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

- 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

Rhizoctonia winter-kill of wheat

Manured Not manured
## Some Diseases Reduced by Sulfur

<table>
<thead>
<tr>
<th>Host Plant</th>
<th>Disease</th>
<th>Effect of S</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cotton, tomato</td>
<td>Fusarium wilt, Verticillium wilt</td>
<td>Decrease</td>
</tr>
<tr>
<td>Crucifers</td>
<td>Club root</td>
<td>Decrease</td>
</tr>
<tr>
<td>Grape</td>
<td>Downy mildew, powdery mildew</td>
<td>Decrease</td>
</tr>
<tr>
<td>Maize</td>
<td>Leaf blight, Stewarts wilt</td>
<td>Decrease</td>
</tr>
<tr>
<td><em>Nicotiana glutinosa</em></td>
<td>Tobacco Mosaic Virus</td>
<td>Decrease</td>
</tr>
<tr>
<td>Peach</td>
<td>Armillaria root rot</td>
<td>Decrease</td>
</tr>
<tr>
<td>Peanut</td>
<td>Cercospora leaf spot</td>
<td>Decrease</td>
</tr>
<tr>
<td>Pine</td>
<td>Needle blight</td>
<td>Decrease</td>
</tr>
<tr>
<td>Potato</td>
<td>Common scab, late blight, stem canker</td>
<td>Decrease</td>
</tr>
<tr>
<td>Rape</td>
<td>Black spot, black leg, late leaf spot, Sclerotinia stem rot,</td>
<td>Decrease</td>
</tr>
<tr>
<td></td>
<td>Verticillium wilt</td>
<td></td>
</tr>
<tr>
<td>Rhododendron</td>
<td>Bud Death</td>
<td>Decrease</td>
</tr>
<tr>
<td>Soybeans</td>
<td>Rhizoctonia root rot</td>
<td>Decrease</td>
</tr>
<tr>
<td>Sugarbeets</td>
<td>Ramularia leaf spot</td>
<td>Decrease</td>
</tr>
<tr>
<td>Turfgrass</td>
<td>Fusarium patch</td>
<td>Decrease</td>
</tr>
<tr>
<td>Wheat</td>
<td>Powdery mildew, sharp eye-spot</td>
<td>Decrease</td>
</tr>
</tbody>
</table>
Interacting Roles of Sulfur on Disease

Vigor, Stage of Growth, Root Exudates
Health PLANT Species

PATHOGENS
Population
Virulence
Activity

Sulfur

ABBIOTIC 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

- Powdered mildews

- Stripe rust on Wheat
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 (NH4Sx, CS2, K2S, H2S, P2S5)
  - Thiosulfates (NH4S2O3)
- Organic sulfur compounds
  - Dithiocarbamates

• Direct Effect of Sulfur on the PATHOGEN
  - 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

- Biological control of *Armillaria* root rot of peach after CS2 fumigation of soil

- Ggt oxidizing Mn in soil and on roots

- Take-all Root rot
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.

Involvement of Sulfur with the Plant

Ca, Mg, S, Fe, Mn

Cu, Zn, B, Mo, I
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.

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

- Off-set reduced efficiency from disease - tolerance

The greatest effect on growth is from deficiency to sufficiency

The greatest effect on growth is from deficiency to sufficiency

Nutrient balance is important for efficiency

Deficiency  Sufficiency  Excess
Resistance mechanisms

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

- Preformed resistance compounds

The Role of Sulfur on the PLANT

Lignified callous around infecting hyphae of Ggt, after Skou, 1975
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, AlSO₄)

**Effect of Soil pH on Nutrient Availability**

<table>
<thead>
<tr>
<th>pH</th>
<th>Potassium</th>
<th>Sulfur</th>
<th>Calcium</th>
<th>Magnesium</th>
<th>Iron</th>
<th>Manganese</th>
<th>Boron</th>
<th>Copper and Zinc</th>
<th>Molybdenum</th>
</tr>
</thead>
<tbody>
<tr>
<td>4.0</td>
<td></td>
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<tr>
<td>5.0</td>
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<td>6.0</td>
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<td>8.0</td>
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<tr>
<td>10</td>
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</tr>
</tbody>
</table>

- Increased nutrient availability as sulfur salts
  
  Ca, Mg, Cu, Fe, NH₄, Mn, Mo, Zn

**Manganese Availability**

pH 5.2 to pH 7.8

Rhizosphere biology
• **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

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**Corynespora root rot of soybean**

- **Control**
- **Inoculated**
- **Inoculated+RU**

**CFU X 1000**

- 80
- 60
- 40
- 20
- 0

**Oxidizers**

- **Reducers**

**Control**

**Glyphosate**
• The Role of Sulfur on the BIOTIC ENVIRONMENT

Sulfur suppresses specific microbial activity:
- Inhibit Fe, Mn, N oxidizers
  CS₂, NH₄Sₓ, K₂S, P₂S₅
- Inhibit Urease
  Sulfur coated urea

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 (NH₄/NO₃ ratios)
  
  CS₂, thiosulfates, xanthates, sulfides

Influence of the FORM of N

Photosynthesis

CHO + NO₃ + H = Amino Acids

CHO + NH₄
Amino Acids

Acid

Rhizosphere

NO₃
Alkaline

Verticillium wilt, potato
Nitrification inhibited

Normal nitrification

Potato scab

K₂S

N-serve

CaNO₃
### The Role of Sulfur on the BIOTIC ENVIRONMENT

Increased uptake of Mn by adding P$_2$S$_5$ with soil applied MnSO$_4$

<table>
<thead>
<tr>
<th>Treatment</th>
<th>P</th>
<th>K</th>
<th>Mg</th>
<th>Ca</th>
<th>S</th>
<th>Fe</th>
<th>Mn</th>
<th>Zn</th>
</tr>
</thead>
<tbody>
<tr>
<td>Control (TSP)</td>
<td>.422</td>
<td>1.92</td>
<td>.512</td>
<td>.907</td>
<td>.325</td>
<td>171</td>
<td>44</td>
<td>35</td>
</tr>
<tr>
<td>+ P$_2$S$_5$</td>
<td>.422</td>
<td>1.84</td>
<td>.512</td>
<td>.918</td>
<td>.338</td>
<td>179</td>
<td>55</td>
<td>35</td>
</tr>
</tbody>
</table>

- Mn oxidizers in soil
- Mn deficiency in soybean
Approaches to Use Sulfur for Disease Control

1. Provide nutrient sufficiency
   - Pathogen
     - Inhibit virulence
     - Reduce population
   - SULFUR
   - Rhizosphere environment
     - Crop sequence
     - Residue management
     - Stimulate biological controls

2. Modify the environments
   - ABiotic environment
     - Alter nutrient solubility
     - Modify soil/rhizosphere pH

3. Enhance beneficial organisms
   - Optimum plant health
   - Vigor, growth, root exudates to escape disease

SULFUR
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-utilized in nutrient-disease interactions
<table>
<thead>
<tr>
<th>Disease Type</th>
<th>Effect on Plant Nutrition</th>
</tr>
</thead>
<tbody>
<tr>
<td>• Root rots, damping-off, insects, nematodes</td>
<td>Immobilization, absorption and distribution</td>
</tr>
<tr>
<td>• “Maceration” (rot) diseases</td>
<td>Distribution (&quot;sinks&quot;), depletion, change metabolism</td>
</tr>
<tr>
<td>• Vascular wilts, leaf spots</td>
<td>Translocation, distribution, efficiency</td>
</tr>
<tr>
<td>• Galls, brooms, over-growth</td>
<td>Distribution (&quot;sinks&quot;) metabolic efficiency</td>
</tr>
<tr>
<td>• Viruses</td>
<td>“Sinks”, depletion, metabolic efficiency</td>
</tr>
<tr>
<td>• Fruit &amp; storage rots</td>
<td>“Sinks”, distribution, nutrient reserves</td>
</tr>
</tbody>
</table>
Effect of Soil pH on Nutrient Availability

- Potassium
- Sulfur
- Calcium
- Magnesium
- Iron
- Manganese
- Boron
- Copper and Zinc
- Molybdenum
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-kil of wheat

- zinc + zinc
### Effect of the Form of Nitrogen on Verticillium Wilt of Potato

<table>
<thead>
<tr>
<th>Source of N</th>
<th>Verticillium wilt index</th>
<th>Yield (kg/ha)</th>
<th>Percent No. 1</th>
</tr>
</thead>
<tbody>
<tr>
<td>(NH₄)₂SO₄</td>
<td>3.9 b</td>
<td>32670</td>
<td>69 a</td>
</tr>
<tr>
<td>Ca (NO₃)₂</td>
<td>9.4 a</td>
<td>21340</td>
<td>57 b</td>
</tr>
</tbody>
</table>