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# Sulfur and Micronutrients in High pH Soils

Paul Stukenholtz

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# Sulfur

- Plants absorb Sulfate ($SO_4^{-2}$) form.
- Concentration in the soil is reported as:
  $SO_4$-S "Sulfate sulfur"
  Pounds of sulfur in the sulfate form
- Sulfate is water soluble and moves freely with soil water.

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# Sulfur

- Amino acid synthesis
- Component of protein
- Nitrate reduction
- Electron transport
- Chlorophyll synthesis
- Moderately mobile in plants

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3009

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Tel: 208-734-3050 Fax: 208-734-3919
Report No: 148476
Date Received: 11/14/2023
Date Reported: 11/15/2023

| SOIL TEST DATA | Sample 1 | | Sample 2 |
|---|---|---|---|
| pH | 7.7 | H | |
| Salts, mmhos/cm | 0.9 | L | |
| Chlorides, ppm | 8 | VL | |
| Sodium, meq/100g | 0.20 | VL | |
| CEC, meq/100g | 14.8 | M | |
| Excess Lime, % | 0.8 | L | |
| Organic Matter, % | 1.56 | M | |
| Organic N, lb/Acre | 60 | M | |
| Ammonium - N, ppm | 2.4 | VL | |
| Nitrate - N, ppm | 11 | M | |
| Phosphorus, ppm | 10 | L | |
| Potassium, ppm | 338 | H | |
| Calcium, meq/100g | 11.6 | H | |
| Magnesium, meq/100g | 1.9 | L | |
| Sulfate - S, ppm | 3 | VL | |
| Zinc, ppm | 0.4 | VL | |
| Iron, ppm | 5.5 | M | |
| Manganese, ppm | 2.5 | L | |
| Copper, ppm | 0.4 | L | |
| Boron, ppm | 0.43 | L | |

| | Sample 1 | Sample 2 |
|---|---|---|
| Grower | U OF WY | |
| Sample Identity | GOSHEN 2 CORN | |
| Crop | SUNFLOWERS | |
| Yield Goal | 27 BU | |
| Acres | 80 | |
| Prev Crop T/Acre | FIELD CORN 1 | |
| Manure T/Acre | | |
| Prev Applied Nut | | |

RECOMMENDATIONS, lbs Nutrients or Units per Acre

| | |
|---|---|
| Nitrogen | 105 |
| $P_2O_5$ – Phosphate | 60 |
| $K_2O$ - Potash | 0 |
| Sulfate - Sulfur | 25 |
| Zinc | 9 |
| Iron | 0 |
| Manganese | 0 |
| Copper | 0 |
| Boron | 1.0 |
| Elemental Sulfur | 0 |

Very Low Sulfur

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Sulfur Deficiency in Alfalfa

6


Sulfur Deficiency

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## Plant Uptake

| Crop | Yield | Uptake (lbs. S) |
|---|---|---|
| Potatoes | 500 cwt/Ac | 25 |
| Sugar Beets | 30 T/Ac | 45 |
| Alfalfa | 8 T/Ac | 40 |
| Corn | 200 bu/Ac | 38 |
| Wheat | 130 bu/Ac | 32 |

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# Reduction / Oxidation

More Energy — *Chromatium* — *Thiobacillus* — Less Energy — *Heterotrophs*

$$2H_2S \xrightarrow{2H^+} {}^{o}2S \xrightarrow[2H^+]{H_20\ 0_2} S_2O_3^{-} \xrightarrow[2H^+]{H_20\ 2\ 0_2} 2SO_4^{-2}$$

More Oxidation = Lower pH

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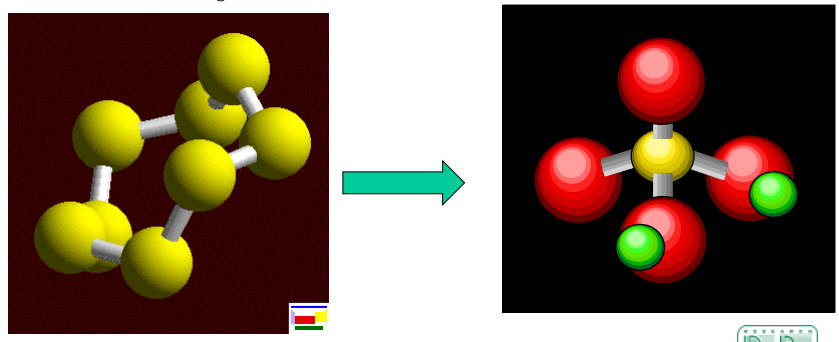
## Sulfur Oxidation

Elemental $S_8$ → Sulfuric Acid



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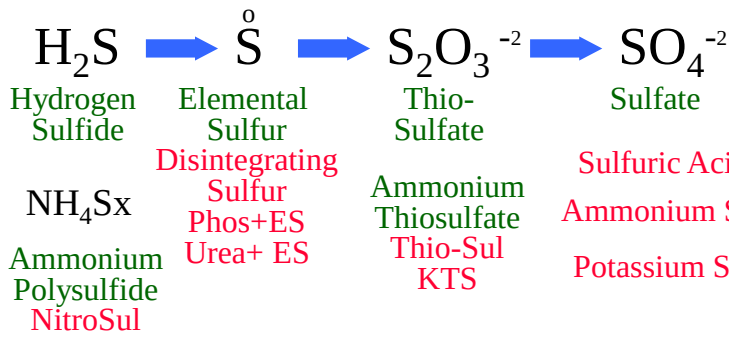
## Oxidation / Sulfur Products

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## Soil Microbes Require:

- Water
- Food Source
- Adequate Temperature
- Oxygen (aerobes only)
- Proper pH
- Nutrients
  - Most limiting: N and P

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## Reduction of Other Elements

$$\overset{o}{S} \xrightarrow[\text{Oxidized}]{} SO_4^{-2}$$

$$Fe^{2+} \xleftarrow[\text{Reduced}]{} Fe^{3+}$$

Available Unavailable

$$Mn^{2+} \xleftarrow[\text{Reduced}]{} Mn^{4+}$$

Available Unavailable

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## Elemental Sulfur & Lime

$$2\overset{o}{S} + 3O_2 + 2H_2O \xrightarrow{\text{Bacteria}} 2H_2SO_4$$

$$H_2SO_4 + CaCO_3 \rightarrow CaSO_4 + H_2O + CO_2$$

(Lime) (Gypsum)

$$CaSO_4 \rightarrow Ca^{+2} + SO_4^{-2}$$

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# Sulfur Required to Lower Soil pH to 6.5

(pounds per Acre)

| Soil pH | Light Soil | Medium to Heavy Soil |
|---|---|---|
| 7.5 | 400-600 | 800-1,000 |
| 8.0 | 1,000-1,500 | 1,500-2,000 |
| 8.5 | 1,500-2,000 | 2,000+ |

What's wrong with this chart?

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# Elemental Sulfur & Lime

$$2S_8 + 3O_2 + 2H_2O \xrightarrow{\text{Bacteria}} 2H_2SO_4$$

$$H_2SO_4 + CaCO_3 \rightarrow Ca^{+2} + SO_4^{-2} + H_2O + CO_2$$

(Lime)

1 pound ES neutralizes 3 pounds excess lime

10% excess lime = 400,000 lbs/Ac = 133,000 lbs/Ac ES

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# Sulfur Required to Lower Soil pH to 6.5

(pounds per Acre)

| Soil pH | Light Soil | Medium to Heavy Soil |
|---|---|---|
| 7.5 | 400-600 | 800-1,000 |
| 8.0 | 1,000-1,500 | 1,500-2,000 |
| 8.5 | 1,500-2,000 | 2,000+ |

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# Sulfur Fertilizers

Soluble

| | | |
|---|---|---|
| Ammonium Sulfate | $(NH_4)_2SO_4$ | 21-0-0 24s |
| Potassium Sulfate | $K_2SO_4$ | 0-0-50 17s |
| Sulfuric Acid | $H_2SO_4$ | 0-0-0 33s |
| MAP-AMS | $NH_4H_2PO_4 \cdot (NH_4)_2SO_4$ | 16-20-0 15s |
| Ammonium Thiosulfate | $(NH_4)_2S_2O_3$ | 12-0-0 26s |

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## Sulfur Fertilizers

Somewhat Soluble

Gypsum $CaSO_4 \cdot H_2O$ 0-0-0 18s

( 1 Acre-ft of water will dissolve about 1 T gypsum)

Insoluble

Disintegrating Sulfur S 0-0-0 90s

Won't break down during the land-lease time.

Flaked Elemental Sulfur S 0-0-0 100s

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## Elemental Sulfur Fertilizers

Flaked Elemental Sulfur / Granulated ES / "Popcorn Sulfur"

100% Elemental Sulfur

Takes many, many years to oxidize

Not effective as a soil amendment

Flammable

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## Elemental Sulfur Fertilizers

Micronized Sulfur

- 100% Elemental Sulfur
- Oxidizes in 1-3 Months if mixed with soil
- EXTREMELY Flammable
- Has been successfully mixed with compost for application

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## Elemental Sulfur Fertilizers

Tiger-Sul / Tiger 90CR / Disintegrating Sulfur

- 90% Elemental Sulfur +
- 10% Bentonite combined in Pastille

Much safer than micronized sulfur

Can be blended with other fertilizers

Slower to oxidize than micronized sulfur

Much faster to oxidize than “popcorn” granulized sulfur

Has micronutrient blends

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## Elemental Sulfur Fertilizers

KegRiver 85S / Disintegrating Sulfur

- 85% Elemental Sulfur +
- 15% Bentonite combined in Pastille

Much safer than micronized sulfur

Can be blended with other fertilizers

Slower to oxidize than micronized sulfur

Slightly faster to oxidize than 10% Bentonite ES

Much faster to oxidize than "popcorn" granulized sulfur

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## Elemental Sulfur Fertilizers

SRx Thrive (11-0-0 75s),

Two Rivers Terminal

- 11% Nitrogen
- 75% Elemental Sulfur
- Pastille of Urea and Micronized Elemental S
- $NH_2$ form of Nitrogen
- Claimed 100% S converted to $SO_4$-S in 60-80 days
- 3x more acid forming than 21-0-0 per lb product

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## Elemental Sulfur Fertilizers

Arctic S (11-0-0 75s),

Northern Nutrients

- 11% Nitrogen
- 75% Elemental Sulfur
- Pastille of Urea and Micronized Elemental S
- $NH_2$ form of Nitrogen
- Claimed 100% S converted to $SO_4$-S in 60-80 days
- 3x more acid forming than 21-0-0 per lb product

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## Elemental Sulfur Fertilizers

MESZ

Mosaic

- 12% Nitrogen
- 40% $P_2O_5$
- 5% $SO_4$-S
- 5% Elemental Sulfur
- 1% Zn
- Basically 11-52-0 + 21-0-0 +ES+ ZnO

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# Oxidation Rate

## Micronized S vs Phos+ES vs Bentonite+ES in Ideal Conditions

From: *Oxidation of Elemental Sulfur in Granular Fertilizers Depends on the Soil-Exposed Surface Area,*
Soil Sci. Soc. Am. J 80:294-305 April 22, 2016

- Micronized / blended ES oxidizes in about 10 weeks
  $T^{1/2}$ = 35 days
- Soluble fertilizer + ES oxidizes in about 40 weeks
  $T^{1/2}$ = 140 days
- 10 % Bentonite + 90% ES with no tillage oxidizes in about 300 weeks $T^{1/2}$ = 900 days

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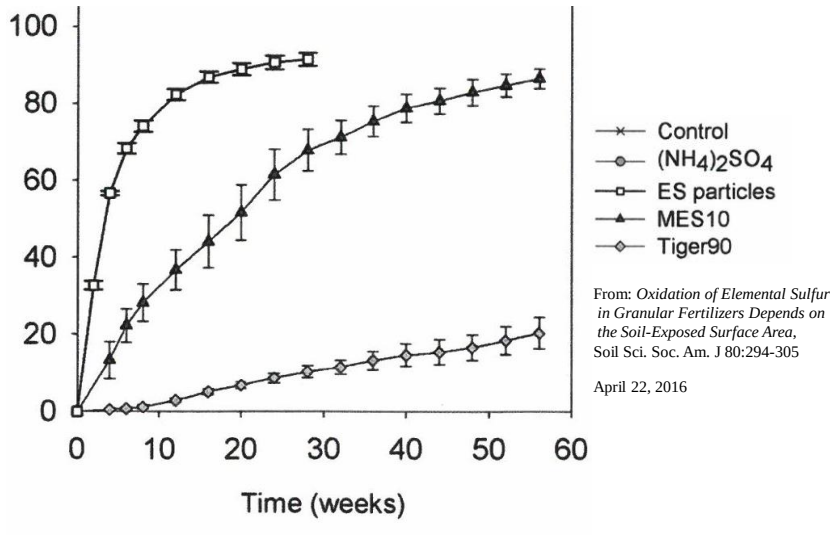
# Oxidation Rate

## Micronized S vs Phos+ES vs Bentonite+ES

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April 22, 2016

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## Using Disintegrating Sulfur + Bentonite

TigerSul, Tiger 90, Keg 90S, Keg 85S

- Apply as early as practical, usually Fall
- Till the soil again after previous application of pastilles have absorbed water
- Expect 3-5 years to fully oxidize in no-till applications such as topdress on alflafa.

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## Spring Elemental Sulfur Application

For 1 year rental, faster oxidizing Elemental Sulfur is preferred over ES + Bentonite.

- Urea + ES like SRx Thrive or Arctic S
- Dry phosphate + ES like MESZ
- Liquid Thio-Sul, KTS, or CaTs
- Soil application of $H_2SO_4$
- Ammonium Sulfate (Ammonium is acidifier)
- Soluble Ca like CaTs or $CaNO_3$ (to reduce Na)

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# Zinc, Iron, Manganese, Copper & Boron

In high pH soils

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## Mineral Micronutrients

Zn - Zinc
Fe - Iron
Mn - Manganese
Cu - Copper
B - Boron
Mo- Molybdenum
Ni- Nickel

Needed in smaller amounts

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## Micronutrients

- Just as important as primary and secondary nutrients.
- Needed in smaller amounts
- Often deficient in high pH, limey soils

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## Other Micronutrients

Mo - Molybdenum More available high pH
Not usually needed in the West

Ni - Nickel Needed for life cycle in vanishinglysmall amounts

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## Beneficial (not essential) Elements

Not necessary for a plant to complete its life cycle, but may be helpful

Si - Silicon

- Increases cell wall strength

Se - Selenium

- Improves growth
- Essential element for Animal Growth

Co - Cobalt

- Essential for nitrogen fixing bacteria in legumes

Na - Sodium

- Improves photosynthesis in certain C-4 plants.

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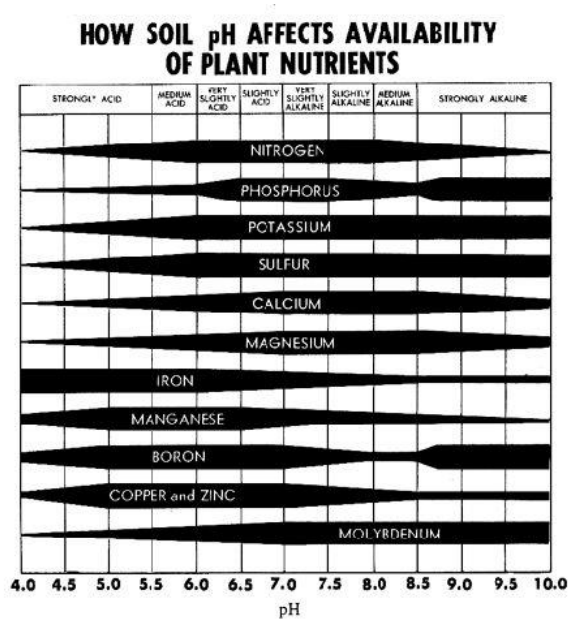


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# Total vs. Available Nutrients at pH of 8.0

| Nutrient | Total in Soil (ppm) | Plant Avail. (ppm) |
|---|---|---|
| Zinc (Zn) | 50 | 0.2-0.5 |
| Iron (Fe) | 35,000 | 2-10 |
| Manganese (Mn) | 500 | 1-10 |
| Copper (Cu) | 30 | 0.1-4.0 |
| Boron (B) | 40 | 0.1-2.0 |

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# Forms of Micronutrients in the Soil

- Zinc $Zn^{2+}$ In basic soils: mostly $Zn(OH)^{+}$
- Iron $Fe^{3+ \text{ or } 2+}$ In basic soils: mostly $Fe(OH)_2^{+}$
- Manganese $Mn^{2+}$ In basic soils: mostly $Mn^{2+}$
- Copper $Cu^{2+}$ In basic soils: mostly $Cu^{2+}$
- Boron $B(OH)_4^{-}$ Same in basic soils

- Molybdenum $MoO_4^{-}$ Same in basic soils

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# Nutrients Removed by Alfalfa

| Nutrient | #/Ac Removed 4T yield | #Ac Removed 8T yield |
|---|---|---|
| P (phosphate) | 24 (56) | 48 (112) |
| K (potash) | 192 (232) | 384 (464) |
| Ca | 120 | 240 |
| Mg | 24 | 48 |
| S | 24 | 48 |
| Mn | 0.5 | 1.0 |
| Fe | 1.2 | 2.4 |
| Zn | 0.2 | 0.4 |
| Cu | 0.04 | 0.08 |
| B | 0.24 | 0.48 |

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# Nutrients Removed by Timothy Hay

| Nutrient | #/Ac Removed 4T yield | #Ac Removed 6T yield |
|---|---|---|
| N | 150 | 225 |
| P (phosphate) | 24 (55) | 35 (82) |
| K (potash) | 210 (250) | 315 (375) |
| Ca | 120 | 180 |
| Mg | 10 | 15 |
| S | 16 | 24 |
| Mn | 0.5 | 0.8 |
| Fe | 1.4 | 2.1 |
| Zn | 0.2 | 0.3 |
| Cu | 0.05 | 0.07 |
| B | 0.26 | 0.39 |

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# Nutrients Removed by Dry Beans

| Nutrient | #/Ac Removed 25 cwt/Ac | #Ac Removed 35 cwt/Ac |
|---|---|---|
| **N** | **175** | **265** |
| **P (phosphate)** | **18 (40)** | **26 (60)** |
| **K (potash)** | **166 (200)** | **250 (300)** |
| **Mg** | **12** | **18** |
| **S** | **10** | **15** |
| **Zn** | **0.2** | **0.3** |
| **Fe** | **0.8** | **1.2** |
| **Mn** | **0.3** | **0.5** |
| **B** | **0.18** | **0.25** |

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# Zinc

- Constituent of many enzymes
- Controls synthesis of indoleacetic acid
  - A plant growth regulator
- Important for protein formation
- Corn, Beans, Onions, & Potatoes are particularly sensitive to deficiency

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## Zinc Deficiency Symptoms

- Severely reduced growth rate & yield
- Decrease in stem & leaf length
- “Bushy” leaf appearance
- Reduced bud formation
- Interveinal chlorosis in some crops
- White striping or banding in some crops
- Dieback of young shoots
- Deformation of fruit

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## Zn Deficiency

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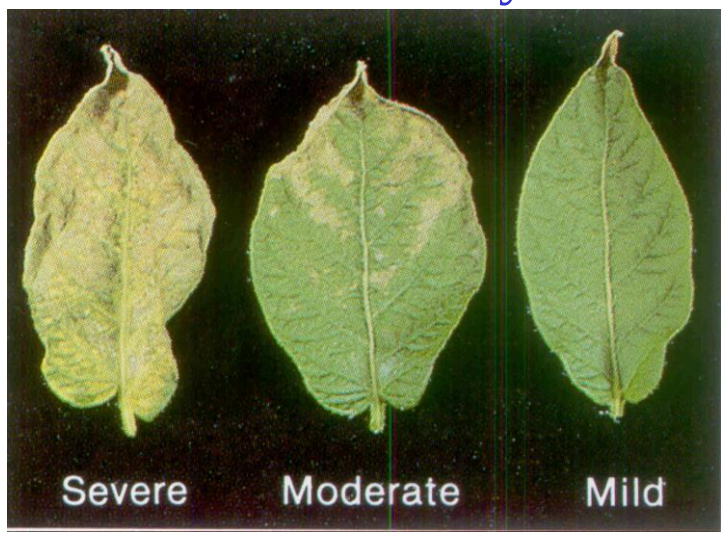
# Zn Deficiency

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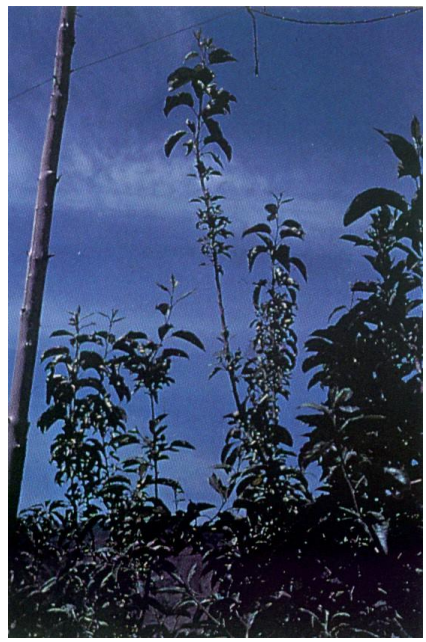

Zn Deficiency
in Apples

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Zn Deficiency in Stone Fruits

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Zn Deficiency in Onions

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# Zn Deficiency Alfalfa

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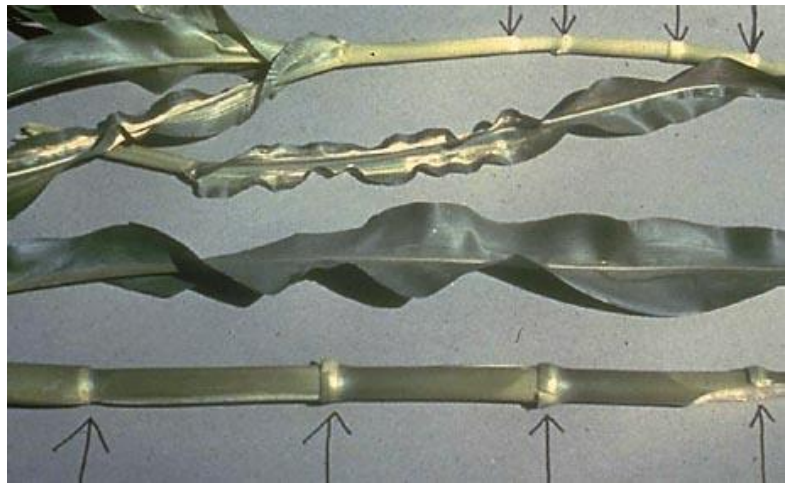
# Zn Deficiency Corn



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# Zn Deficiency Dry Beans

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| Organic Matter, % | 1.56 | M | |
| Organic N, lb/Acre | 60 | M | |
| Ammonium - N, ppm | 2.4 | VL | |
| Nitrate - N, ppm | 11 | M | |
| Phosphorus, ppm | 10 | L | |
| Potassium, ppm | 338 | H | |
| Calcium, meq/100g | 11.6 | H | |
| Magnesium, meq/100g | 1.9 | L | |
| Sulfate - S, ppm | 3 | VL | |
| Zinc, ppm | 0.4 | VL | |
| Iron, ppm | 5.5 | M | |
| Manganese, ppm | 2.5 | L | |
| Copper, ppm | 0.4 | L | |
| Boron, ppm | 0.43 | L | |

Very Low Zinc

| | Sample 1 | Sample 2 |
|---|---|---|
| Grower | U OF WY | |
| Sample Identity | GOSHEN 2 CORN | |
| Crop | SUNFLOWERS | |
| Yield Goal | 27 BU | |
| Acres | 80 | |
| Prev Crop T/Acre | FIELD CORN 1 | |
| Manure T/Acre | | |
| Prev Applied Nut | | |
| RECOMMENDATIONS, lbs Nutrients or Units per Acre | | |
| Nitrogen | 105 | |
| $P_2O_5$ – Phosphate | 60 | |
| $K_2O$ - Potash | 0 | |
| Calcium | 0 | |
| Zinc | 9 | |
| Iron | 0 | |
| Manganese | 0 | |
| Copper | 0 | |
| Boron | 1.0 | |
| Elemental Sulfur | 0 | |

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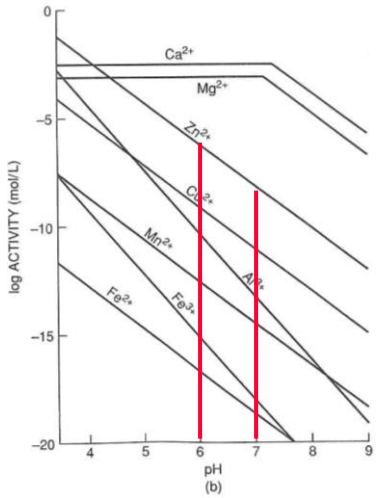
# Zn Activity vs. pH




1 unit pH increase
=
100 x decrease
in $Zn^{2+}$ Concentration

FIGURE 9.3 The solution Fe species in equilibrium with soil Fe (a) and the influence of pH on solution $Fe^{3+}$ concentration relative to other cations (b). *(a) Lindsay*, Chemical Equilibria in Soils, *John Wiley & Sons, 1979; (b) Lindsay*, Chemistry in Soil Environment, *p. 189. Madison, Wisc.: ASA.*

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Tel: 208-734-3050 Fax: 208-734-3919
Report No: 148466
Date Received: 11/14/2023
11/15/2023

| SOIL TEST DATA | Sample 1 | |
|---|---|---|
| pH | 6.7 | M |
| Salts, mmhos/cm | 1.0 | L |
| Chlorides, ppm | 11 | L |
| Sodium, meq/100g | 0.10 | VL |
| CEC, meq/100g | 15.8 | M |
| Excess Lime, % | 0.0 | VL |
| Organic Matter, % | 6.46 | VH |
| Organic N, lb/Acre | 120 | H |
| Ammonium - N, ppm | 4.7 | VL |
| Nitrate - N, ppm | 2 | VL |
| Phosphorus, ppm | 14 | M |
| Potassium, ppm | 139 | L |
| Calcium, meq/100g | 11.3 | H |
| Magnesium, meq/100g | 3.0 | M |
| Sulfate - S, ppm | 20 | M |
| Zinc, ppm | 2.5 | H |
| Iron, ppm | 56.1 | VH |
| Manganese, ppm | 5.9 | H |
| Copper, ppm | 1.8 | H |
| Boron, ppm | 0.44 | L |

Neutral pH
Not-Alkaline

| | Sample 1 | Sample 2 |
|---|---|---|
| | U OF WY | |
| | SUBLETT GRS | |
| | GRASS | |
| Yield Goal | 3 T | |
| Acres | 80 | |
| Prev Crop T/Acre | GRASS | |
| Manure T/Acre | | |
| Prev Applied Nut | | |

RECOMMENDATIONS, lbs Nutrients or Units per Acre

| | |
|---|---|
| Nitrogen | 125 |
| $P_2O_5$ – Phosphate | 35 |
| $K_2O$ - Potash | 40 |

Adequate Zinc

| | |
|---|---|
| Zinc | 0 |
| Iron | 0 |
| Manganese | 0 |
| Copper | 0 |
| Boron | 1.0 |
| Elemental Sulfur | 0 |
| Gypsum | 0 |
| Lime | 0 |

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## Correcting Zn Deficiencies

- Build up soil Zn levels
  - 33 to 36% $ZnSO_4$
  - 78 to 80% ZnO
    very low solubility at high pH
    10% in one Nebraska study at pH 7.5
- Apply 4 to 12 lb Zn / Acre
  - High rates give adequate coverage
  - About 1 lb / year is removed + tied up
- 3-5 tillage operations to completely disperse Zn
- Acid producing fertilizers help keep available

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## Correcting Zn Deficiencies

- Apply enough Zinc for just this year
  Use available form that gives adequate coverage
- Product that coats other fertilizer prills.
  - Wolf Trax Zn, GET
- Low concentration soluble product
  - microSync
- Uniprill product containing Zn
  - Elemental Sulfur with Zn
  - 40 Rock, MESZ, NPSZ, GET 12-30-0
  - TranZform with Zn

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## Correcting Zn Deficiencies

- Wolf Trax Zn 62%
  - 60% ZnO and 40% $ZnSO_4$
  - Apply up to 1 unit Zn per 100# fertilizer
  - Also has foliar label
- GET, LandView
  - 11.7% Zn, 4.7% Mn
  - $ZnSO_4$ $MnSO_4$

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## Correcting Zn Deficiencies

- microSyncZINC , Verdesian
  - 10% Zn
  - 8% water soluble Zn from $ZnSO_4$
  - 2% Zn from Zn Sucrate (ZnO reacted w/ molasses)
  - 12% $SO_4$-S
  - Has polymer complex resin like Avail, NSN
  - Designed to not segregate when blended with other fertilizer

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## Correcting Zn Deficiencies

- Tiger Potato Mix
  - 82% ES, 1.5% Zn, 2.0 % Fe, 0.03% Cu
  - All micronutrients are Oxide forms (less soluble)
  - Oxidation of S should make them available

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## Reduction of Other Elements

$S^{o}$ → Oxidized → $SO_4^{-2}$

$ZnO$ → Reduced → $ZnSO_4$

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## Correcting Zn Deficiencies

- 40 Rock, Simplot
  12-40-0 6.5 S 1.0 Zn
  11-52-0 + 21-0-0 + $ZnSO_4$
  S is $SO_4$-S

- MESZ, Mosaic
  12-40-0 10 S 1.0 Zn
  11-52-0 + 21-0-0 +ES+ ZnO
  5% $SO_4$-S + 5% ES

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## Correcting Zn Deficiencies

- NPSZ, Valley Agronomics
  12-45-0 5S 1.0 Zn
  11-52-0 + 21-0-0 + $(Mg,Fe,Al)HPO_4$ + $CaSO_4$ + ZnO
  S is $SO_4$-S

- TranZform, CHS
  20-0-0 24 S 0.9 Zn
  21-0-0 + $ZnSO_4$
  S is $SO_4$-S

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## Correcting Zn Deficiencies

- GET 12-39-0 5S, LandView
  12-39-0 5S 0.2 Zn 0.05 Mn
    11-52-0 + 21-0-0 + $ZnSO_4$ + $MnSO_4$
    Unipril (similar to 16-20-0)
    S is $SO_4$-S

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## Correcting Zn Deficiencies

- Liquid Zn in starter fertilizer bands
  Zn Chelates are most effective
  Zn Complex fertilizer also work at higher rates
- Zn foliar sprays at 0.1 to 0.4 lbs. /Ac

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## Iron

- Required for Chlorophyll complex
- Activator for respiration, photosynthesis & nitrogen fixation
- Immobile once fixed in the plant
- Electron carrier
- Exists as $Fe^{3+}$ "Ferric" Not very soluble
  $Fe^{2+}$ "Ferrous" Soluble

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## Iron Deficiency Symptoms

- Halting of new growth
- Interveinal chlorosis
  (yellow between leaf veins)
- Interveinal necrosis if severe
  (dead spots between leaf veins)
- Newest leaves are white

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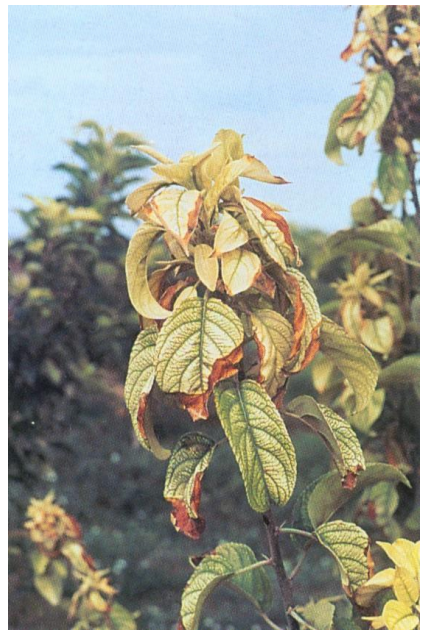

Iron Deficiency
in Apples

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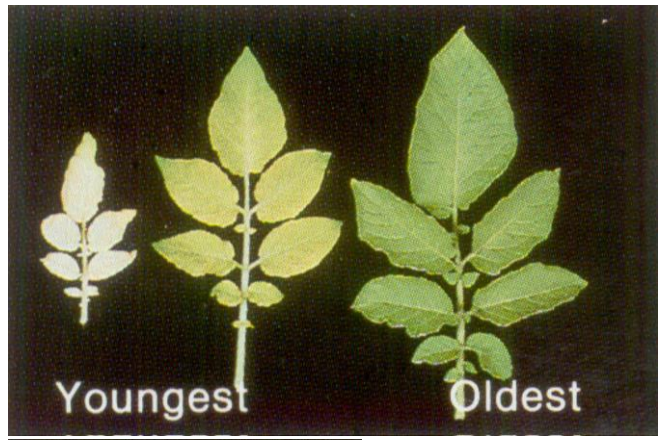
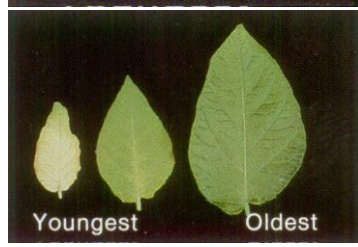
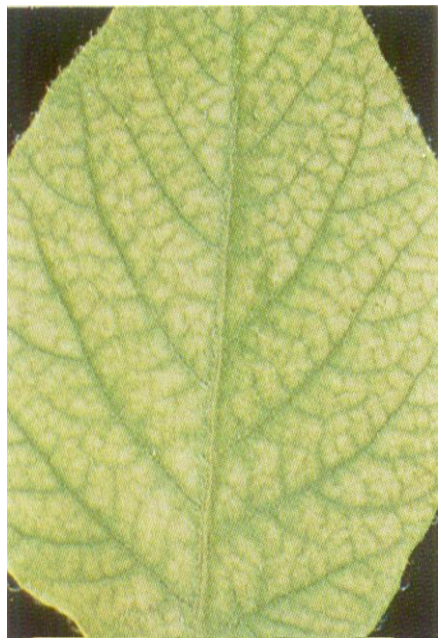



Iron Deficiency
in Potatoes

68



Interveinal Chlorosis
symptom of
Iron Deficiency
in Potatoes

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## Iron Deficiency is More Common if:

- pH >7.3 or <4.5
- Soil is calcareous (has excess lime)
- Low O.M.
- Heavy soils
- Excessive water / poor aeration
- Excess of Zn, Mn, & Cu
- Excessive P (Especially in Acid soils)

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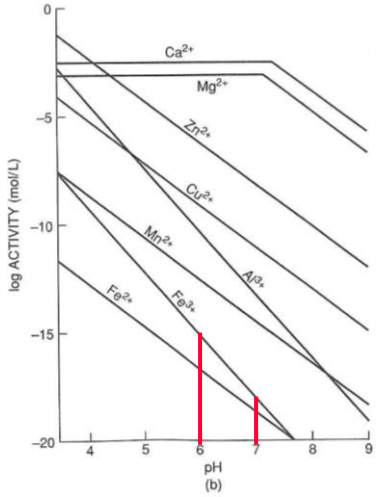
# Iron Activity vs. pH




1 unit pH increase
=
1,000 x decrease
in $Fe^{3+}$ Concentration

FIGURE 9.3 The solution Fe species in equilibrium with soil Fe (a) and the influence of pH on solution $Fe^{3+}$ concentration relative to other cations (b). *(a) Lindsay,* Chemical Equilibria in Soils, *John Wiley & Sons, 1979; (b) Lindsay,* Chemistry in Soil Environment, *p. 189. Madison, Wisc.: ASA.*

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# Iron Availability

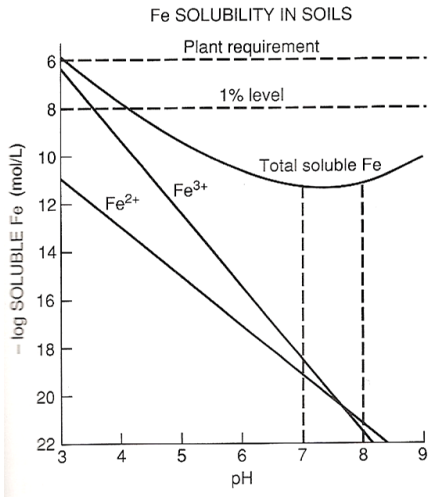


FIGURE 9.6 The influence of pH total solution Fe concentration and its relationship to and Fe required by plants. *Lindsay,* Plant Root and Its Environment, *p. 508, Univ. Press of Virginia, 1974.*

72

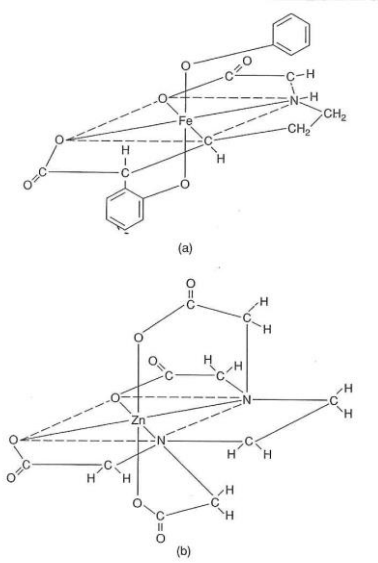

FIGURE 9.8 The structure of Fe-EDDHA (A) and Zn-EDTA (B). *Follett et al.*, Fertilizers and Soil Amendments, *Prentice-Hall, Englewood Cliffs, N.J., 1981.*

# Natural Chelates

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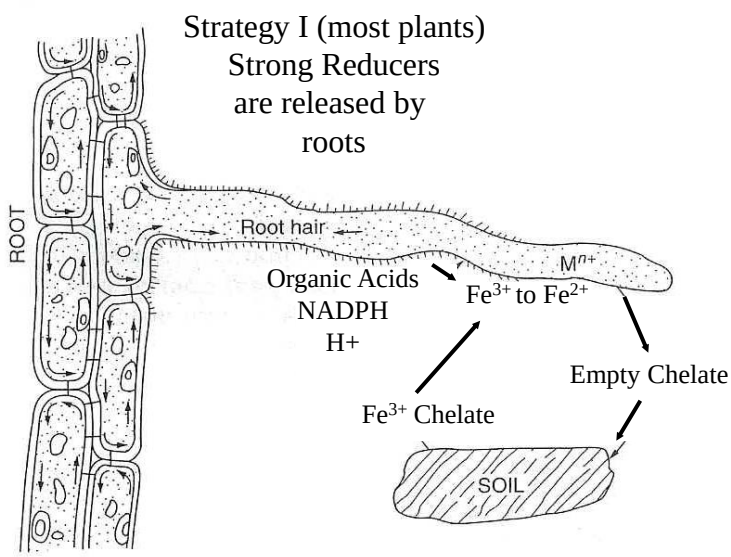
# Iron and Natural Chelates

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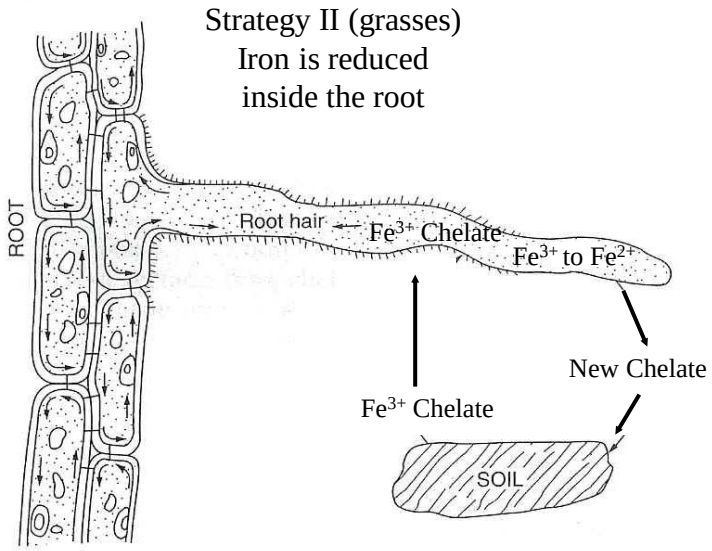
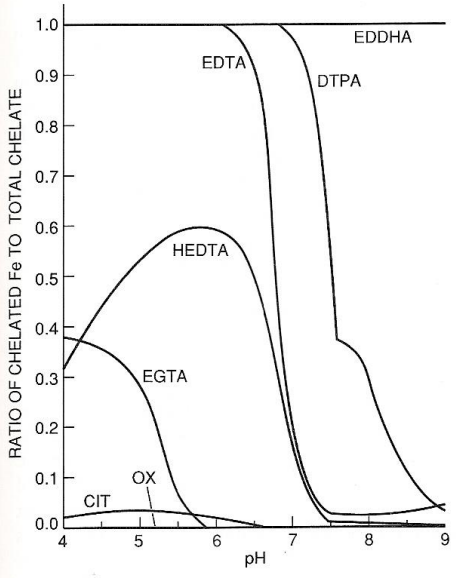
# Iron and Natural Chelates




75




## Chelates Have Limited Lifespan at High pH

FIGURE 9.12 Stability of selected synthetic chelates with Fe in soils. *Norvell*, Micronutrients in Agriculture, *p. 126, 1972.*

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## Correcting Fe Deficiencies

- Elemental Sulfur
- Acid producing fertilizers
- Manure
- Soil applied Fe
  - Reduced S
  - Acids through the water
  - Humic or other organic acids
  - Chelates (EDDHA is best but expensive)
  - EDDHSA appears to be as good
- Foliar Sprays

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## Correcting Fe Deficiencies

- Sequestrene 138
  - 6.0% Fe as Iron Chelate EDDHA
  - Foliar or soil application
  - Application rate 1 to 5 lbs/Ac when soil applied
  - Very effective
  - Very expensive

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# Correcting Fe Deficiencies

- Tiger Potato Mix
  - 82% ES, 1.5% Zn, 2.0 % Fe, 0.03% Cu
  - All micronutrients are Oxide forms (less soluble)
  - Oxidation of S should make them available

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# Reduction of Other Elements

$S^{o}$ → $SO_4^{-2}$ Oxidized

$Fe^{2+}$ ← Reduced $Fe^{3+}$

| Available | Unavailable |
|---|---|
| Ferrus Sulfate | Ferric Sulfate |
| Iron II Sulfate | Iron III Sulfate |
| $FeSO_4 \cdot xH_2O$ | $Fe_2(SO_4)_3$ |
| typ Blue-Green | typ Yellow |

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## Correcting Fe Deficiencies

- SulFeGro G, PHT
  - 8.0% Fe as Ferrous Sulfate
  - 8.0% Zn as $ZnSO_4$
  - 5.0% S as $SO_4$-S
  - pH 2.0
  - Application rate 50 to 100 lbs/Ac
  - Will stain concrete, pivots, clothes

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## Correcting Fe Deficiencies

- SulFeGro liquid, PHT
  - 5.0% Fe as Ferrous Sulfate
  - 2.0% Zn as $ZnSO_4$
  - 3.0% S as $SO_4$-S
  - pH 2.0
  - Application rate 10 to 75 gallons/Ac
  - Will stain concrete, pivots, clothes
  - Foliar application may burn leaves

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## Correcting Fe Deficiencies

- Red Vigor, PHT
  - 2.0% Fe as EDDHSA Chelate
  - 1.4% S as $SO_4$-S
  - pH 8.0
  - Application rate 1pt to 5 qts/Ac
  - In-furrow, drip, or water applied
  - Not a foliar

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## Correcting Fe Deficiencies

- Ironclad IDC microSync, Verdesian
- 2.5% Fe
  - 1.55% Fe as EDDHA Chelate
  - 0.95% Fe as Ferrous Sulfate and Iron Citrate
  - 1.0% Zn 0.5% EDTA Chelate
  - 4.0% S as $SO_4$-S
  - 2.0% N as $NH_4$-N
  - Application rate 5 to 15 lbs/Ac
  - In-furrow or banded is preferred

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## Manganese

- Main component of first enzyme in photosynthesis (liberates $O_2$ from water)
- Activates enzymes
  - respiration
  - nitrogen metabolism
- Immobile in the plant

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## Manganese Deficiency Symptoms

- Interveinal chlorosis and/or necrosis
  (yellow or brown between leaf veins)
- Upward cupping of leaves
- Slow growth
- White or yellow Specks
  - Grey speck of oats
  - Marsh spot of peas
  - Speckled yellows of sugar beets

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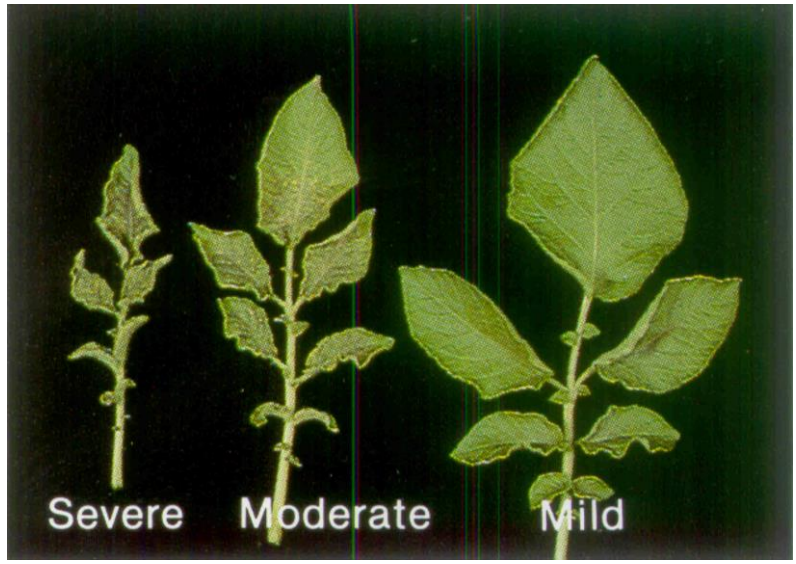


Manganese Deficiency
in Potatoes

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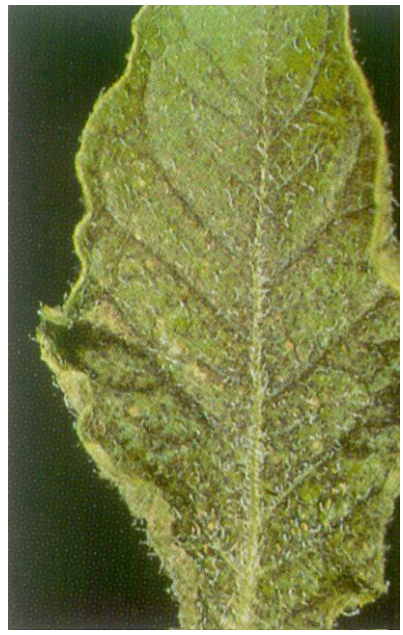

Interveinal Necrosis
symptom of
Manganese Deficiency
in Potatoes

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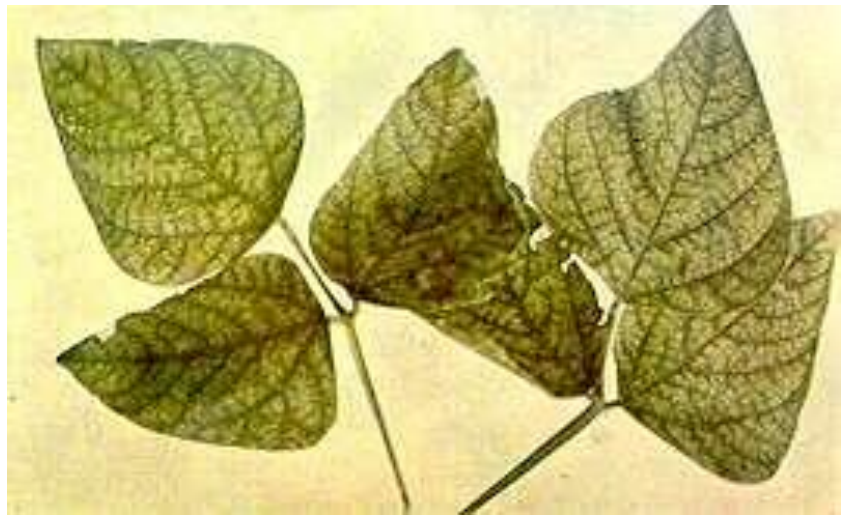
Interveinal Chlorosis Symptom of
Iron Deficiency in Beans

89



Interveinal Necrosis Symptom of
Manganese Deficiency in Beans

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Interveinal Chlorosis and Necrosis
symptoms of
Manganese Deficiency in Beans

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## Manganese Deficiency is More Common if:

- pH >7.0
- Soil is calcareous (has excess lime)
- Low O.M  or Very High O.M.
- Dry Soils (Mn is very available in Saturated soils)
- Excess of Zn, Fe, & Cu
- Low salts, low K

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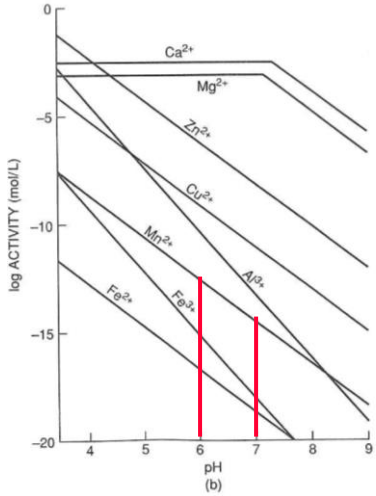
# Manganese Activity vs. pH




1 unit pH increase
=
100 x decrease
in $Mn^{2+}$ Concentration

FIGURE 9.3 The solution Fe species in equilibrium with soil Fe (a) and the influence of pH on solution $Fe^{3+}$ concentration relative to other cations (b). *(a) Lindsay,* Chemical Equilibria in Soils, *John Wiley & Sons, 1979; (b) Lindsay,* Chemistry in Soil Environment, *p. 189. Madison, Wisc.: ASA.*

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# Correcting Mn Deficiencies

- Elemental Sulfur
- Acid producing fertilizers
- Manure
- Soil applied Mn
  - $MnSO_4$ works - but little soil buildup of Mn
  - Humic or other organic acids
  - Chelates
  - Complexes
- Foliar Sprays at 0.1 to 0.4 lbs. /Ac

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## Copper

- Activator of enzymes
- Important in cell division & expansion
- Part of secondary compounds
  - Disease defense
  - Flavor
  - Color
- Moderately mobile in plant

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## Copper Deficiency Symptoms

- Young leaves yellow and stunted
- Necrotic (dead) tissue along leaf edges
- Limp older leaves and stems
- Increased disease susceptibility
- Poor color, taste, & quality in fruit & tubers

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# Cu Deficiency

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# Correcting Cu Deficiencies

Some Value

- Acid producing fertilizers
- Manure

Works but Expensive

- Soil applied Copper Sulfate
- Copper Chelate

Foliar Sprays

Most effective and most cost-effective

0.05 to 0.2 lbs. / Ac

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# Boron

- Flowing, fruiting, & seed formation
- Protein synthesis
- Cell division & development in roots
- Immobile in the plant

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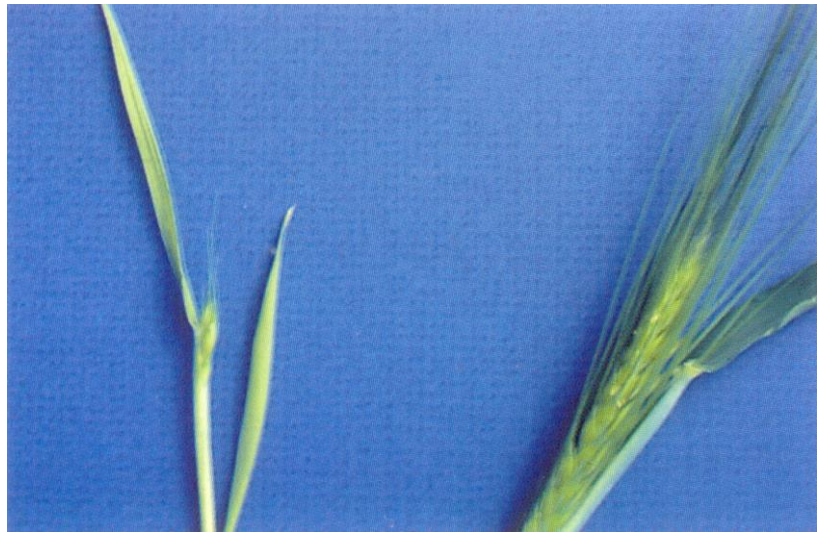
# B Deficiency



100

# B Deficiency

101

# Correcting B Deficiencies

- Soil applied works great
  - 0.5 to 3.0 lbs. / Ac
  - Only after soil test
  - No chelates or complexes made or needed
- Foliar sprays work great
  - 0.1 to 0.3 lbs. / Ac

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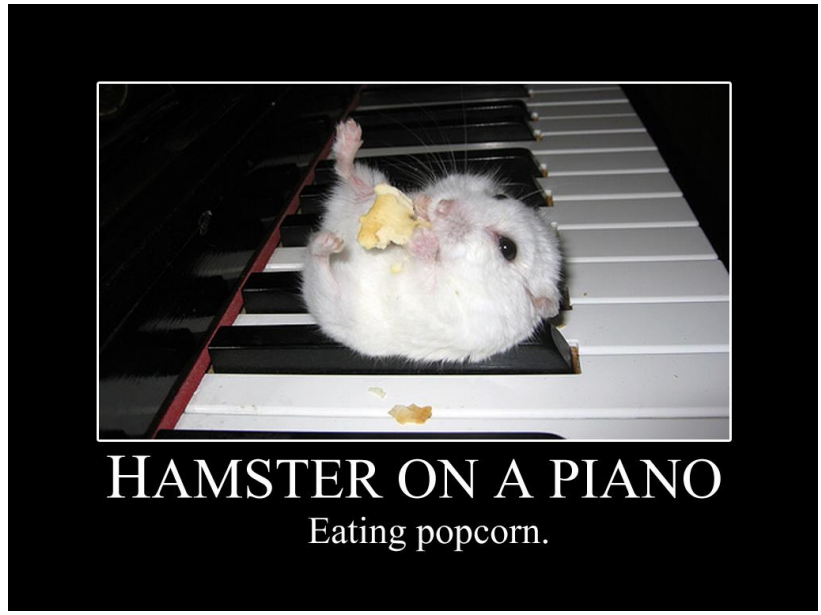


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