33rd Annual NATIONAL NO-TILLAGE CONFERENCE

January 7-10, 2025 • Louisville, Ky.

# Digging Deep into Nutrient Content & Function

**James J. Hoorman**
**Hoorman Soil Health Services**

33rd Annual NATIONAL NO-TILLAGE CONFERENCE
January 7-10, 2025 • Louisville, Ky.

Hoormansoilhealthservices@gmail.com
419-421-7255

# Instructions

- ***Send your presentation to Joseph Kuenzle @ jkuenzle@lessitermedia.com prior to December** 30th.*

***If your presentation is too large to submit via email, please upload your presentation to Google Drive.***

- ***We will have your presentation loaded on the computer and ready for you when you arrive. We will also arrange for printouts.***

- ***NTF* will provide the computer and projector. Plan on giving your presentation from the podium on the laptop computer**

**Should you have any questions on how to use this template or upload your files, contact Joseph Kuenzle at 262-782-4480, ext. 434 or jkuenzle@lessitermedia.com**

33rd Annual NATIONAL NO-TILLAGE CONFERENCE
January 7-10, 2025 • Louisville, Ky.

# Relative Plant Concentration of Nutrients

## (In relation to Nickel)

| Macronutrients | Atoms | % of Plant Tissue |
|---|---|---|
| Hydrogen – H | 60 Million | 6% |
| Carbon – C | 40 Million | 45% |
| Oxygen – O | 30 Million | 45% |
| Nitrogen –N | 1 Million | 1.5% |
| Potassium –K | 250,000 | 1.0% |
| Calcium – Ca | 125,000 | 0.5% |
| Magnesium – Mg | 80,000 | 0.2% |
| Phosphorus –P | 60,000 | 0.2% |
| Sulphur – S | 30,000 | 0.1% |
| Silicon – Si | 30,000 | 0.1% |

# Relative Plant Concentration of Nutrients
## (In relation to Nickel)

| Micronutrients | Atoms | % of Plant |
|---|---|---|
| Chlorine –Cl | 3,000 | 0.0100 |
| Iron – Fe | 2,000 | 0.0067 |
| Boron – B | 2,000 | 0.0067 |
| Manganese -Mn | 1,000 | 0.0033 |
| Sodium –Na | 400 | 0.0012 |
| Zinc – Zn | 300 | 0.0010 |
| Copper –Cu | 100 | 0.0003 |
| Cobalt –Co | 2 | |
| Molybdenum – Mo | 1 | |

# Maximum Nutrient Availability based on pH

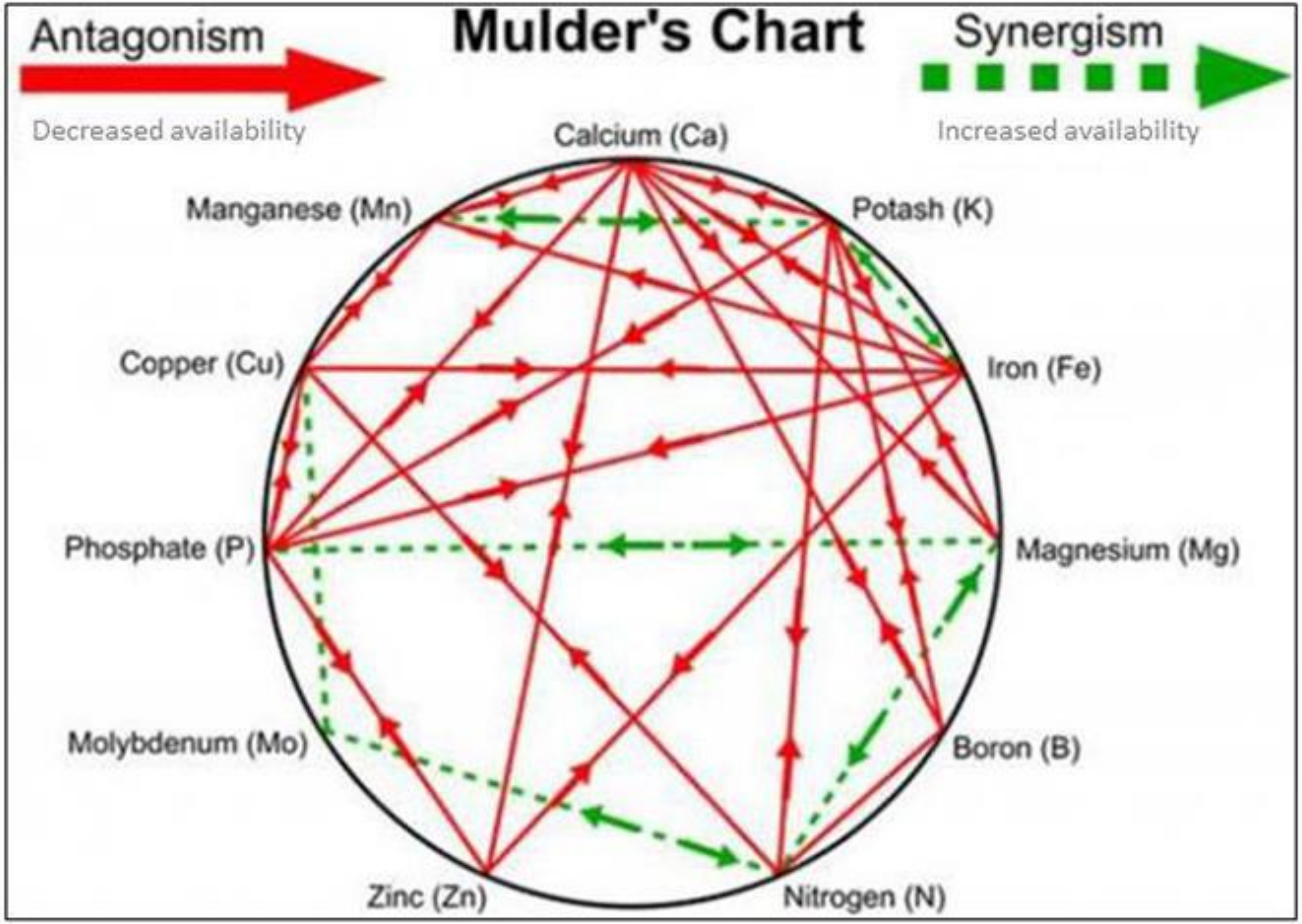
| Nutrient | Lowest pH | Highest pH | Minimum soil level | Minimum tissue level |
|---|---|---|---|---|
| Nitrogen<br>Sulfur | 6<br>6 | 8<br>10 | Depends<br>10-20 ppm | 2.6-4.0%<br>0.18-0.24% |
| Phosphorus | 6.5 | 7.5 | 20-100 ppm | 0.20-0.5% |
| Potassium | 6 | 10 | .5 meq/100g | 1.7-3.0% |
| Calcium | 7 | 8.5 | .5 meq/100g | 0.21-1.0% |
| Magnesium | 7 | 8.5 | 1.6 meq/100g | 0.2-0.6% |
| **Iron** | **4** | **6.5** | 10 ppm | 21-250 ppm |
| **Manganese** | **5** | 7 | 10-50 ppm | 15-200 |

# Maximum Nutrient Availability based on pH

| Nutrient | Lowest pH | Highest pH | Minimum soil level | Minimum tissue level |
|---|---|---|---|---|
| Boron | 5.5 | 7 | 0.5-4 ppm | 1-25 ppm |
| Copper | 5 | 7 | 2-50 ppm | 3-20 ppm |
| Zinc | 5 | 7 | 1-200 ppm | 15-150 ppm |
| Molybdenum | 7 | 10 | 2 ppm | 0.3 -1.5 ppm |
| Nickel | 6.5 | 7 | 1-20 ppm | 0.5-5.0 ppm |
| Chromium | 6.5 | 7 | 10-50 ppm | 4-50 ppm |
| Selenium | 6.5 | 7 | LT 200 ppm | 5-50 ppm |
| Cobalt | 6.5 | 7 | 1-2 ppm | 100 ppb |

# Law of Minimum and Maximum

- Law of Minimum states that what ever element is missing is the element that reduces yield.
- Example:  Staves on a barrel full of water
- Law of Maximum states that what ever nutrient is in surplus, that element may have a negative effect on other elements and limit yield.  Too much N-P-K can tie up other nutrients especially micro-nutrients needed for amino acid and protein formation.  See Mulder's Chart.


Mulder's Chart
Antagonism
Decreased availability
Synergism
Increased availability
Calcium (Ca)
Manganese (Mn)
Potash (K)
Copper (Cu)
Iron (Fe)
Phosphate (P)
Magnesium (Mg)
Molybdenum (Mo)
Boron (B)
Zinc (Zn)
Nitrogen (N)

# Mulder Element Relationships
# Nitrogen (N)

**Excess N and S (These two elements are closely related and have similar effects on other soil nutrients):**

* ↓ Boron (B), Potassium (K), Copper (Cu)
- Excess N ↑ Magnesium (Mg) (creates tight soil)
- Adequate Mo- and Mg2+ tend to increase Plant N
- Need adequate Mo- to increase N efficiency.
- Liming acid soils increases Mo- and N fixation. Legumes and clovers increase N through N fixation.
- Rhizobia Need adequate Cobalt to increase nodules 2-3X!

# Oxidation and Reduction
# Redox

- Redox: Type of Chemical Reactions and element state.
- Oxidation: Transfer or loss of electrons. Originally described how an element combined with oxygen. Example: $Mg^{2+}$ + $O^{2-}$ = MgO (Magnesium oxide)
- Reduction: Gain of electrons or decrease in the oxidation state. Most plant available ions need to be in a reduced state to be absorbed. Ex $Ca^{2+}$, $Mg^{2+}$, $Cu^{2+}$, $Zn^{2+}$, $Fe^{2+}$, $Mn^{2+}$

# Soil Redox Conditions

- **Soil Oxidizing Conditions: Dry soil, Aerobic soils, Lots of available oxygen**.
- **Soil Reducing Conditions: Wet saturated soil, anerobic soils, compacted, and poor soil structure lead to highly reduced soils and leaching of plant available nutrients.**
- **Can roots grow in highly reduced soils?  No**
- **Can dry (droughty soils release adequate plant available nutrients? Not likely**
- Million-dollar rain **(Goldilocks).** Oscillating wet and dry soil conditions in microenvironment.  Moist areas allow reduction and aerated areas allow good root growth. Roots absorb reduced elements and get oxygen for root respiration. Respiration releases energy and allows plants to grow.

# Cover Crops and Nitrogen

Cover crops have three Nitrogen (N) functions

A) N Makers (Legumes & Clovers)

B) Slow N Recyclers (Grasses)

C) Quick N Recyclers (Brassicas)

Rhizobia bacteria inoculants are crucial for Legume and Clovers to make N.

# Life span of the strains needed to properly inoculate:

- Soybeans – liquid inoculants that contain extenders are good past 120 days
  - Sterile peat products are good for 30 days
  - Standard planter box product would be 2-4 days
- Alfalfa / Red Clover - Alfalfa clay pre-inoculants are good for 2 years
  - Clover clay pre-inoculants would be 1 year
  - Peat-based planter box products = 48 hours max
- Crimson Clover – pre-inoculants = 48 hours max
- Hairy Vetch – planter box treatments = 12-24 hoursmax
- Winter Peas – planter box treatments = 12-24 hours max

# Nitrogen Recyclers

- Grasses are slow recyclers: (4% to 5% N)
- Depends on Biomass Produced

Best are Sorghum Sudan Grass (Summer Annual)

Cereal Rye, Annual Ryegrass, Oats, Barley, Wheat,

Pearl Millet

- Brassicas are quick /recyclers and very efficient (4.5% to 5.5% N)

    A) Oilseed radish is a great recycler but dies in the winter.

# Nutrient Losses/Tie up: N-P

1)Nitrogen Losses: 1% SOM lost equals loss of 1,000# of Soil N. Current N nutrient use efficiency is only 30-50% (50-70% loss of SOM) Why? 80-90% of Soil N is Organic N. Compaction = Denitrification

2) Phosphorus (Especially SRP)

Current P nutrient use efficiency is only 10-50%.
Why? 50-70% of Soil P is tied up as Organic P
90% P runoff (compaction) occurs with intense rains.
30% P runoff is surface, 70% from Preferential Flow.

# Nutrient Losses/Tie up: K

**3) Tillage reduces Potassium (K) plant uptake.**
**Why? With poor soil structure & compaction & anaerobic conditions, K becomes sealed and fixed in clay soil particles (Related to Iron Reduction)**

# Soil Organic Matter (SOM)
# SOM = MOM

**SOM is Like Your MOM!**

*Buffers pH (makes nutrients plant available)
*Buffers soil temperature (blanket, hot/cold)
*Buffers nutrients (feeds the plants),
* ↑ water holding capacity (water plants)
* ↑ water infiltration (less ponding water)

* ↓ water & nutrient runoff

Hoorman Soil Health Services

**SOM chelates (claw) macro/micro nutrients**
**Importance of Humates (Fulvic & Humic Acid)**

# Mulder Element Relationships

## Phosphorus (P)

Phosphorus (P) is needed for building DNA and RNA, for energy transfer (ATP), and cell walls

- Excess P ⬄ ↓ Ca, Fe, Mg;  Grasses increase P
- Excess P: ↓ K, Cu, Zn
- Compacted soils ↑ Fe, Mg and tie up P and Ca.

# Phosphorus (P) in Cover Crops

Relatively easy to calculate. All plants need and use about 0.2% P of their biomass. The cover crops with the highest biomass take up the most P. P is used in a relatively fixed amount or ratio in plants.

Best P cover crops for making P available
Sorghum Sudan/oats in summer
Winter Annual grasses in the Winter
Radish and Buckwheat

# Soluble Reactive P (SRP) Runoff

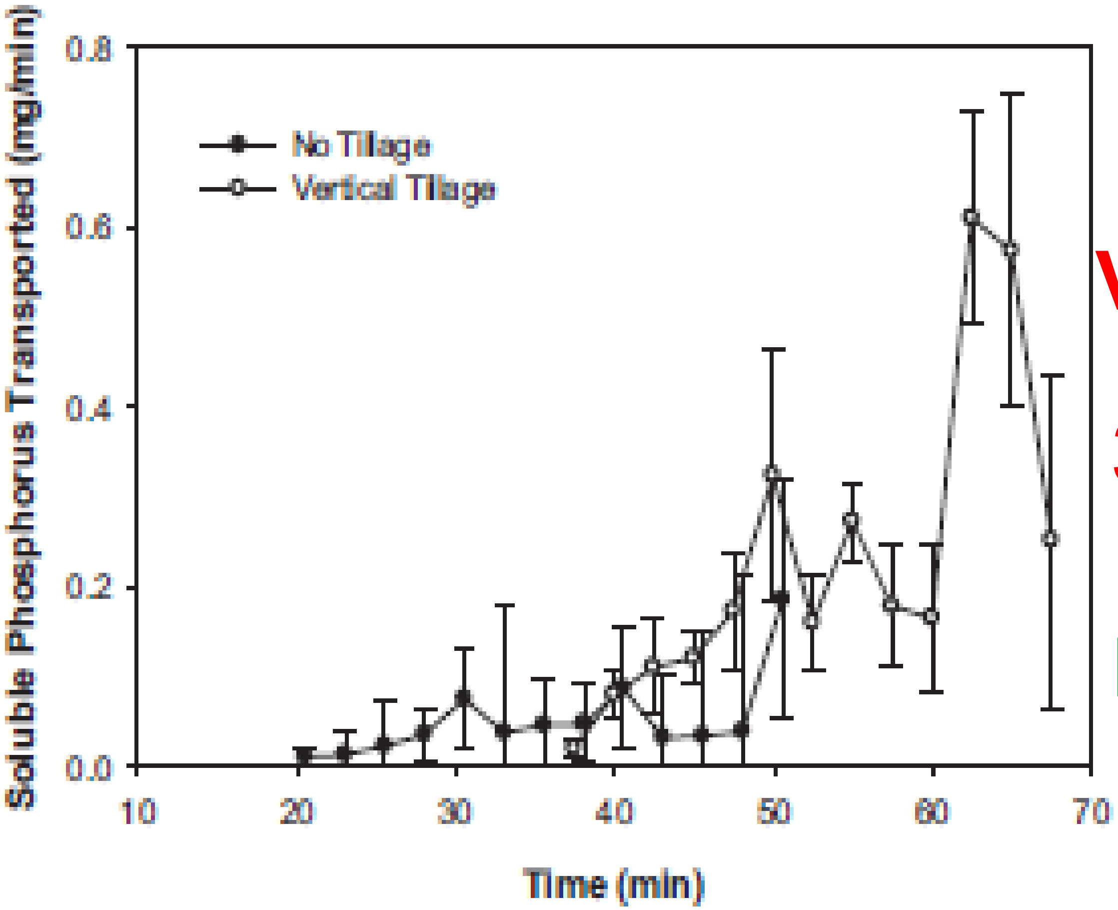



Fig. 1. Soluble phosphorus transported via runoff from no-tillage and vertical tillage plots. Error bars represent standard error.

**Vertical tillage**

**3X higher**

**No-till**

Smith & Warnemuende-Pappas, 2015
Soil & Tillage Research 153:155-160

# Total P Runoff

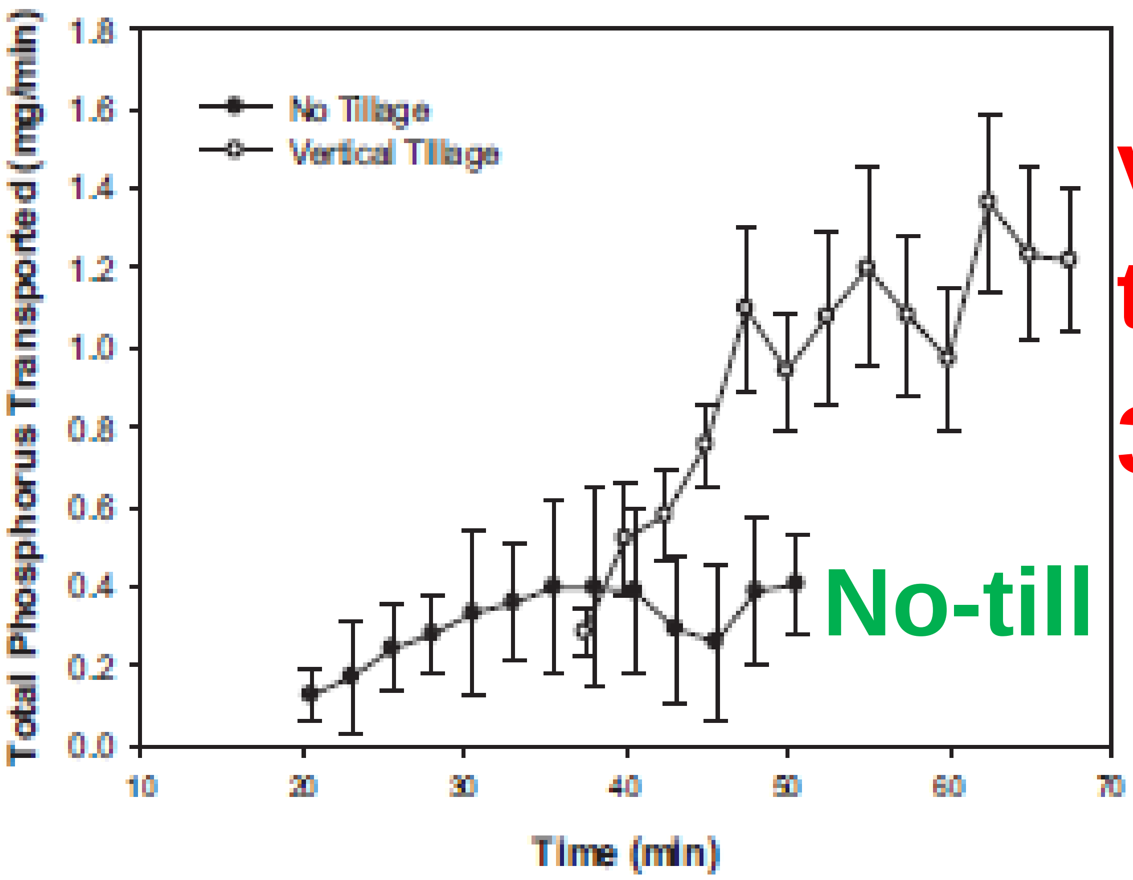



Fig. 2. Total phosphorus transported via runoff from no-tillage and vertical tillage plots. Error bars represent standard error.

**Vertical tillage**

**3X higher**

**No-till**

Smith & Warnemuende-Pappas, 2015
Soil & Tillage Research 153:155-160

# Sediment Runoff

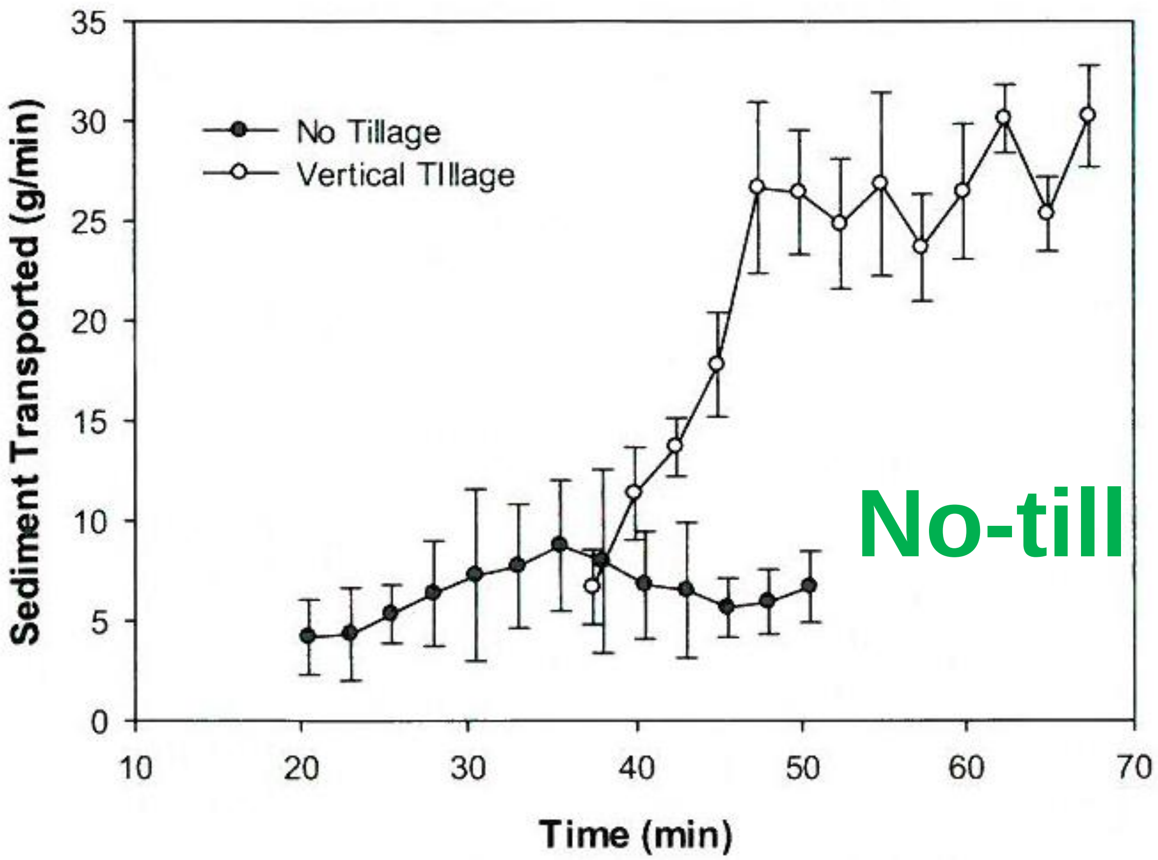



**Fig. 3.** Sediment transported via runoff from no-tillage and vertical tillage plots. Error bars represent standard error.

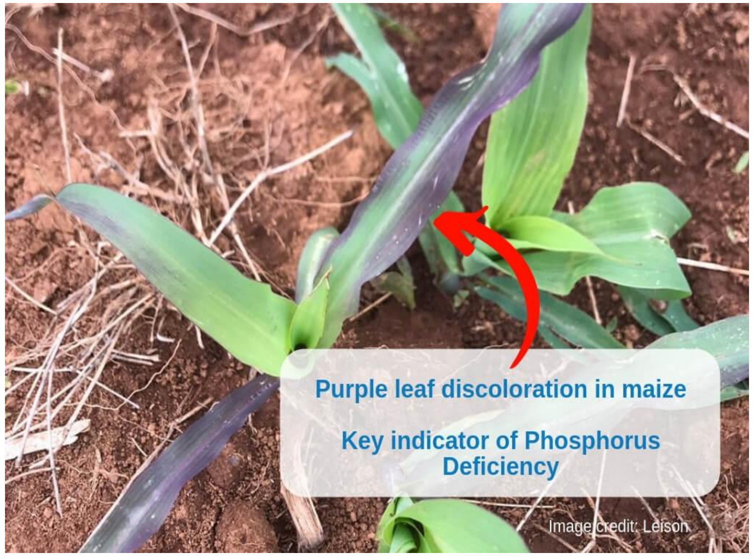
**Vertical tillage**

**5X higher**

**No-till**

Smith & Warnemuende-Pappas, 2015
Soil & Tillage Research 153:155-160

# Phosphorus and Potassium Deficiency




**Good P** **Deficient P**
Photo from IPNI


*Maize showing signs of potassium deficiency.*

K Deficient University Lincoln Nebraska

# Potassium (K) Uptake by Cover Crops

**Potassium (K) in plants is used to accumulate other nutrients. Ion pumps. K is not apart of any molecule. It's like oil in a tractor! It's not really part of the tractor but it is critical for optimal tractor (plant) performance.**

**Legumes and clovers have the highest concentration of K because K is used to recycle N and to make N.**

**Alfalfa, Winter Peas; Cow Peas, Hairy & Common Vetch, Clovers: Balansa, Crimson, Red, White.**

# Potassium (K) uptake of Crops

| Crop | Yield bu./ac | Grain # K20/ac. | Straw # K2O/ac. | Total # K2O/ac. | Total Uptake # $K_2O$/bu. |
|---|---|---|---|---|---|
| Wheat | 40 | 16-19 | 49-61 | 65-80 | 1.63-2.00 |
| **Barley** | **80** | **23-28** | **73-89** | **96-117** | **1.20-1.46** |
| **Oat** | **100** | **17-20** | **114-140** | **131-160** | 1.3-1.6 |
| Corn | 100 | 26-30 | 91-111 | 116-141 | 1.2-1.4 |
| Canola | 35 | 16-20 | 57-69 | 73-89 | 2.10-2.54 |
| Flax | 24 | 13-16 | 26-32 | 39-48 | 1.63-2.00 |
| **Pea** | **50** | **32-39** | **91-111** | **123-150** | **2.46-3.00** |
| Lentil | 30 | 29-36 | 40-48 | 69-84 | 2.30-2.80 |
| Soybean | 30 | 41-42 | 31-90 | 72-132 | 2.4-4.4 |
| **Faba** | **85** | **60-70** | **80-120** | **140-190** | **1.7-2.4** |
| Grass | 1.5 | - | - | 59-72 | 39-48 $K_2O$/ton |
| Alfalfa | 2 tons | - | - | 108-132 | 54-66 $K_2O$/ton |

33rd Annual NATIONAL NO-TILLAGE CONFERENCE
January 7-10, 2025 • Louisville, Ky.

# Mulder Element Relationships

## Potassium or Potash (K)

**For potassium (K), too much calcium, N, or P can decrease K plant availability.**

Excess K: Leads to decreased Boron (B), Indirectly less plant Calcium (Ca).

- Excess Ca, N, P: ↓ K, K Induction with saturated soil.
- Adequate Molybdenum: ↑ K, & N Fixation
- SOM is a storehouse of all plant available nutrients.
- Adequate K enhances Iron (Fe) and Manganese (Mn) plant availability.

# Boron and Calcium

**Boron**: Anion (- charge) **Bus Driver to getting Calcium into the plant** Sands are low in Boron, Most B in cell walls. Critical for germinating seeds.

**Calcium:** Cation (2+) **Activates 146 key plant enzymes.**

5th most abundant element, Available at Neutral pH, Acid soils and excess potassium tie up Calcium.

**Deficiency Symptoms**: **Parallel tracks outside leaf – Boron**

**Parallel tracks inside leaf, leaf necrosis– Calcium**

Ca2+ is immobile in plants. **Look for deficiency in young leaves**.

**Calcium stimulates both growth (auxin hormone) and yield (cytokinin) 85% of calcium absorbed at Pollination. Both ammonium and potassium decrease soil calcium.**

**Gypsum in spring source of Ca & S.**

# Boron and Calcium

**Importance of Calcium**

**Adequate calcium decreases diseases**: powdery mildew, pythium, sclerotina, fusarium, rhizoctonia, leaf and fruit scab –

Defense mechanism signal

Stimulates seed germination, root hairs, root growth and reproduction (pollen)

**Stabilizes plant cell wall** (Tomato Blossom end rot)

**Calcium flocculates clay soil for good aeration**

Really important in fruit quality: Apples

Grain Quality:  Higher Test Weights/Longer Storage.

# Calcium and Boron Deficiency

Aggie-horticulture.tama.edu

Tiger Sul

Boron Deficiency

Calcium Deficiency

# Calcium (Ca) Uptake by Cover Crops

**Calcium is needed by earthworms and mycorrhizae fungi. Radish, sorghum sudan, oats are high in calcium and exchangeable Ca. Most grasses are good sources Ca.**

**Excess Ca = Decreased K, P, Fe, Mn, Zn, B and excess of any of these nutrients decreases Calcium.**

# Boron (B) Uptake by Cover Crops

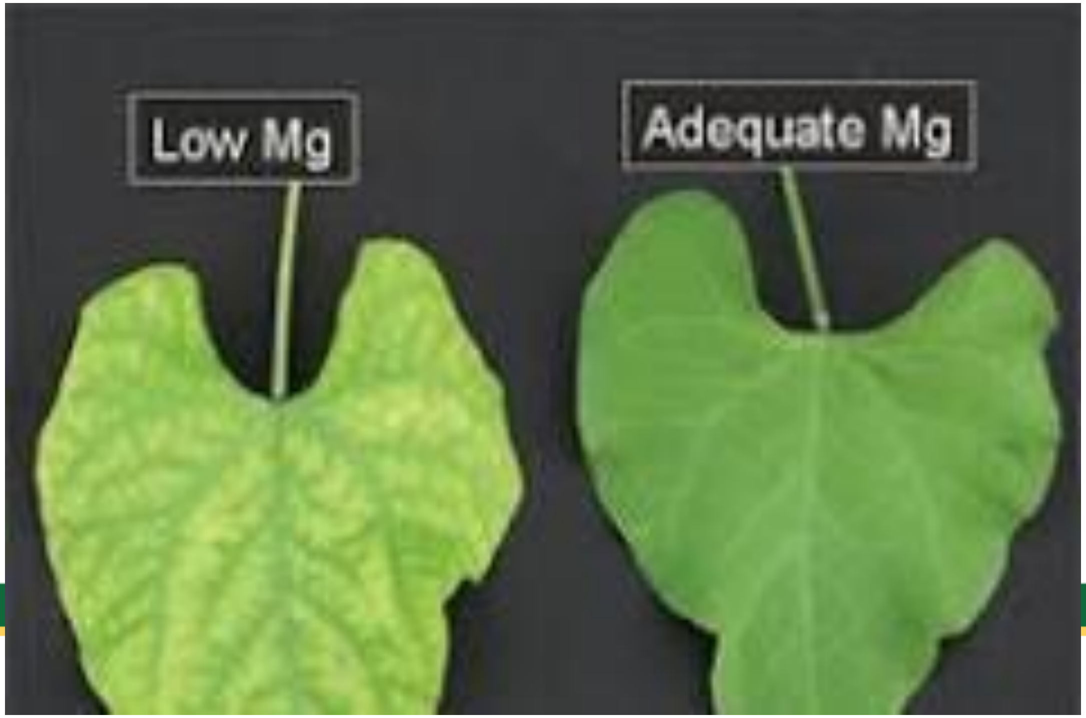
**Legumes, clovers, and brassicas (radish, kale, rape) have the highest concentration of B. B is needed to make N.**

**Legumes: Alfalfa, Hairy Vetch; Winter Peas; Cow Peas**
**Clovers: Balansa, Crimson, Red, White**

**Brassicas: radish, kale, rape**

# Magnesium (Mg) Uptake by Cover Crops

**Magnesium ($Mg^{2+}$) is critical for photosynthesis. Mg is the central element in chlorophyll formation. Mg is often deficient on sandy soils. Magnesium soil recycling is poorly understood!**




**Oats are high in calcium (Ca) and Magnesium (Mg)**

# Sulphur (S)

**Sulphur:** Inorganic forms 10% Organic (Humus) 90%
In 1970's: Acid rain supplied 20-30# S/year. **Need 20# S per acre**. Now only getting LT10# S/year. **Sulphur Deficiency Symptoms**: Yellow or pale green coloring in young leaves.

**For every 10# of N, need 1# of Sulphur!**
**Sulphur is used in critical amino acids: Cysteine, Methionine**
**Sulphur is in key vitamins: Biotin, Thiamine**

Roots take up ($SO4^{2-}$) while leaves can absorb atmospheric S
Sulphur lets proteins form cage like structure to form enzymes.

# Sulphur (S)

Sulfur is an electron donor:  Great Antioxidant in Plant Defense

**Controls excess light, drought, wounds, cold weather, heavy metals**

**Brassicas (radish, turnips) are high in Sulfur.** Slugs can not digest sulfur so may help in slug control. **Also, legumes, clovers with higher protein levels have higher sulfur levels.**

# Sulfur Deficiency

University Lincoln Nebraska


University of Georgia

Hoorman Soil Health Services

# Sulfur Deficiency

Pre-Clean Air Act: 30# S/Acre, Now getting 6-10#S from Air, Need minimum 20#S/A

Quick Example: 60 Bushel Soybean need 17# S/Acre, Assume 2% SOM:
6# S from Air, 2.5# S/1% SOM = 5# S/Acre. Missing about 6# S/acre for optimal yields. From Tony Vyn (Purdue)

On Mulder Chart relationships, N and S are closely related and have similar relationships.

# Iron (Fe)

**Iron:** 4th most abundant nutrient, Reduced forms are plant available.Tied up in High pH soils. Readily available in low pH soils.

**Every 1 unit increase in pH decreases Iron by factor of 1000X. At normal pH, not enough iron in plant available form usually. Needs SOM to chelate iron to make it plant available.**

**Deficiency Symptoms of Iron**: iron chlorosis looks like yellow leaves between dark green veins turning to white leaves and death over time.

**Iron is Central element used in enzyme making chlorophyll.**



Iron is in enzymes associated with energy transfer, **nitrogen reduction and fixation**, and lignin formation.

# Iron (Fe)

Typical Ohio soils have .43% iron.

Soil tests can be misleading! Plants take up reduced and oxidized form of iron but only reduced form ($Fe^{2+}$) is plant available.

Extremely high soil test iron (Fe) indicates soil compaction, poor soil structure. Plant health increases when high Fe levels decrease. Only $Fe^{2+}$ is plant available and iron (Fe) has many chemical valences.

Iron reacts with SOM to make soil P (SRP) available in saturated soil. May account for up to 50% of SRP in soil.

# Iron (Fe) Deficiency: Iron Chlorosis

University of Lincoln Nebraska

University of Georgia

Hoorman Soil Health Services

# Iron (Fe) Tie

**Excess Fe = Decreased P, Ca, Mn, Zn, Cu and vice versa. Excess of any of these elements decrease plant iron (Fe). Glyphosate (Roundup) had negative impact on Fe.**

**Cover crops high in available Fe2+: legumes and clovers that acidify the soil. Fe2+ is more plant available at lower soil pH. Buckwheat, Sweet clover, red clover and oats are best at making Fe2+ plant available.**

# Zinc (Zn)

**Zinc:** Found in inorganic (clay) and organic forms (Humus), Reduced forms (2+) are plant available. Humus has 50% available forms of Zinc.
Tied up in High pH soils. Readily available in low pH soils.

**Deficiency Symptoms of Zinc**: White midrib in corn. About 30% of our soils are zinc deficient. **Zinc is one of the most yield limiting elements in soils and is critical for achieving high yields!**

**Central element used in 300 enzymes many are somewhat redundant.**
**C4 plants (Corn) need zinc for carbon fixation.**

# Zinc (Zn)

Helps with genetic formation of DNA and RNA.
Helps plants survive excess light and high temperatures (drought tolerance.
Activates enzymes when soils are water logged.

**Zinc is deadly to fungus and bacteria. Decreases rhizoctonia fusarium, corn smut, late blight, pythium and increases beneficial pseudomonas microbes (plant growth). Zinc suppresses disease by breaking down disease cell wall.**

What about the fungus tar spot??? Manganese + Zinc decrease.
Fungicide: Mancozeb =Maneb (Manganese) + Zineb (Zinc)
**Iron (Fe) + Copper (Cu) also decrease tar spot.**

**Zicam** – Common cold; COVID -19, taste & smell.

# Zinc (Zn) Deficiency

Maize showing signs of potassium deficiency.

**University of Lincoln Nebraska**

**University of Georgia**

**Excess Zn ties up P, Ca, and Fe and vice versa.**
**Cover crops that make zinc plant available: (milk weed), sunflowers, oats, cereal rye, radish, and also legumes and clovers.**

33rd Annual NATIONAL NO-TILLAGE CONFERENCE
January 7-10, 2025 • Louisville, Ky.

**Sandy soils are often Zn deficient.**

# Copper (Cu)

**Copper**:  Poorly understood. Reduced forms are plant available ($Cu^{2+}$)
Tied up in High pH soils. Readily available in low pH soils.
Acts a lot like iron. **Most abundant in organic residues and least abundant in sandy soil.**

**Deficiency Symptoms of Copper**: Corn brace roots may be a sign of copper deficiency.  Varies by corn variety. Brace roots are bypassing (like heart bypass) around affected area to move critical nutrients into plant. **Excess N, P, Zinc, and Manganese tie up copper.  Only 5% of soil copper is plant available. In no-till fields, can take 2-3 years to mineralize copper.**

# Copper (Cu)

**Central element used in enzyme making cellulose and lignin. Critical for stalk stability and vascular structures.**

Electron transfer to reduce oxygen to form water (O2 to H20). Protein synthesis and Vitamin A needed to improve disease resistance and immune system. Heals wounds. Copper has many beneficial fungicidal properties. Helps with Arthritis.

**Cereal rye, triticale, peas, and canola increase soil copper.**

# Copper (Cu) Deficiency

**University of Georgia** **www.atpnutrition.ca**

**www.alamy.com**

.

**Hoorman Soil Health Services**

# Copper (Cu) Deficiency

**Excess copper (Cu) decreases N, P, and iron (Fe) and vice versa.**

**Molybdenum (Mo-) enhances Cu and vice versa. Adequate copper enhances legume and clover growth and in making N so they tend to be high sources of Cu. Cow peas, winter peas, vetches are good sources. Brassicas like radish and grasses like oats (highly mycorrhizal plants) enhance Cu.**

# Manganese (Mn)

**Manganese: Reduced forms (Mn 2+) are plant available. Chelated or tied up by glyphosate (Roundup).**

**Deficiency Symptoms of Manganese (Mn)**: Magnesium (Mg) competes with Manganese (Mn) for sites. Often deficient in soybeans and limits yields. Yellow streaking, yellow on tips of midrib and between leaves. **Oats makes both iron (Fe) and manganese (Mn) more plant available. Counteracts glyphosate (Roundup).**

# Manganese (Mn)

**Importance of Manganese (Mn): Activates 36 enzymes. Splits water molecule (2H20) into oxygen (O2) and hydrogen (2H2).**
Reduces oxygen free radicals.
Needed for carbon dioxide fixation in C4 (corn) plants.
**Manganese accelerates germination and maturity while increasing the availability of phosphorus (P) and calcium (Ca).**
**Decreases most fungus and bacterial diseases but may increase virus diseases.**

# Manganese (Mn) Deficiency

University of Georgia

University of Lincoln Nebraska

Excess Mn decreases Ca, iron (Fe), and Copper (Cu), Zinc (Zn), nickel (Ni) and vice versa. Adequate Mn increases K and vice versa. Glyphosate (Roundup) decreases Mn.

Best cover crops for higher plant Mn are oats (AMF), cereal rye, barley, sorghum sudan, and radish and legumes (peas and beans).

# Molybdenum (Mo)

**Molybdenum (Mo):** Anion **(-).** **Enzyme co-factor needed for nitrogen metabolism.**
Activates nitrogen reductase, needs iron and molybdenum to convert nitrate to nitrite and then ammonia. Most available in high pH soils.

**Deficiency Symptoms of Molybdenum (Mo)**: Looks like Nitrogen and Sulfur deficiency.
**Importance of Molybdenum**
Influences legume plant growth and nodule formation and involved in nitrogen metabolism.
Decreases Phytophthora, nematodes, and decreases sprouting in stored grains.  Deactivates virus and proteins.

# Cobalt (Co) & Nickel (Ni)

**Cobalt:** **Used in N fixation in soybeans and legumes. If cobalt is deficient, can increase soybeans yields 3X. Activates urease enzyme!!**

**Cobalt deficiency symptoms:** Pale yellow leaves.

**Nickel (Ni):** **Needed to active Urease enzyme**. Critical for adequate N fertilization in converting urea to ammonia and carbon dioxide.

# Molybdenum (Mo-) Deficiency

Tiger Sul

www.atpnutrition.ca

# Molybdenum (Mo-) Deficiency

**Molybdenum (Mo-) deficiency is difficult to diagnosis but is often a source of plant hidden hunger. Mo- is most available in high pH soils and least available in low pH soils. Adequate Mo- enhances N and Copper (Cu uptake). Lime (calcium oxide) tends to enhance Mo- availability but may limit uptake of other soil nutrients if pH gets too high. Acid and sandy soils are low in Mo- plant availability.**

**All legumes and clovers tend to be higher in plant available Mo-, Cobalt (Co) and nickel (Ni). Oats can also increase micro-nutrient availability. Buckwheat also increases Ni availability.**

# Silica

**Silica:** Poorly understood and not well studied. Organic Silica is plant available. Silica is quite abundant in soils: Sand, Silt, Clay. Most abundant in organic residues and least abundant in sandy soil.

**Did you know?**

1) Many plants have higher concentration of silica than N & K!
2) Silica is needed for optimal plant health.

# Silica (Si)

**Benefits of Silica (Si):**

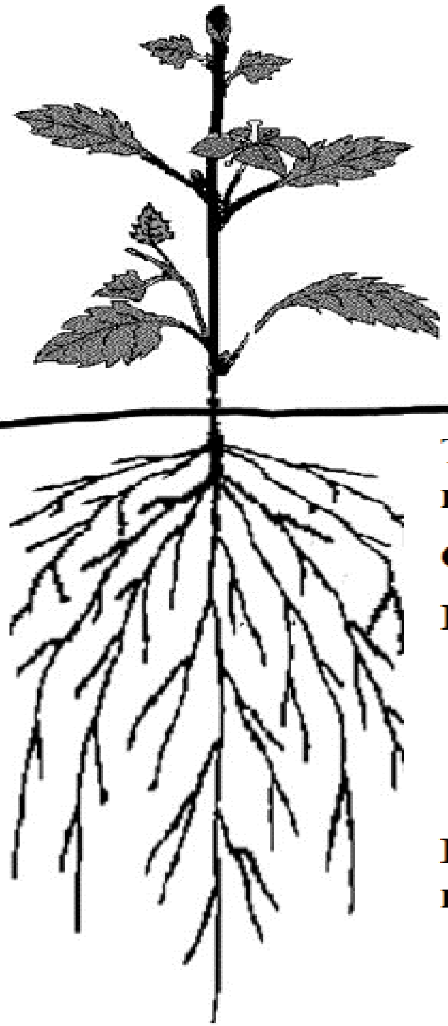
1) Stronger cell walls, bigger stems and vascular structures
2) Increased resistance to environmental stress
   a) Improves plant performance when hot and dry
   b) Improves frost tolerance (cold weather)
   c) Less Disease: Pythium, Powdery Mildew
   d) Less Pathogens & Insects due to rigid cells.
3) Increases metabolic function
   a) Increased Plant Magnesium (Mg) and chlorophyll
4) Liquid clear organic silica without dyes and not chalky are best (foliar sprays).
5) Increases Drought and cold (freezing) tolerance.

# Major Crop Nutrients

- **<u>Growth Nutrients</u>: $NO_3^-$, $K^+$, $Cl^-$, Auxin in leaf tips**
- **<u>Yield Nutrients</u>: $NH_4^+$, P, $Mn^{2+}$, Cytokinin in Root tips, delays plant maturity**
- **<u>Growth and Yield Nutrients</u>: $Ca^{2+}$**

- Apply gypsum (calcium sulfate, mined) at 200-300 pounds/A 30-40 days before blooming or tasseling.
- 90% of calcium is taken up at pollination and grain fill.
- Add compost or manures which are high in micronutrients to optimize yield.

# Glyphosate Impacts



Foliar application of glyphosate

Systemic movement throughout the plant

Chelation of micronutrients

Intensified drought stress

Accumulation of glyphosate in meristematic tissues (shoot, reproductive, and root tips).

Translocation of glyphosate from shoot to root and subsequent release into the rhizosphere

Glyphosate accumulates in soil
(not biodegraded - co-metabolism)
Glyphosate desorbed from soil by P

Glyphosate toxicity to:
- N-fixing microbes
- Bacterial shikimate pathway
- Mycorrhiza
- Mn & Fe reducing organisms
- Biological control organisms
- Earthworms
- PGPR organisms

Toxicity to root tips by glyphosate or its toxic metabolites (e.g. AMPA)

Compromise of plant defense mechanisms

Promotion of:
- Soilborne plant pathogens
  (*Fusarium*, *Pythium*, *Rhizoctonia*, etc.)
- Nutrient oxidizers (Mn, Fe, N)
- Microbial nutrient sinks (K, Mg)

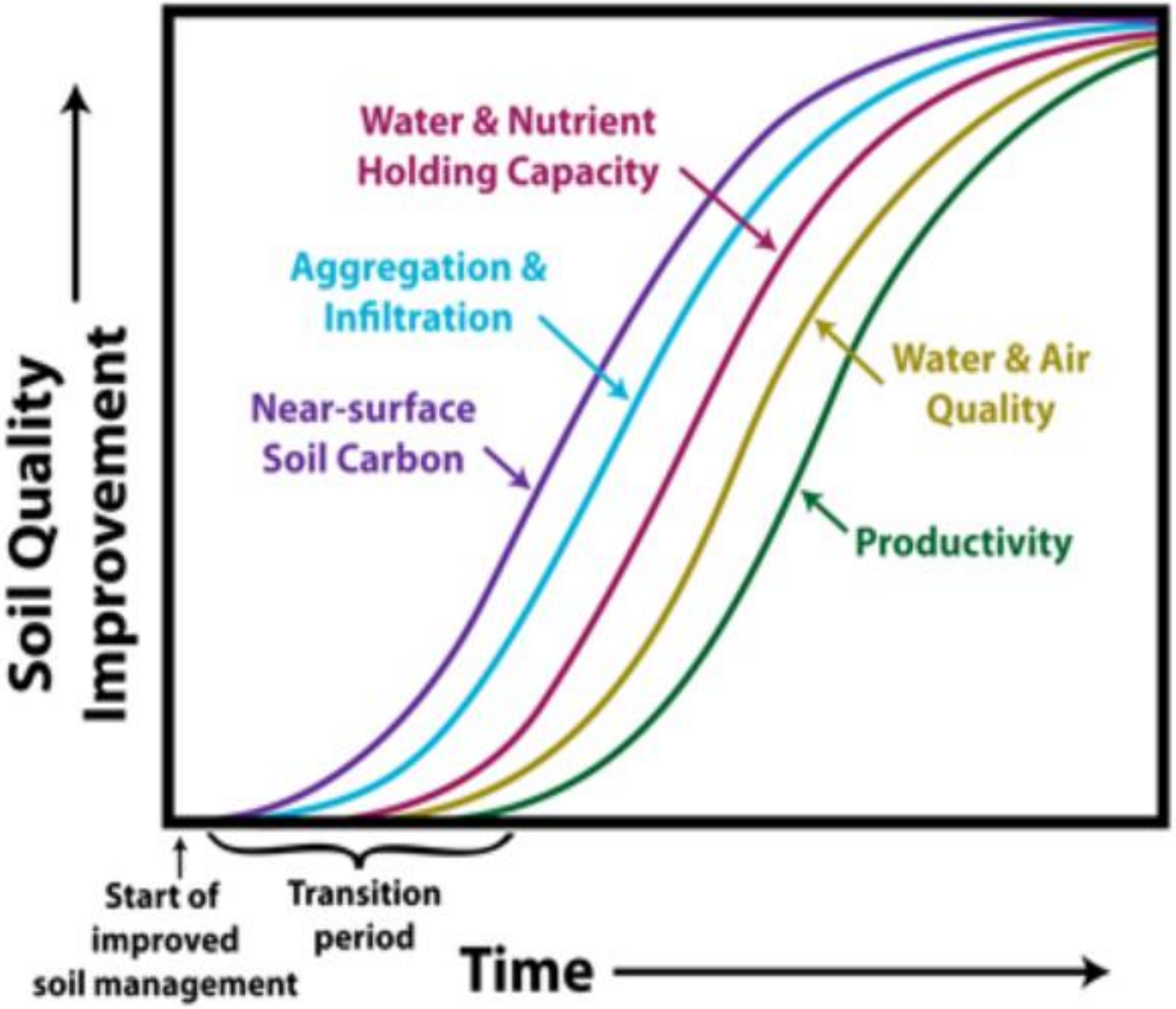
Reduced availability or uptake of essential nutrients (Cu, Fe, K, Mg, Mn, N, Ni)

Schematic of glyphosate interactions in soil

Proceedings Fluid Fertilizer Forum, Scottsdale, AZ February 14-16, 2010. Vol. 27.
Fluid Fertilizer Foundation, Manhattan, KS.

# Soil Health Improvement

**Soil Microbes make nutrients plant available.**
**Each microbe is a soluble bag of fertilizer.**




**Soil Health is a Journey that takes some Time to Succeed!**

**Fix soil compaction first, then build SOM & microbes**

# Digging Deep into Nutrient Content & Function

James J. Hoorman
Hoorman Soil Health Services

Hoormansoilhealthservices@gmail.com
419-421-7255