Mineral Nutrition and Plant Health - II
Managing Nutrition to Control Plant Disease

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Tough Love Alternative to Spanking

When it comes to child discipline, most of us are looking for positive alternatives to spanking.

One that worked well when our child was having "one of those moments" was to take them for a car ride.

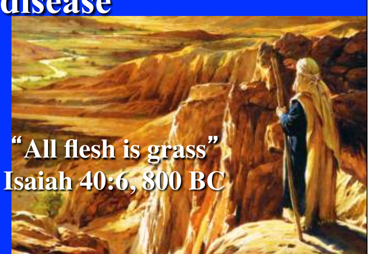
Some say it's the vibration from the car; others that its the time away from distractions such as TV, etc.

Either way, our kids usually calm down and behave after our car ride together.

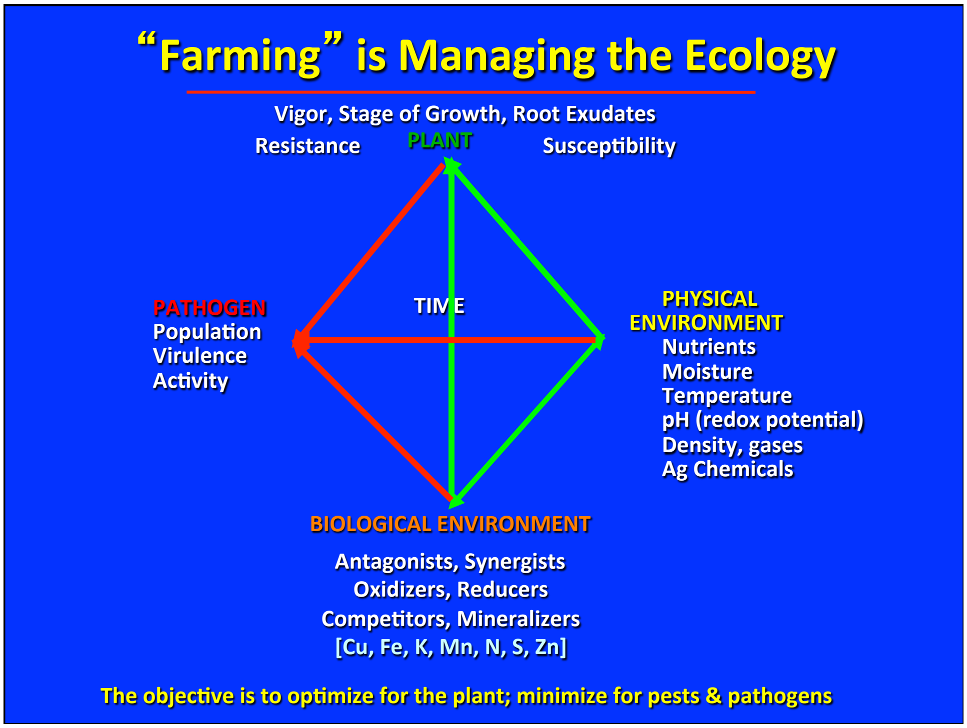
Eye-to-eye contact helps a lot too as you can see fr one of our sessions.

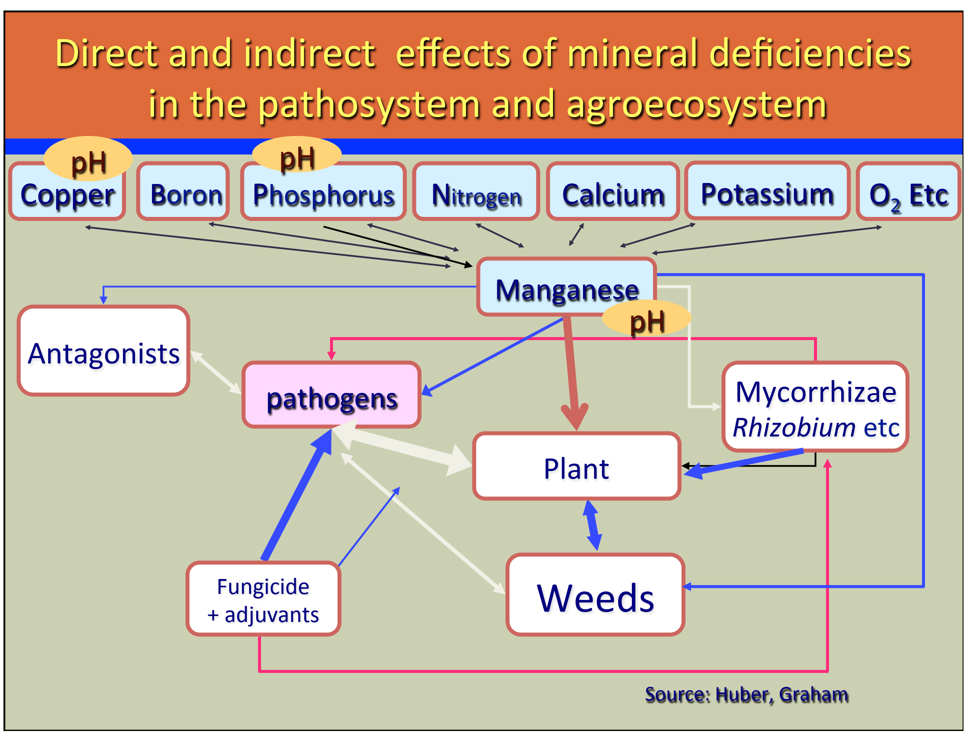
Nutrition and Plant Health

- Background
- Recognizing the interactions
  - Symptoms - nutrition, disease
- Keys to using nutrition to control disease
  - Genetic efficiency
  - Nutrient form
  - Nutrient rate
  - Time and method applied
  - Source
  - Integration with farm operations

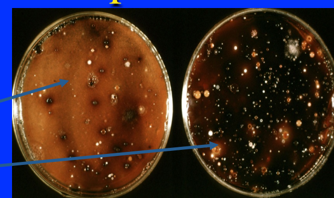


- Glyphosate and GMO impact on nutrition and disease: Failed promises; Flawed science
- Summary and Conclusions


"Farming" is Managing the Ecology
Vigor, Stage of Growth, Root Exudates
Resistance
PLANT
Susceptibility
PATHOGEN
Population
Virulence
Activity
TIME
PHYSICAL ENVIRONMENT
Nutrients
Moisture
Temperature
pH (redox potential)
Density, gases
Ag Chemicals
BIOLOGICAL ENVIRONMENT
Antagonists, Synergists
Oxidizers, Reducers
Competitors, Mineralizers
[Cu, Fe, K, Mn, N, S, Zn]
The objective is to optimize for the plant; minimize for pests & pathogens


Direct and indirect effects of mineral deficiencies in the pathosystem and agroecosystem
pH
Copper
Boron
pH
Phosphorus
Nitrogen
Calcium
Potassium
O_2 Etc
Manganese
pH
Antagonists
pathogens
Mycorrhizae
Rhizobium etc
Plant
Fungicide
+ adjuvants
Weeds
Source: Huber, Graham

Take-all and Populations of Mn-oxidizing Rhizosphere Bacteria



Mn Availability & Biological Activity

pH: **5.2** ⟷ **7.8**

Biological Activity

Mn form: Mn^{2+} → Mn^{+4}

Available: **Yes** → **No**

Dynamics of the Ag Production System When Managing the Ecology

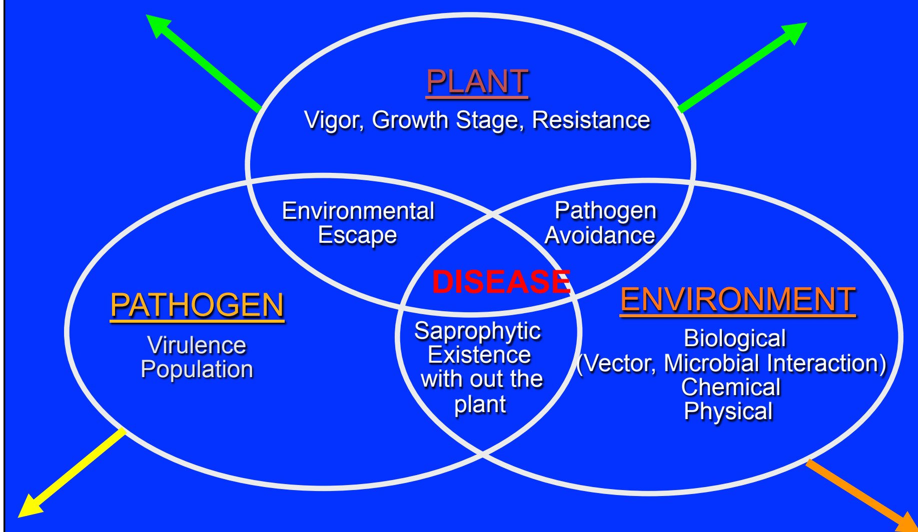
1. Inter-related genetics, growth, environment
2. Balance in rate, ratios, timing, substitutions
3. Modify the interactions – biology, physical, chemical
4. Why disease

   Favorable environment

   Susceptible crop

   Virulent pathogen (-vector)

The Interaction of Three Factors Over Time Determines if a Disease will be Latent or Severe



Plant Disease

"The inability to perform physiological functions to its full genetic potential"

Resistance

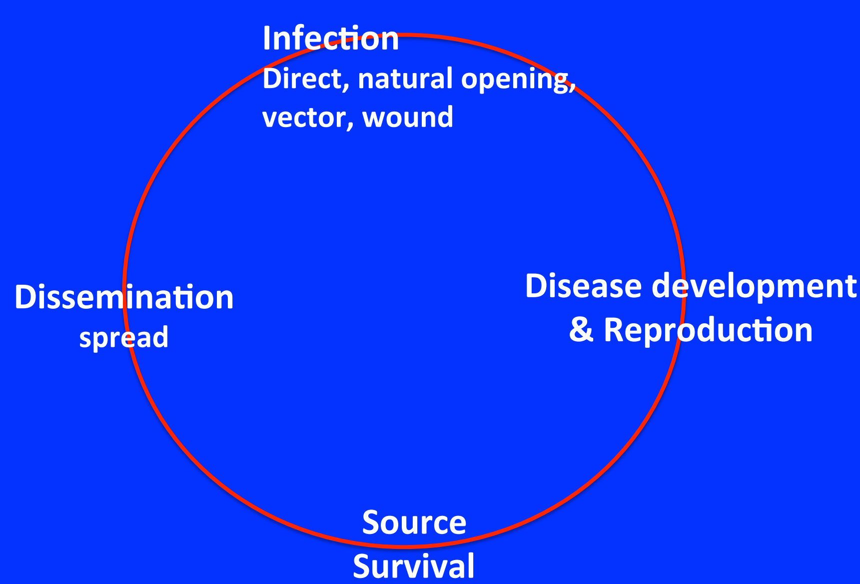
- Physical – impenetrable
  Cell thickness, walling off, water barrier
- Physiological – Preformed or active inhibitors
  Amino cmpd, glycoproteins, phytoalexins,etc.
- Immunity – 'No response'
  Lack of nutritional support – reducing sugars vs sucrose

Understanding the Interactions

- **Immunity = Absence of disease**
  Pathogen present but no infection
- **Escape = Avoidance of disease**
  Pathogen or environment not conducive for infection
- **Resistance = Restriction in pathogenesis**
  Plant resists the pathogen
- **Tolerance = Productivity in spite of infection**
  Plant produces new roots to compensate

  Susceptibility → Tolerance → Resistance
- **Epidemic = Extensive area of disease development**
- **Predisposition = Conditions increasing disease severity**

Disease Cycle



Pathogen Dissemination

- **Pathogens**
  Bacteria, fungi, viruses, nematodes, (parasitic plants)
- **Vectors:**
  Insects, nematodes, fungi, Man/animals
- **Dissemination:**
  Seeds, plant parts = Bacteria, fungi, viruses, nematodes
  Wind = Bacteria, fungi, vectors
  Water = Bacteria, fungi, nematodes, viruses
  Vectors = Viruses, bacteria, fungi
  Man/animals = all

Disease Effects Nutrition

- **Availability**
  Immobilization (sink, form)
  Nutrient balance
  Toxicity
- **Uptake**
  Root rots, blights
  Nutrient balance
- **Distribution**
  Wilts, plugs, sinks, necrosis
- **Function**
  Necrosis, toxins, plugging, viruses
- **Loss**
  Rots, blights, theft, sinks

Nutrient Mechanisms that Reduce Disease

- **Increased plant resistance**
  Physiology, inhibitors
  Defenses - callous, cicatrix, etc.
- **Disease escape, tolerance**
  Increased root, leaf growth
  Shorter susceptible stage
  Compensate for disease damage
- **Modify the environment**
  Ph, other nutrients
  Rhizosphere biology interactions
- **Inhibit pathogen activity**
  Reduced virulence, survival
  Biological control and growth

Disease Control

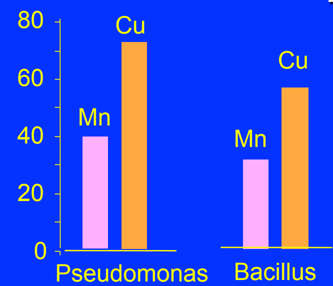
- Resistance
  Genetic (+ nutrition, environment, chemical)
- Exclusion
  Quarantines, Pathogen free 'seed'
- Suppression
  Biological (crop sequence/rotation), nutrition, environment, chemical, physical (heat, radiation, solarization, drying)
- Eradication
  Chemical, crop rotation, biological
- Integrated management (IPM)

Plant Defenses

- No response
  No chemical receptors, nutritional support, ?
- Pre-existing structural or chemical defenses
  Phenolics, glycoproteins, suberized tissues, etc.
- Induced structural or chemical defenses
  Phenolics, phytoalexins, cork/callous/tyloses/gums, glycopeptides, hypersensitive response, SARs, glycopeptides, siderophores,etc
- Germination inhibitors
  Germination inhibitors, stimulants
- Cross protection
  Viral protection

Disease as a Symptom of Deficiency

- **Take-all:** manganese (Huber, Thompson)
- **Stem melanosis, ergot, take-all:** copper (Evans)
- **Ergot, root rot fungi, damping-off :** Mn, B, Cu (Comeau, Evans)
- **Fusarium head blight:** worse in low Copper (Franzen et al.)
- **Verticillium wilt and common scab of potatoes:** Mn, NH_4

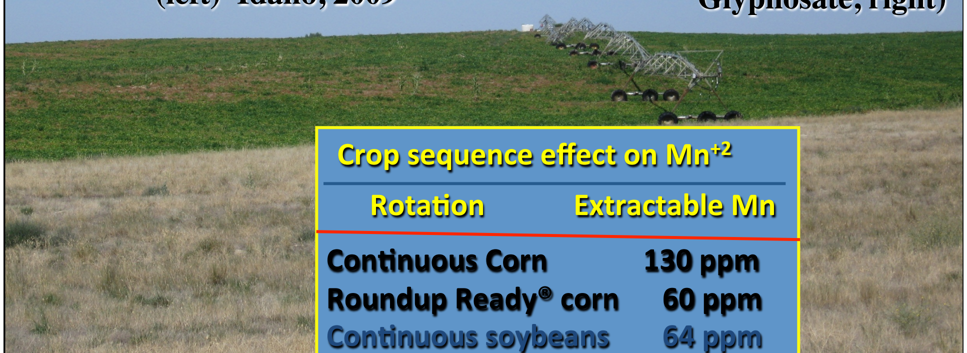


Taken up in 90 hours from hydroponics solutions by wheat rhizosphere bacteria
After Voss 2001

Effects of Crop Sequence and Glyphosate

Severe Verticillium wilt after 1 year of RR corn (left) Idaho, 2009

Mild Verticillium after wheat (no Glyphosate, right)



Crop sequence effect on Mn^{+2}

Rotation	Extractable Mn
Continuous Corn	130 ppm
Roundup Ready® corn	60 ppm
Continuous soybeans	64 ppm
Soybean, wheat, corn	91 ppm
Wheat, corn, soybean	79 ppm

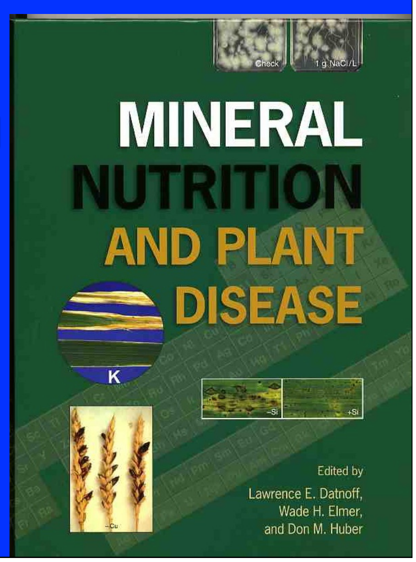
Reported* Effects of Nutrients on Disease

	Disease is:			
Mineral element	Decreased	Increased	Variable	Total
Nitrogen ($N/NH_4/NO_3$)	168	233	17	418
Phosphorus (P)	82	42	2	126
Potassium (K)	144	52	12	208
Calcium (Ca)	66	17	4	87
Magnesium (Mg)	18	12	2	32
Manganese (Mn)	68	13	2	83
Copper (Cu)	49	3	0	52
Zinc (Zn)	23	10	3	36
Boron (B)	25	4	0	29
Iron (Fe)	17	7	0	34
Sulfer (S)	16	3	0	19
Other (Si, Cl, etc.)	71	6	8	85

*Based on 1,200 reports in the literature

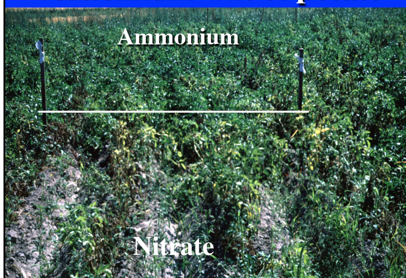
Nutrition Changes the Host Environment for Disease Control

- Specific nutrients
- Form of nutrient - esp. N
- Time applied
- Rate applied
- Nutrient interactions
- Herbicide interactions
- Disease severity



Implications of Nutrition in Disease

Verticillium wilt of potato



Rhizoctonia winter-kill of wheat

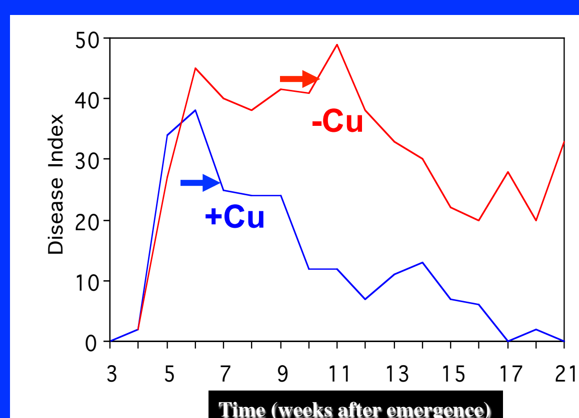
1. Observed effects of nutrient amendment on disease severity
2. Comparison of plant tissue levels of resistant and susceptible plants
3. Comparison of plant tissue levels of diseased and non-diseased plants
4. Association of conditions Affecting a specific nutrient with differences in disease
5. A combination of the above

Effect of Copper on Two Wheat Diseases

Treatment	Grain yield (bu/a)	Ergot per acre
Check	13.3	17,743
10 kg/ha Cu	42.0	2,420

After Evans, 2004

Effect of soil-applied copper on powdery mildew of wheat*



*After Graham and Webb, 1991

Mineral Content of Caster Bean Leaves Relative to Susceptibility to Botrytis

(after Thomas and Orellana, 1964)

Cultivar	Ca	Mg	Na	K
Resistant	122	21	3.2	16.1
Susceptible	38	13	8.1	224.0

Factors Affecting N Form, Mn Availability & Some Diseases*

Soil Factor or Cultural Practice	Effect on: Nitrification	Mn Availability	Disease Severity
Low Soil pH	Decrease	Increase	Decrease
Green Manures(some)	Decrease	Increase	Decrease
Ammonium Fertilizers	Decrease	Increase	Decrease
Irrigation (some)	Decrease	Increase	Decrease
Firm Seed bed	Decrease	Increase	Decrease
Nitrification Inhibitors	Decrease	Increase	Decrease
Soil Fumigation	Decrease	Increase	Decrease
Metal Sulfides	Decrease	Increase	Decrease
Glyphosate	----	Decrease	Increase
High Soil pH	Increase	Decrease	Increase
Lime	Increase	Decrease	Increase
Nitrate Fertilizers	----	Decrease	Increase
Manure	Increase	Decrease	Increase
Low Soil Moisture	Increase	Decrease	Increase
Loose Seed bed	Increase	Decrease	Increase

*Potato scab, Rice blast, Take-all, Phymatotrichum root rot, Corn stalk rot

Nutrient Mechanisms that Reduce Disease

- Increased plant resistance
  - Physiology, inhibitors
  - Defenses - callous, cicatrix, etc.
- Disease escape, tolerance
  - Increased root, leaf growth
  - Shorter susceptible stage
  - Compensate for disease damage
- Modify the environment
  - Ph, other nutrients
  - Rhizosphere biology interactions
- Inhibit pathogen activity
  - Reduced virulence, survival
  - Biological control and growth

Physiologic Roles of Manganese

Mn CHO

Photosynthesis

Glycolysis (energy reactions)

Mn

Shikimic Acid

Carbohydrate, hormone &

Mn

Root Growth

Amino Acid Synthesis

Amino Acids

Mn

Cyanogenic

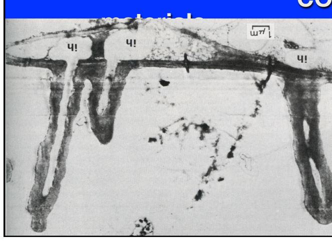
Glycosides

Phenylalanine ammonia-lyase

Mn

Cu

COUMARINS LIGNINS FLAVANOIDS = Defense



"Lignituber" formed in response to cell Penetration.

Wheat

Triticale

(After Skou, 1975)

Some Diseases Influenced by Magnesium

Plant	Disease	Causal agent	Mg effect
Bean	Root rot	*Rhizoctonia solani*	Decrease
Carnation	Wilt	*Fusarium oxysporum*	Decrease
Caster bean	Leaf spot	*Botrytis* spp.	Decrease
Cereals	Leaf/stem rusts	*Puccinia* spp.	Increase
Cotton	Bacterial blight	*Xanthomonas malvacearum*	Decrease
Cotton	Damping-off	*Rhizoctonia solani*	Decrease
Cotton	Root rot	*Phymatotrichum omnivorum*	Increase
Cotton	Wilt	*Fusarium oxysporum*	Decrease
Crucifers	Club root	*Plasmnodiophora brassicae*	Decrease
Grapevine	Die-back	*Eutypa lata*	Decrease
Maize	Southern leaf blight	*Bipolaris maydis*	Increase
Peanut	Pod rot	*Fusarium/Pythium/Rhizoctonia*	Increase
Pepper	Bacterial spot	*Xanthomonas vesicatoria*	Increase
Poppy	Downy mildew	*Peronospora arborescens*	Decrease
Potato	Gangreen	*Phoma exigua* var. *foveata*	Decrease
Potato	Soft rot	*Erwinia carotovora*	Decrease
Rice	Leaf spot	*Helminthosporium* spp.	Decrease
Rice	Panicle blast	*Pyricularia grisea*	Increase
Rye	Stalk smut	*Urocystis occulta*	Increase
Soybean	Root rot	*Rhizoctonia solani*	Decrease
Soybean	Twin stem	*Sclerotium* spp.	Increase
Tomato	Bacterial spot	*Xanthomonas vesicatoria*	Increase
Wheat	Flag smut	*Urocystis tritici*	Increase

Some Diseases Influenced by Sulfur

Host Plant	Disease	Effect of S
Cereals	Stem rust, stripe rusts	Increase
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

The Effect of Sulfur on the PATHOGEN

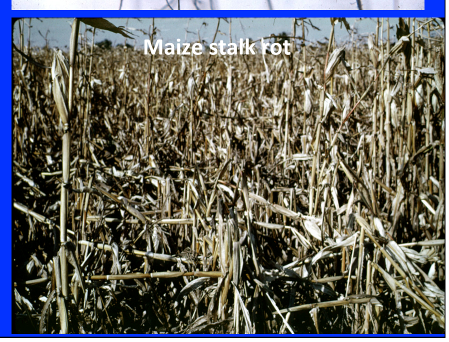
- **Sulfur Compounds are Applied:**
  - **Preplant** - seed or soil treatments
  - **During plant growth** - foliage and fruit spra
  - **Post harvest** - dips, sprays, fumigants
  - **Greenhouse** – sublimed or gas
- **Some Sulfur compounds used**
  - Inorganic sulfur compounds
    - Sulfur, sulfur 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

The Abiotic Environment affects Nutrients - pH

High pH Diseases

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



Keys to Using Nutrition to Manage Disease

1. Genetics of the Plant
2. Nutrient Form or Availability
3. Rate Applied or Available
4. Method and Time Applied
5. Source of Element & Associated Ions
6. Integration with other practices

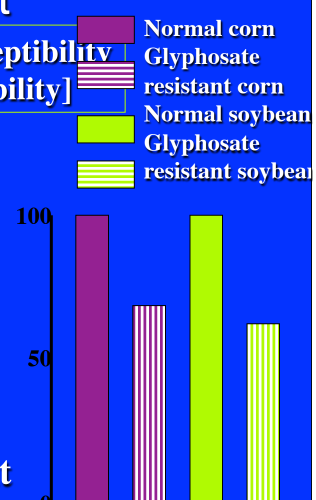
Keys to Using Nutrition to Manage Disease

1. Genetics of the Plant

Immunity<-->Resistance<-->Tolerance<-->Susceptibility
[Nutrient uptake efficiency, nutrient availability]

Mn efficient Mn inefficient

- Stage of growth
- Age
- Health
- Environment



Effect of the glyphosate resistance gene on Mn uptake efficiency

Response of Barley Genotypes to N and Leaf Blotch (*Rhynchosporium secalis*)

(after Jenkyn, 1976)

Cultivar	N rate (kg/ha)		
% leaf area infected	0	66	132
Proctor (R)	0.4	1.3	4.5
Cambrinus (T)	15.4	21.3	30.5
Deba Abed (S)	3.6	20.5	57.3

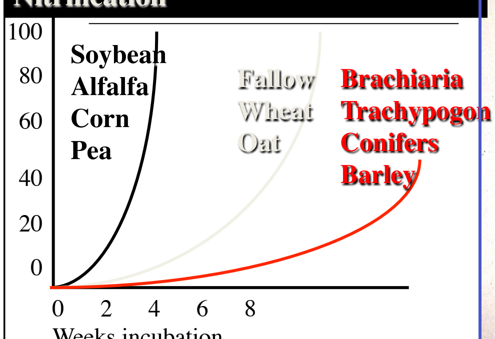
Keys to Using Nutrition to Manage Disease

2. Nutrient Form or Availability

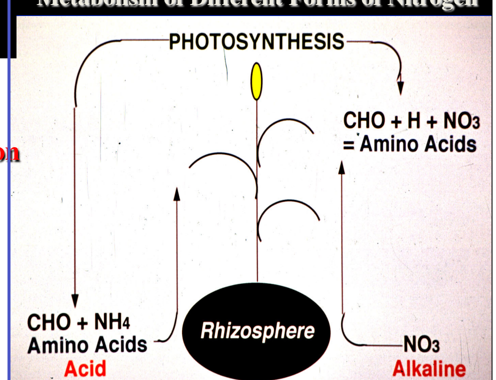
Oxidized<-->Reduced, Soluble<-->Non-soluble

Nitrogen, Iron, Manganese, Sulfur

Effect of Crop Residues on Nitrification



Metabolism of Different Forms of Nitrogen



Some Diseases Decreased by NO_3-N & alkaline pH

Crop	Disease	Pathogen
Asparagus	Wilt	*Fusarium oxysporum*
Bean (*P. vulgaris*)	Chocolate spot	*Botrytis*
	Foot and hypocotyl rot	*Fusarium solani*
		Rhizoctonia solani
Beet	Damping-off	*Pythium* spp.
Cabbage	Club root	*Plasmodiophora brassica*
	Yellows	*Fusarium oxysporum*
Celery	Yellows	*Fusarium oxysporum*
Cucumber	Yellows	*Fusarium oxysporum*
Pea (*Pisum sativum*)	Damping-off	*Rhizoctonia solani*
Pepper	Wilt	*Fusarium oxysporum*
Potato	Stem canker	*Rhizoctonia solani*
Tomato	Gray mold	*Sclerotina* spp.
	Sclerotium blight	*Sclerotium rolfsii*
	Wilt	*Fusarium oxysporum*
Wheat	Eye spot	*Pseudocercosporella herpotrichoides*

Some Diseases Decreased by NH_4-N & acid pH

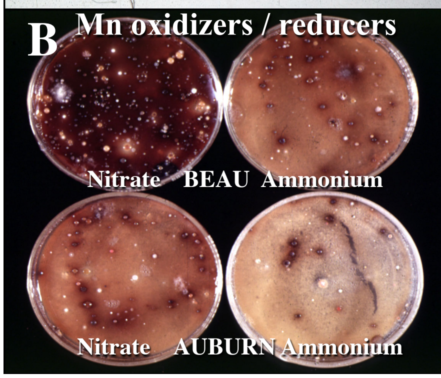
Crop	Disease	Pathogen
Bean *(P. vulgaris)*	Root rot	*Thielaviopsis basicola*
	Root knot	*Meloidogyne*
Carrot	Root rot	*Sclerotium rolfsii*
Corn	Stalk rot	*Gibberella zeae*
EggPlant	Wilt	*Fusarium oxysporum*
Onion	White rot	*Sclerotium rolfsii*
Pea	Root rot	*Pythium* spp.
Potato	Scab	*Streptomyces scabies*
	Wilt	*Verticillium dahliae*
	Virus	*Potato virus x*
Rice	Blast	*Pyricularia grisea*
Tomato	Southern wilt	*Pseudomonas solanacearum*
	Anthracnose	*Colletotrichum* spp.
	Wilt	*Verticillium dahliae*
	Virus	Potato virus x
Wheat	Take-all	*Gaeumannomyces graminis*

Effect of N form & inhibiting nitrification on Take-all and rhizosphere Mn oxidizers

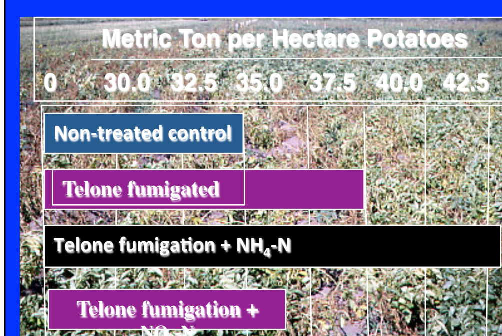
A. N form on Take-all

B. Manganese oxidizers

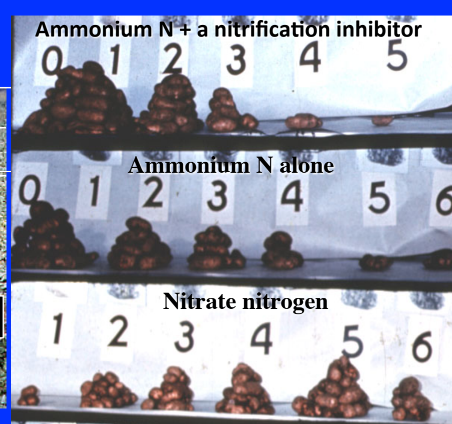
C. -/+ Nitrification inhibitor



Effect of N Form on Yield of *Verticillium* Infected Potato



Effect of Inhibiting Nitrification on Potato Scab

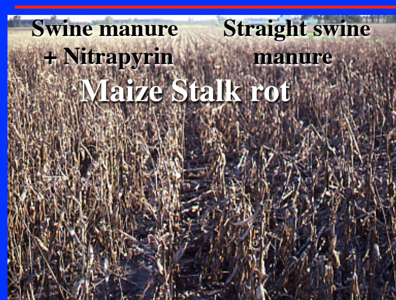


Disease scale: 0=no surface scab, 2=10% surface scab, 6=30% scab.

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

Effect of N source & Inhibiting Nitrification on Stalk Rot of Corn



# of Trials	Nitrogen Source	% Stalk Rot N	% Stalk Rot N+Inhibitor
6	NH3	38	16
4	Manure	54	23

Spring versus Fall application of manure