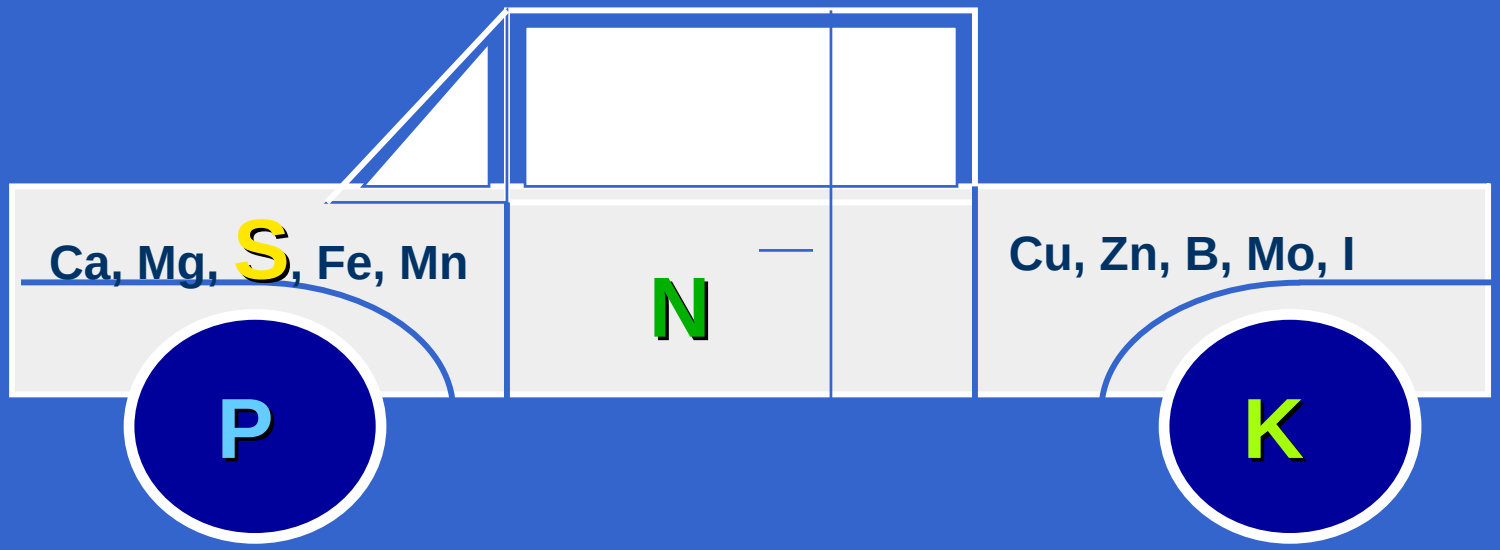




Take-all Root rot

• Involvement of Sulfur with the PLANT

As a nutrient element, sulfur functions
As part of a delicately balanced
INTERDEPENDENT SYSTEM with the
Plant's genetics and the environment



Nutrient Balance is Important

• The Role of Sulfur on the PLANT

Nutrient: growth - vigor - disease escape

- **A constituent of plants and metabolites**
  - Amino acids, proteins, coenzymes,
  - sulfolipids, polysaccharides, etc.


Club root

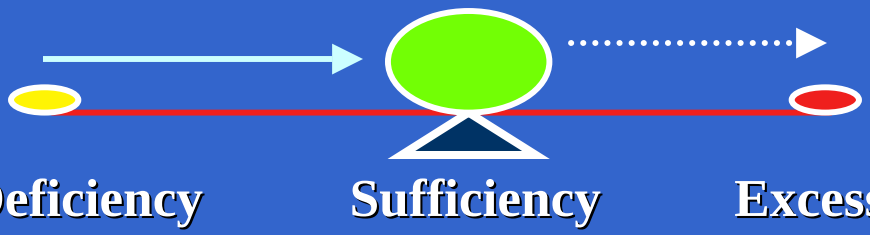
- **Interaction with other nutrients - efficiency**
  - Involved in C, N and secondary metabolism
  - Solubility of sulfate salts, micronutrients


Sharp eye spot

- **Off-set reduced efficiency from disease - tolerance**

The greatest effect on growth is from deficiency to sufficiency

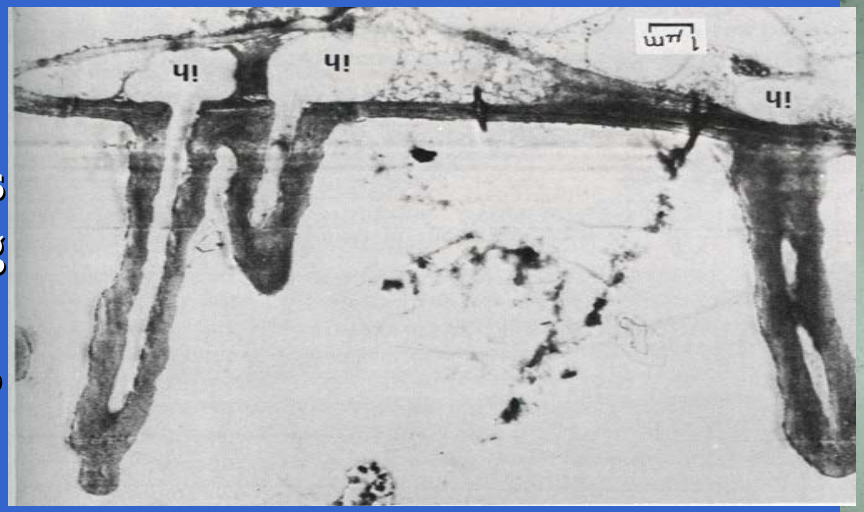
Nutrient balance is important for efficiency



• The Role of Sulfur on the PLANT

Resistance mechanisms

- **Physiological resistance**
  - Glutathione, glycosinolates, cysteine, methionine
  - Phytoalexins
  - Lignification



Lignified callous around infecting hyphae of Ggt, after Skou, 1975

- **Preformed resistance compounds**

Affect of Sulfur on the Abiotic Environment - pH

High pH Diseases;
Reduced by lowering pH

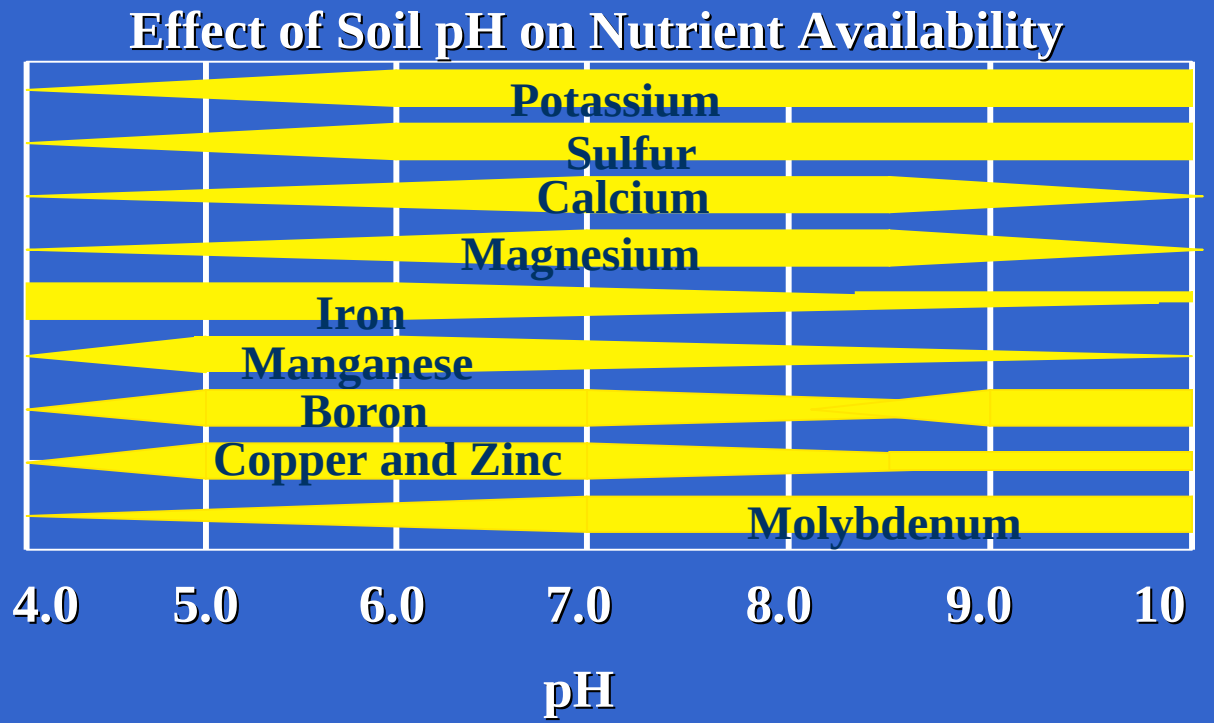
- Take-all of cereals
- Root knot nematode
- Sclerotium root rot
- Verticillium wilt
- Potato scab
- Onion white rot
- Anthracnose
- Potato virus X
- Maize stalk rot


Take-all root, crown, and root rot


Maize stalk rot

• The Role of Sulfur on the ABIOTIC ENVIRONMENT

➢ Lower the soil pH (S, $AlSO_4$)



Manganese Availability

pH 5.2 to pH 7.8

Rhizosphere biology

➢ Increased nutrient availability as sulfur salts

Ca, Mg, Cu, Fe, NH_4, Mn, Mo, Zn

• The Role of Sulfur on the ABIOTIC ENVIRONMENT

➢ Sulfur is important to detoxify toxic compounds

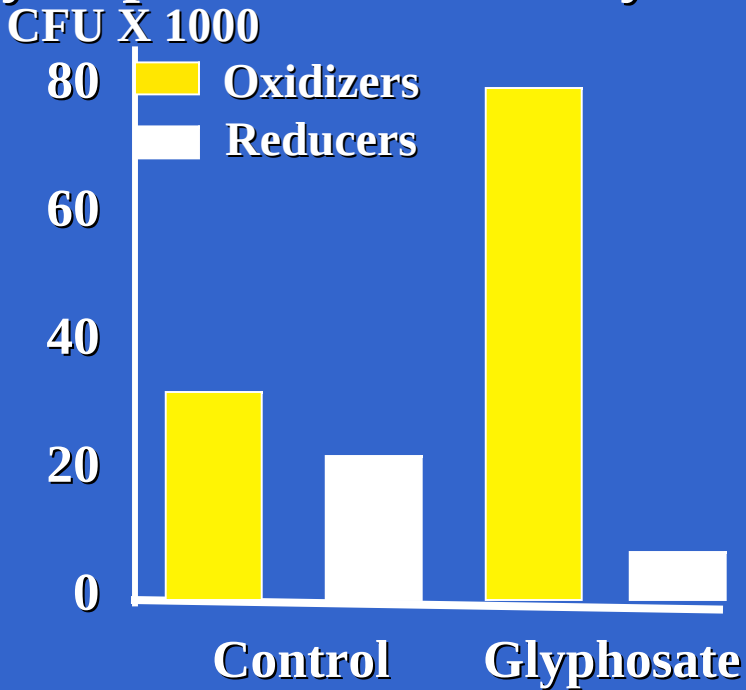
- Heavy metals - (Physiologic)

  Plants and fungi that accumulate heavy metals have active glutathione reductase systems

- Pesticides - (complexing)

  Gypsum detoxification of glyphosate in root exudates

  Fusarium crown rot of Canola, Corynespora root rot of soybean



• The Role of Sulfur on the BIOTIC ENVIRONMENT

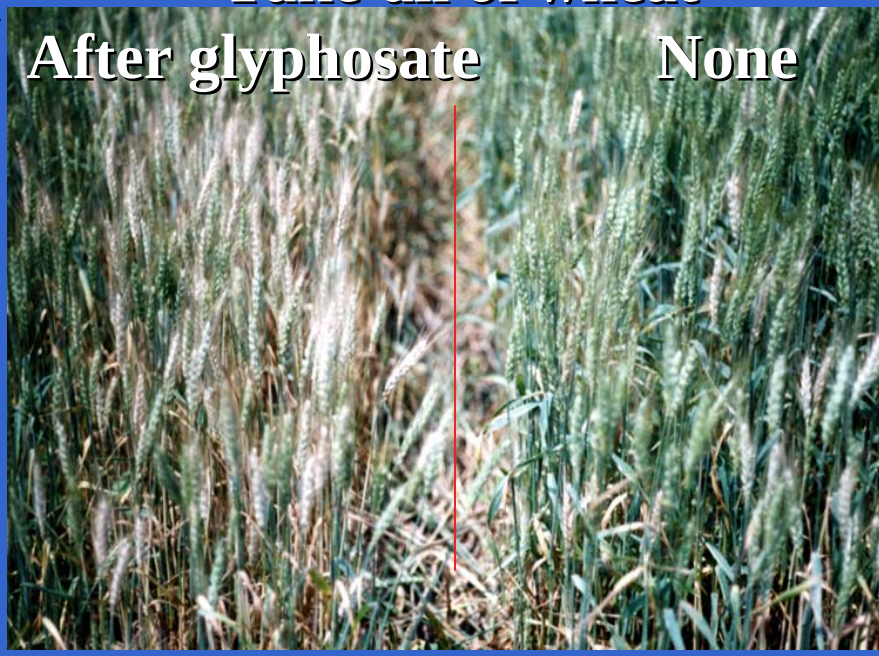
- **Sulfur suppresses specific microbial activity:**
  - **Inhibit Fe, Mn, N oxidizers**

    CS_2, NH_4S_x, K_2S, P_2S_5

  - **Inhibit Urease**

    Sulfur coated urea

Take-all of wheat



- **Stimulate specific microbial activity:**

  Mn reducing organisms

  Biological control organisms

  Mineralizers

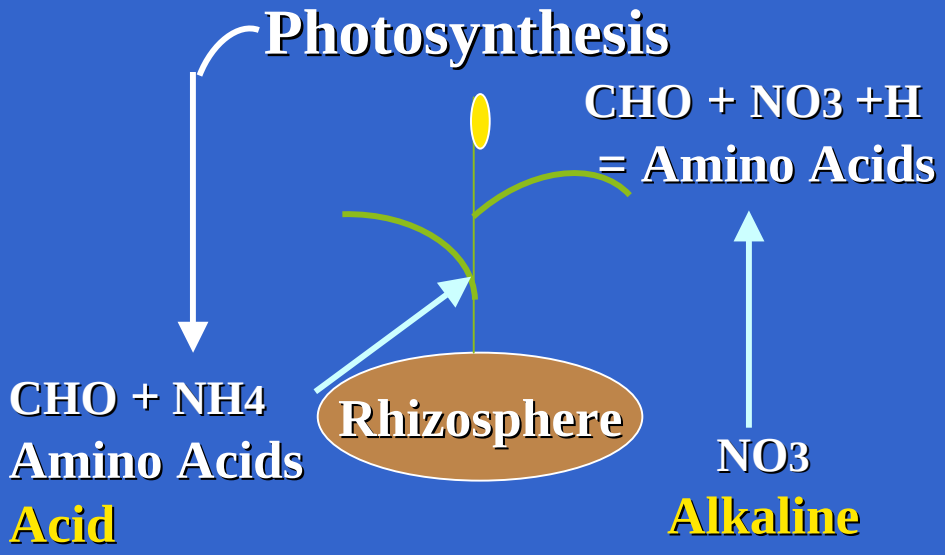
  Release sulfur decomposition metabolites (Oil seed rape)]

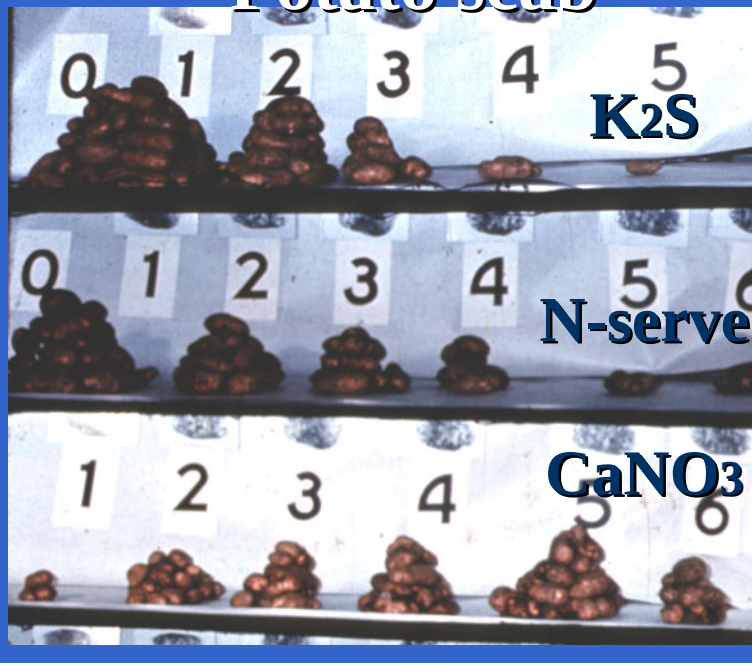
• The Role of Sulfur on the BIOTIC ENVIRONMENT

- Inhibit nitrification (NH_4/NO_3 ratios)

  CS_2, thiosulfates, xanthates, sulfides

Influence of the FORM of N

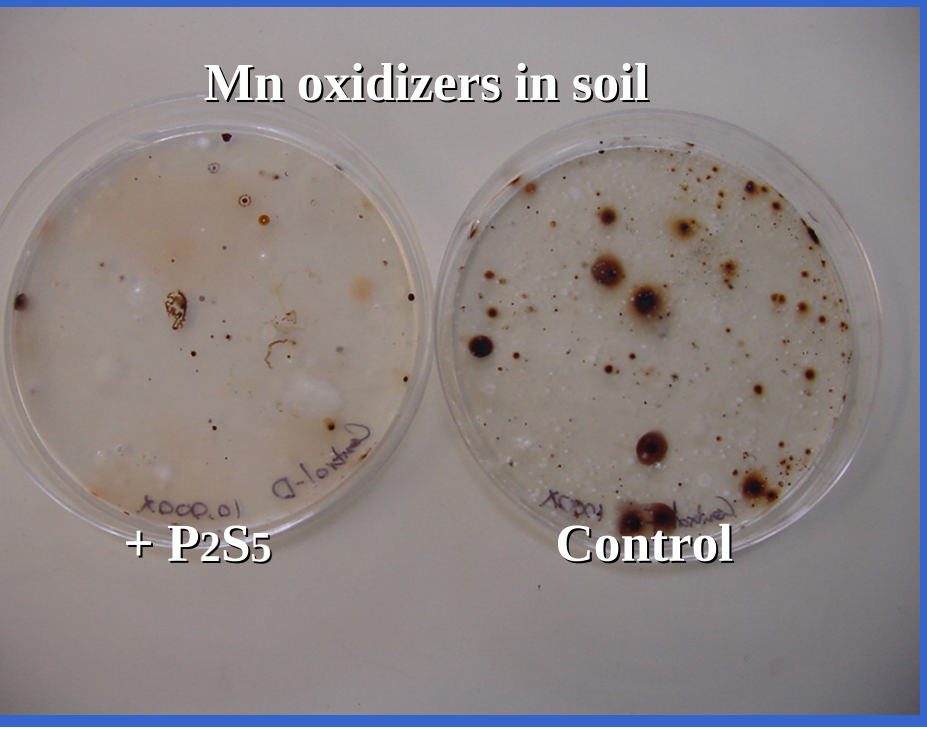




• The Role of Sulfur on the BIOTIC ENVIRONMENT

Increased uptake of Mn by adding P_2S_5 with soil applied $MnSO_4$

Tissue:	P	K	Mg	Ca	S	Fe	Mn	Zn
Treatment	----------%					----------PPM		
Control (TSP)	.422	1.92	.512	.907	.325	171	44	35
+ P_2S_5	.422	1.84	.512	.918	.338	179	55	35

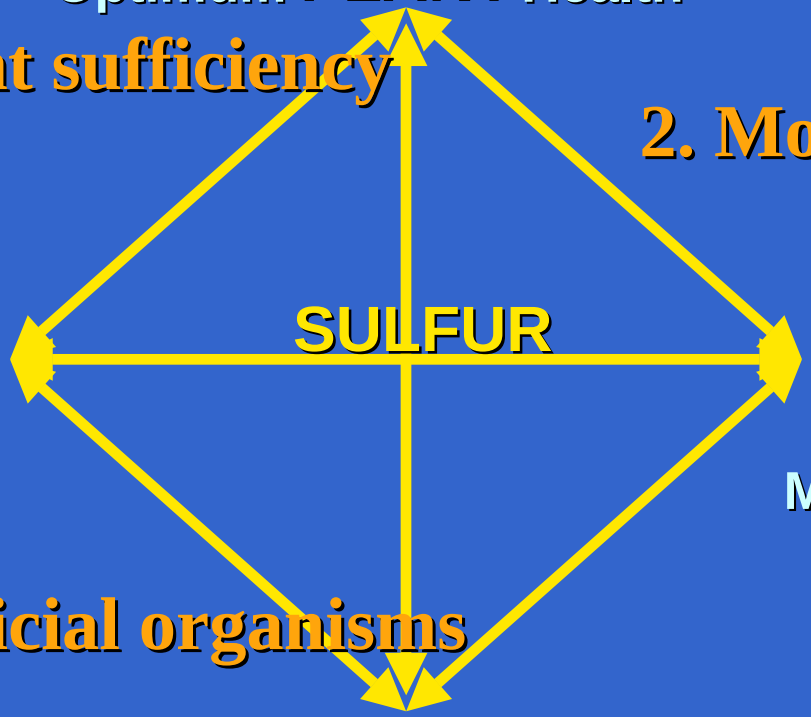


Approaches to Use Sulfur for Disease Control

Vigor, Growth, Root Exudates to Escape Disease
Optimum PLANT Health

1. Provide nutrient sufficiency

2. Modify the environments



Pathogen
Inhibit virulence
Reduce population

ABIOTIC ENVIRONMENT
Alter nutrient solubility
Modify soil/rhizosphere pH

3. Enhance beneficial organisms

RHIZOSPHERE ENVIRONMENT
Crop sequence
Residue management
Stimulate biological controls

Conclusions

1. **Sulfur has direct and indirect effects on disease through:**
   - **Plant growth and resistance**
   - **Reduced Pathogen virulence or survival**
   - **Changing the abiotic environment**
   - **Changes in the biological environment**

2. **Sulfur compounds in root exudates, and metabolites from residue decomposition affect pathogen virulence, plant resistance, and biological control.**

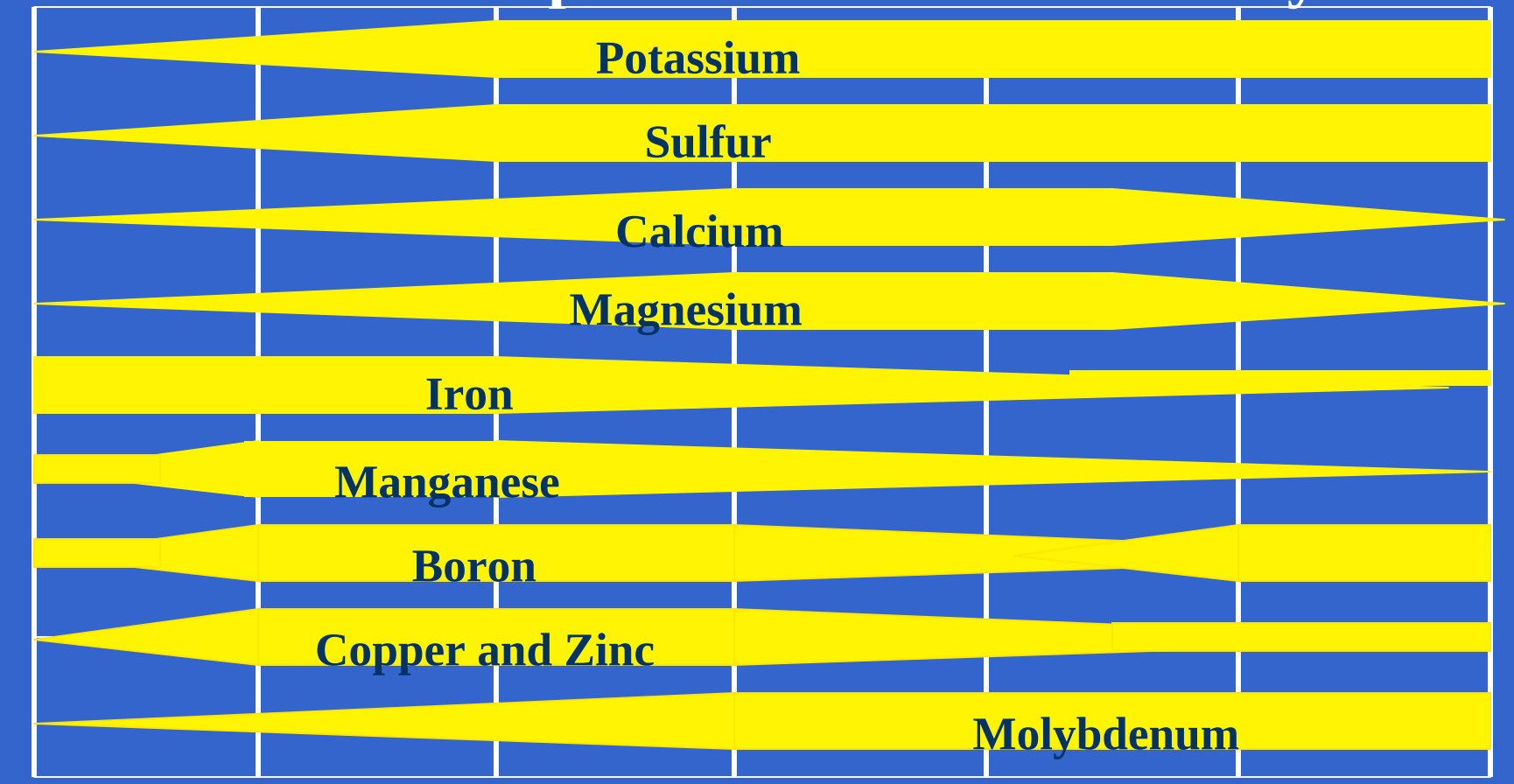
3. **Sulfur can be used to balance other nutrients and make the environment less favorable for the pathogen.**

4. **Sulfur is under-utalized in nutrient-disease interactions**

Compensate for Reduced Nutrient Efficiency by Disease

Disease Type	Effect on Plant Nutrition
• Root rots, damping-off, insects, nematodes	Immobilization, absorption and distribution
• "Maceration" (rot) diseases	Distribution ("sinks), depletion, change metabolism
• Vascular wilts, leaf spots	Translocation, distribution, efficiency
• Galls, brooms, over-growth	Distribution ("sinks") metabolic efficiency
• Viruses	"Sinks", depletion, metabolic efficiency
• Fruit & storage rots	"Sinks", distribution, nutrient reserves

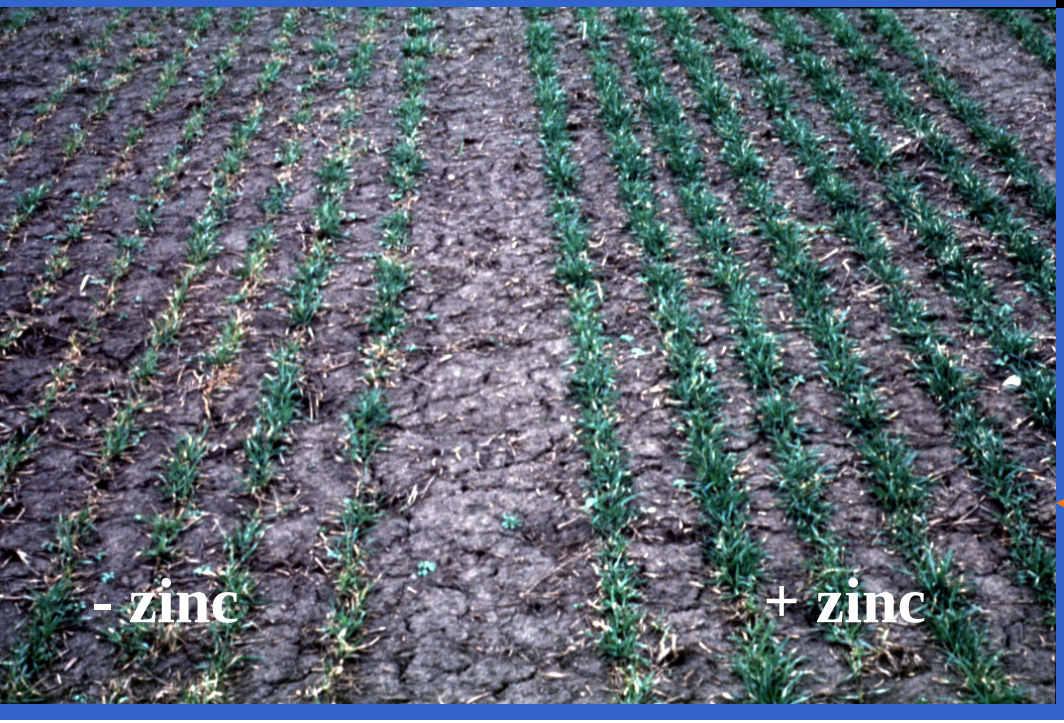
Effect of Soil pH on Nutrient Availability



Disease can alter plant nutrition

- Availability
- Impaired utilization
- Mobilization

Frenching of Tobacco caused by Bacillus cereus (Mn toxicity)



Nutrition can alter Disease severity

Effect of Zn sufficiency on Rhizoctonia winter-kill of wheat

Effect of the Form of Nitrogen on Verticillium Wilt of Potato

Source of N	Verticillium wilt index	Yield (kg/ha)	Percent No. 1
$(NH_4)_2SO_4$	3.9 b	32670	69 a
$Ca(NO_3)_2$	9.4 a	21340	57 b