The Role of Nitrogen and Sulfur on Plant Disease Incidence and Resistance

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potafos

Tecnologia para Agricultura

SIMPÓSIO SOBRE

RELAÇÕES ENTRE NUTRIÇÃO MINERAL E INCIDÊNCIA DE DOENÇAS DE PLANTAS

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The Role of Nitrogen and Sulfur on Plant Disease Incidence and Resistance

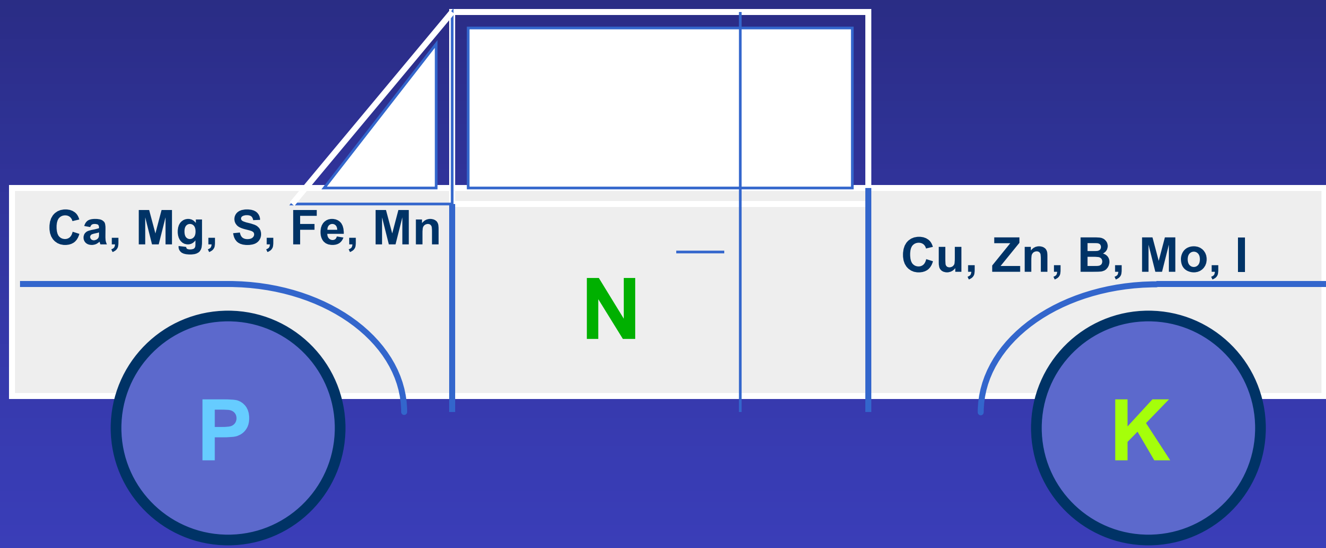
- Background
- Disease in the agricultural production system
- Considerations for using nutrition in disease control
  - Plant genetics
  - Nutrient form
  - Rate applied
  - Method and time applied
  - Nutrient source and associated ions
  - Integration with other practices
- Mechanisms for nutrient control of disease
- Modifying nutrition to control disease

Reported* Effects of Nutrients on Disease

Mineral element	Disease is: 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

EACH ELEMENT FUNCTIONS AS PART OF A DELICATELY BALANCED INTERDEPENDENT SYSTEM WITH THE PLANT'S GENETICS AND THE ENVIRONMENT

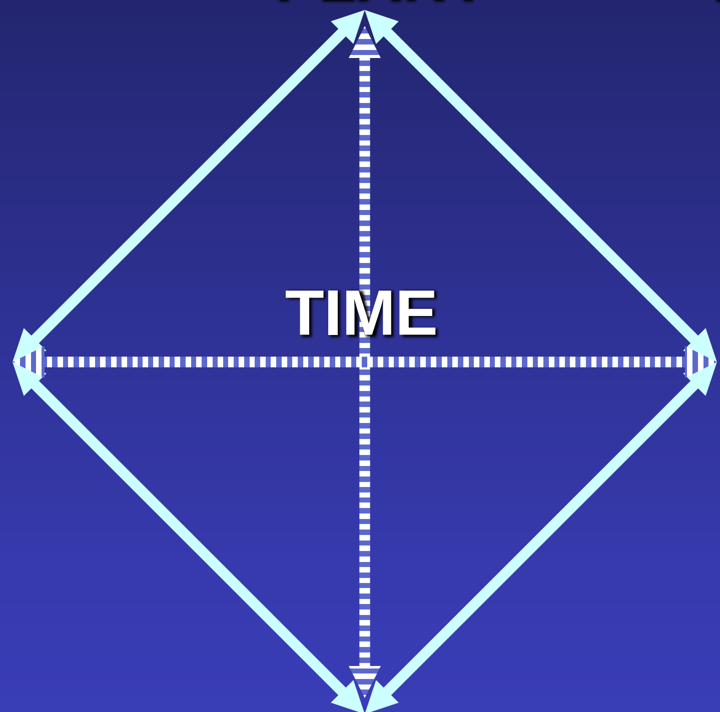


Nutrient Balance is Important

INTERACTING FACTORS DETERMINING DISEASE SEVERITY

Vigor, Stage of Growth, Root Exudates

Resistance **PLANT** Susceptibility



PATHOGEN

Population
Virulence
Activity

ABIOTIC ENVIRONMENT

Nutrients
Moisture
Temperature
pH (redox potential)
Density, gases

BIOTIC ENVIRONMENT

Antagonists, Synergists
Oxidizers, Reducers
Competitors, Mineralizers
[Fe, Mn, N, S]

Biotic Environment

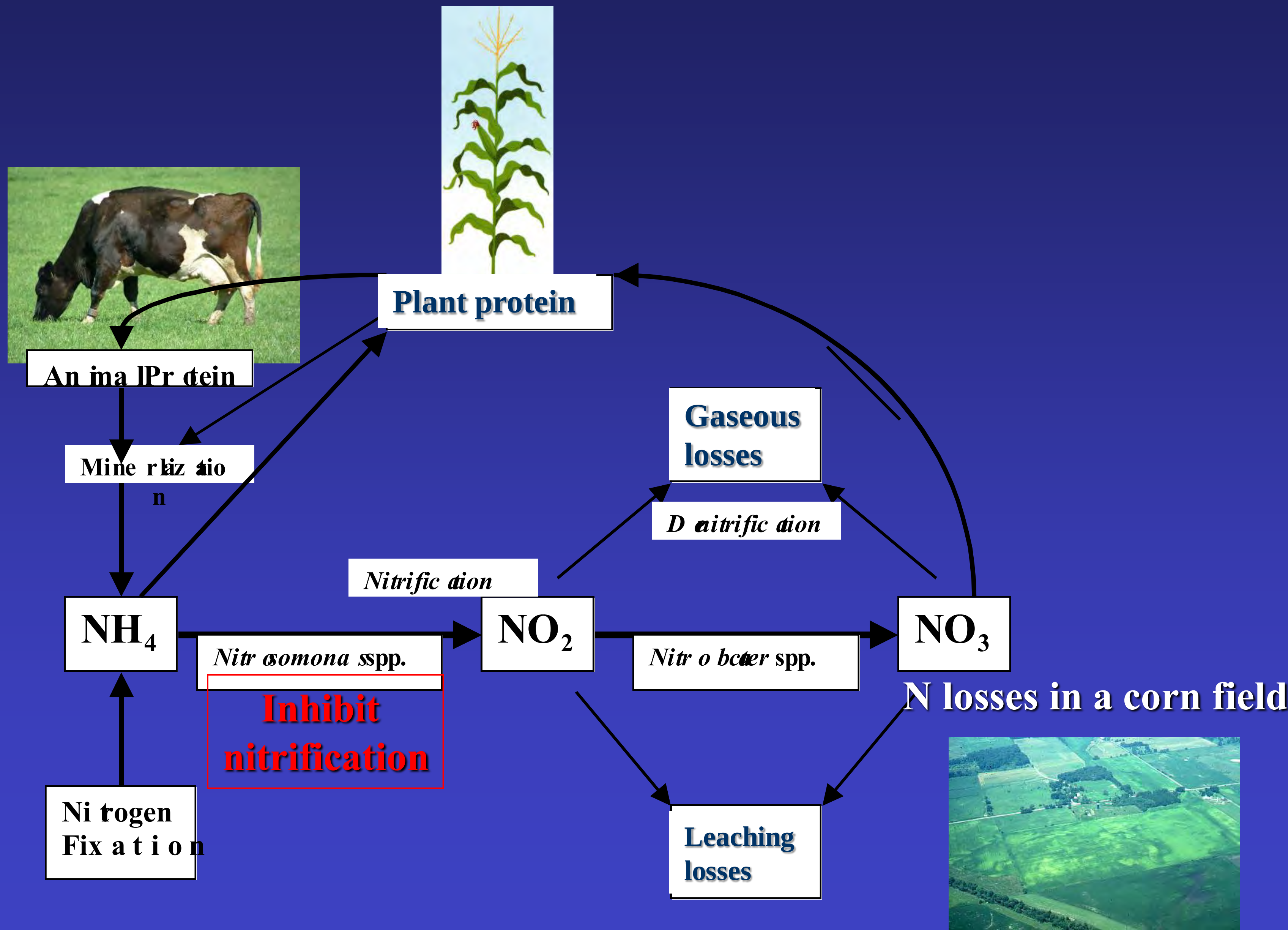
- Indirect effect on disease
  - Previous cropping (rotation)
    - Soil tilth, microbial balance, weed control, organic matter, etc.
  - Microbial activity:
    - Mineralization, oxidation-reduction, nutrient immobilization

- Direct effect on disease
  - Pathogen
  - Synergists
  - Biocontrol organisms

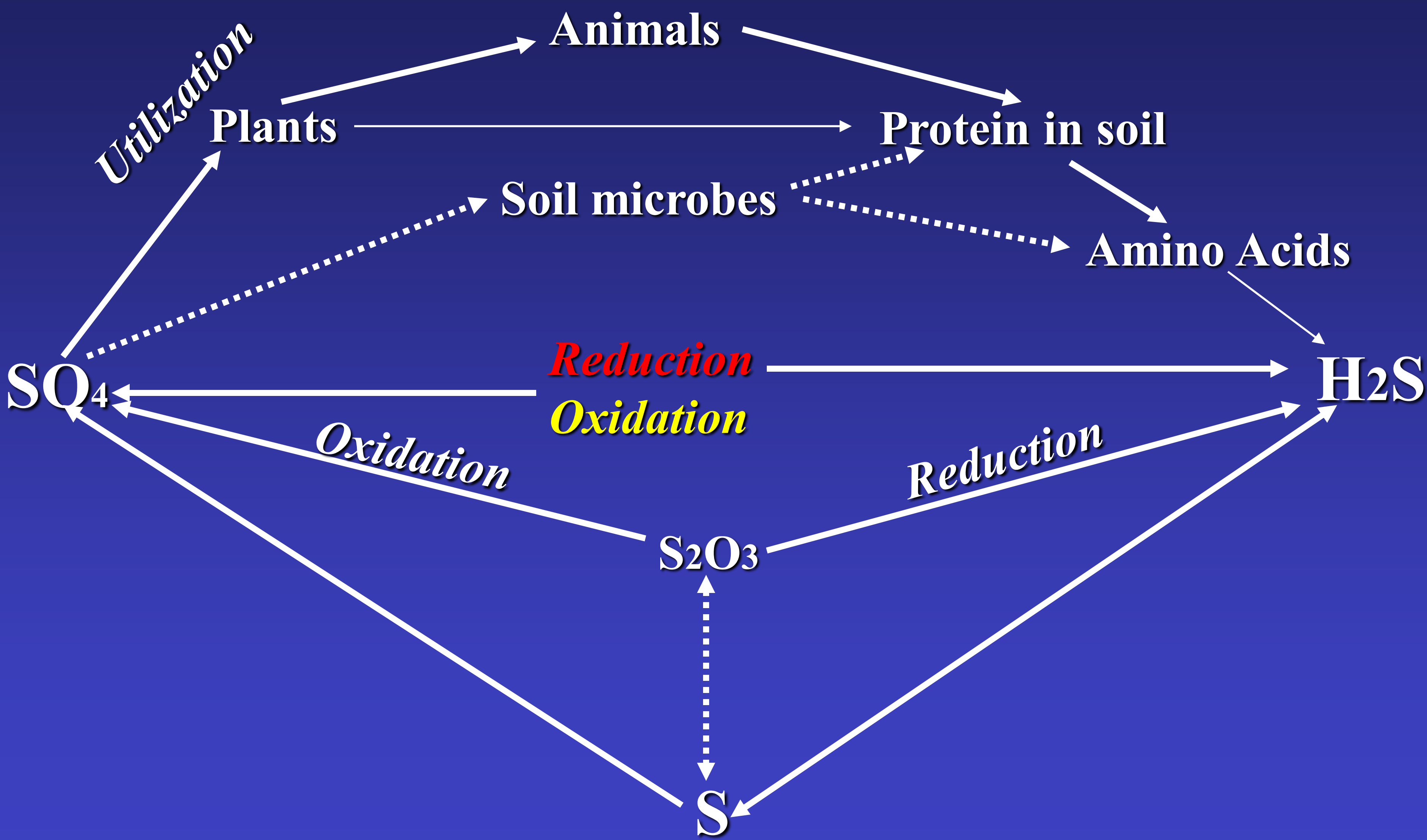
Mn availability & biological activity

pH:	5.2		7.8
Mn form:	Mn^{2+}	Biological activity	Mn^{4+}
Available:	Yes		No

Schematic of the Nitrogen Cycle

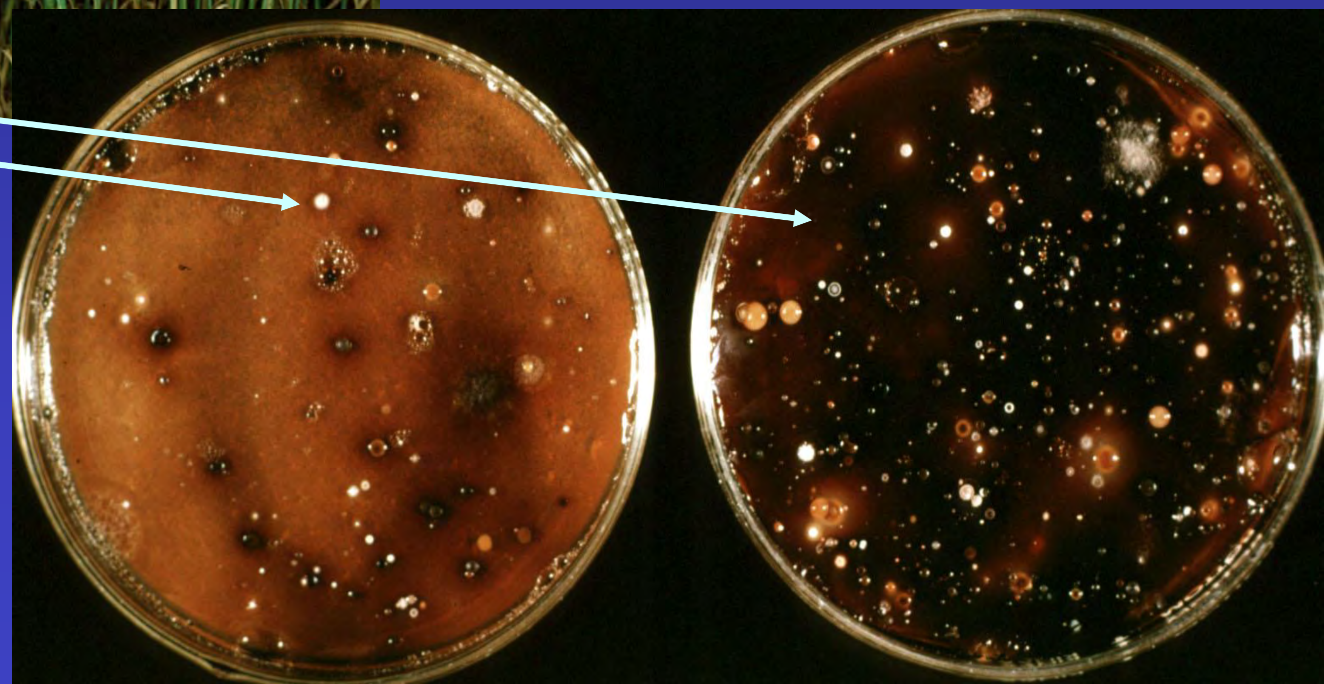


Sulfur Cycle



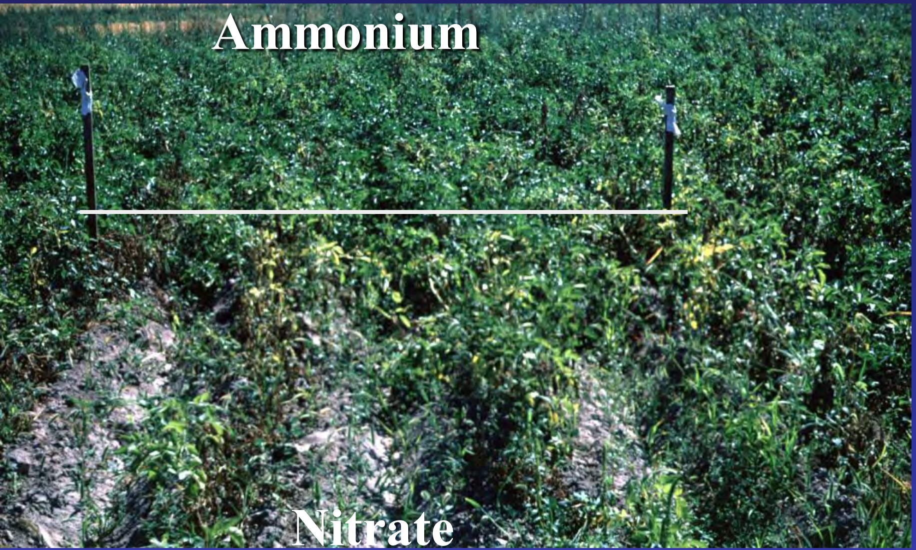
Take-all and Populations of Mn-oxidizing Rhizosphere Bacteria

Cattle dung (manure)



Implications of Nutrition in Disease

Verticillium wilt of potato



Rhizoctonia winter-kill of wheat

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

Relationship of Nitrogen & Sulfur to Disease

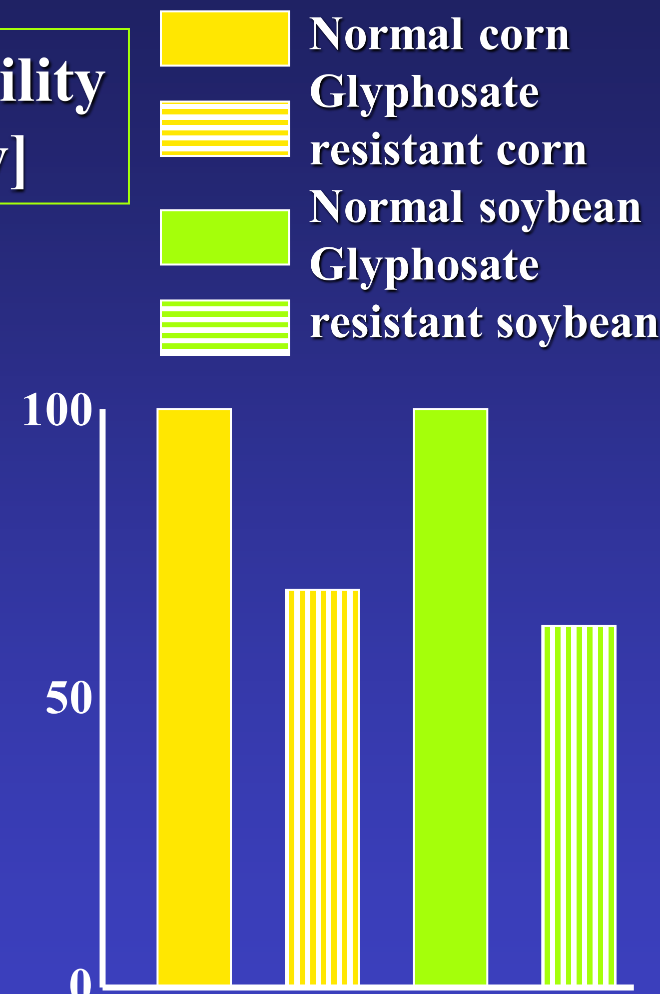
1. Genetics of the Plant
2. Nutrient Form or Availability
3. Rate Applied or Available
4. Method and Time Applied
5. Source of Element & Associated Ions
6. Integration with other practices

Relationship of Nitrogen & Sulfur to Disease

1. Genetics of the Plant

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

- Stage of growth
- Age
- Health
- Environment



Effect of the glyphosate resistance gene on Mn uptake efficiency

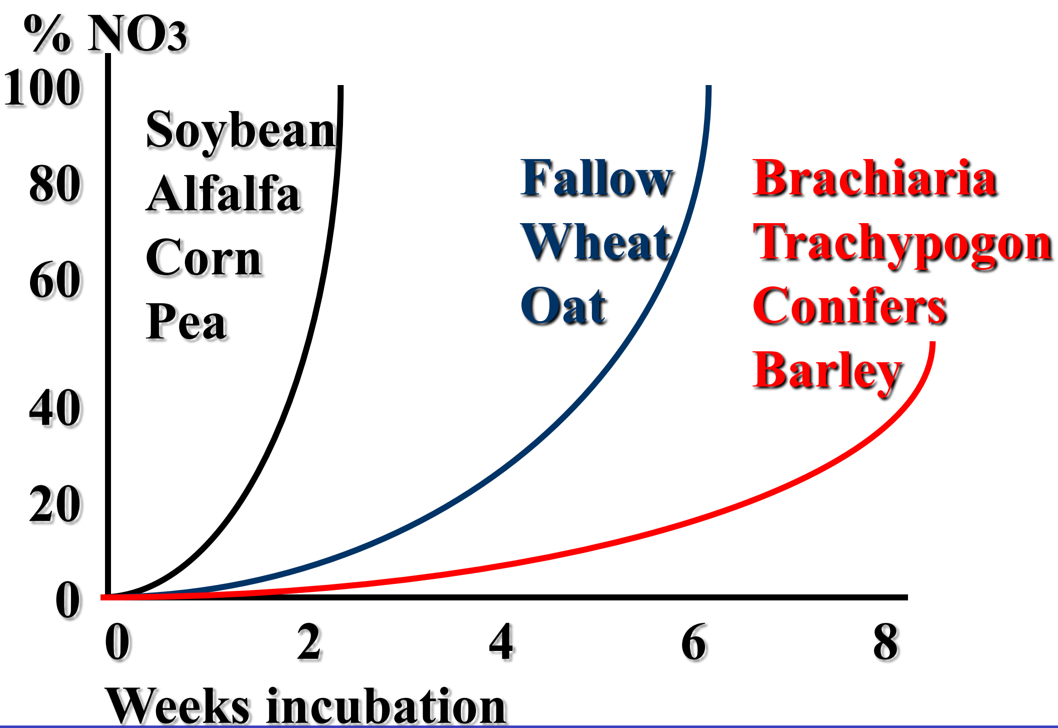
Relationship of Nutrition with Disease

2. Nutrient Form or Availability

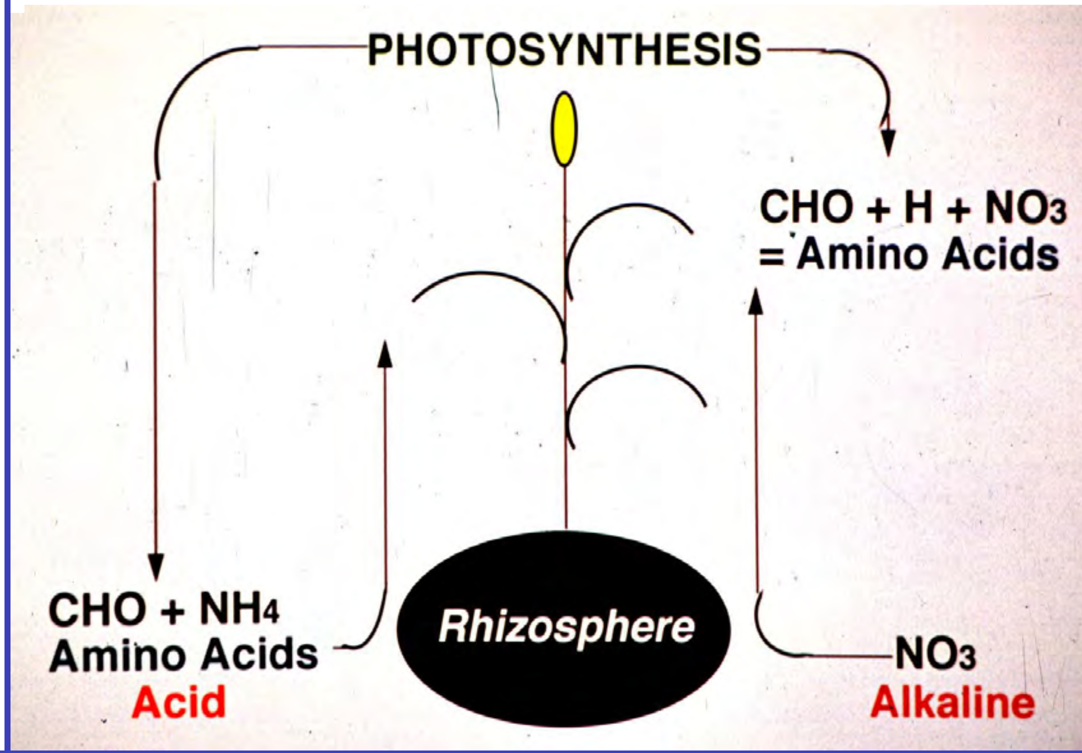
Oxidized<-->Reduced, Soluble<-->Non-soluble

Nitrogen, Iron, Manganese, Sulfur

Effect of Crop Residues on Nitrification



Metabolism of Different Forms of Nitrogen



Effect of the Form of Nitrogen on Potato Diseases

	Disease			
Source of N	Rhizoctonia Canker	Verticillium Wilt	Yield (kg/ha)	Percent No. 1
$(NH_4)_2SO_4$	6.2 a	3.9 b	32670	69 b
$Ca(NO_3)_2$	4.8 b	9.4 a	21340	57 a

Some Diseases Reduced by N03, High pH, Ca

Crop	Disease	Pathogen
Asparagus	Wilt	*Fusarium*
Bean	Chocolate Spot	*Botrytis*
Many	Root Rot	*Fusarium*
Many	Root Rot	*Rhizoctonia*
Beet	Damping Off	*Pythium*
Cabbge	Club Root	*Plasmodiophora*
Many	Yellows	*Fusarium*
Celery	Yellows	*Fusarium*
Corn	Ear rot	*F. moniliforme*
Cucumber	Wilt	*Fusarium*
Pea	Damping-Off	*Rhizoctonia*
Pepper	Wilt	*Fusarium*
Potato	Stem Canker	*Rhizoctonia*
Tobacco	Frenching	*Bacillus cereus*
Tomato	Gray Mold	*Botryti*
Many	White Mold	*Sclerotinia*
Many	S. Blight	*Sclerotium*
Many	Wilt	*Fusarium*
Ornamentals	*Crown gall*	*Agrobacterium tumefaciens*

Fusarium Wilt/Yellows Diseases

- Disease of fruit, vegetable, fiber and ornamental crops
- Increased with ammonium-N
- Severe in low (acid) pH soils
- Control: Adequate liming PLUS nitrate-N
- (Decreases Mn and Fe availability)

Diseases Reduced by NH_4, Low pH, Mn

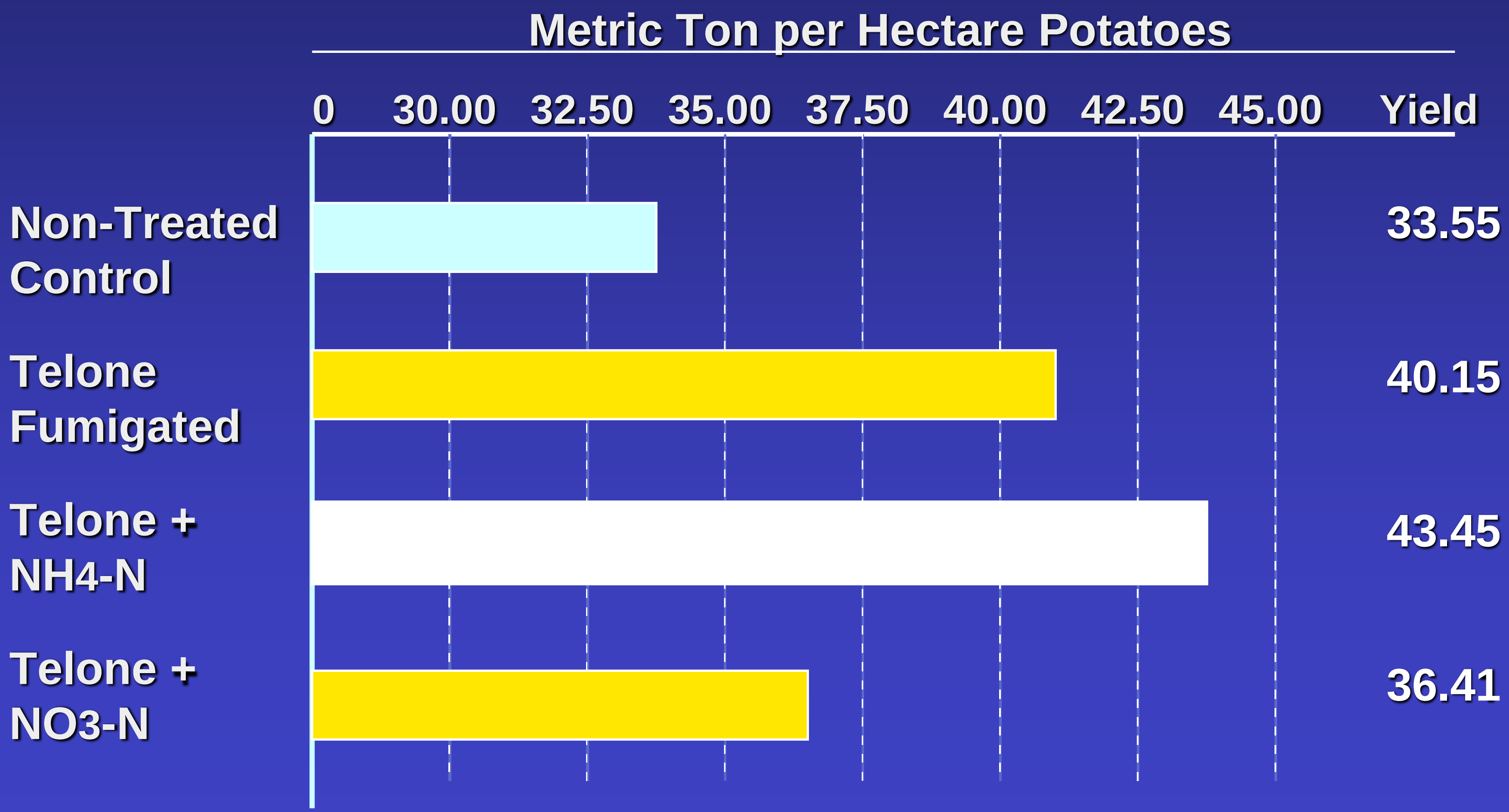
Crop	Disease	Pathogen
Bean	Root Rot	*Thielaviopsis*
	Root Knot	*Meloidogyne*
Carrot	Root Rot	*Sclerotium*
Corn	Stalk rot	*Gibberella*
Egg Plant	Wilt	*Verticillium*
Many	Root rot	*Phymatotrichum*
Onion	White Rot	*Sclerotium*
Pea	Root Rot	*Pythium*
Potato	Scab	*Streptomyces*
	Wilt	*Verticillium*
	Virus	*Potato Virus X*
Rice	Blast	*Magnaporthe*
Tomato	S. Wilt	*Pseudomonas*
	Anthracnose	*Colletotrichum*
	Wilt	*Verticillium*
	Virus	*Potato Virus X*
Wheat	Take-all	*Gaeumannomyces*

Factors Affecting N Form, Mn Availability and Severity of 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
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

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

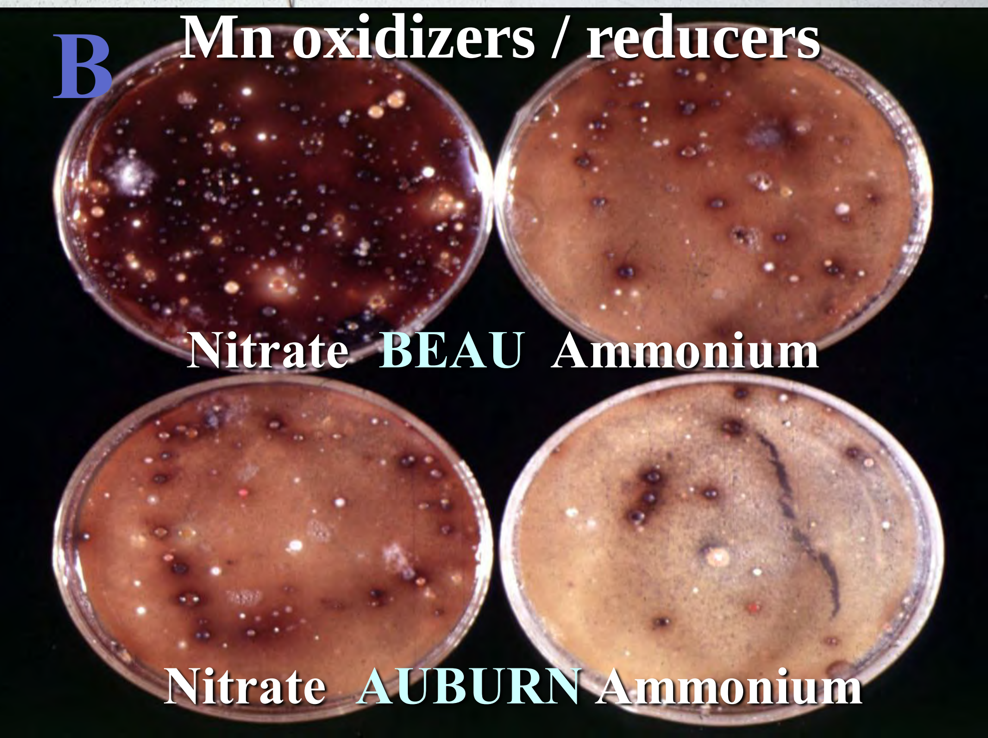


Effect of N form & inhibiting nitrification on take-all and rhizosphere Mn oxidizers

A. Take-all

B. Manganese oxidizers

C. +/- Nitrification inhibitor



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

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

Swine manure + Nitrapyrin

Swine manure

Maize Stalk rot

Ammonium N with a nitrification inhibitor

Ammonium N without inhibiting nitrification

Nitrate nitrogen

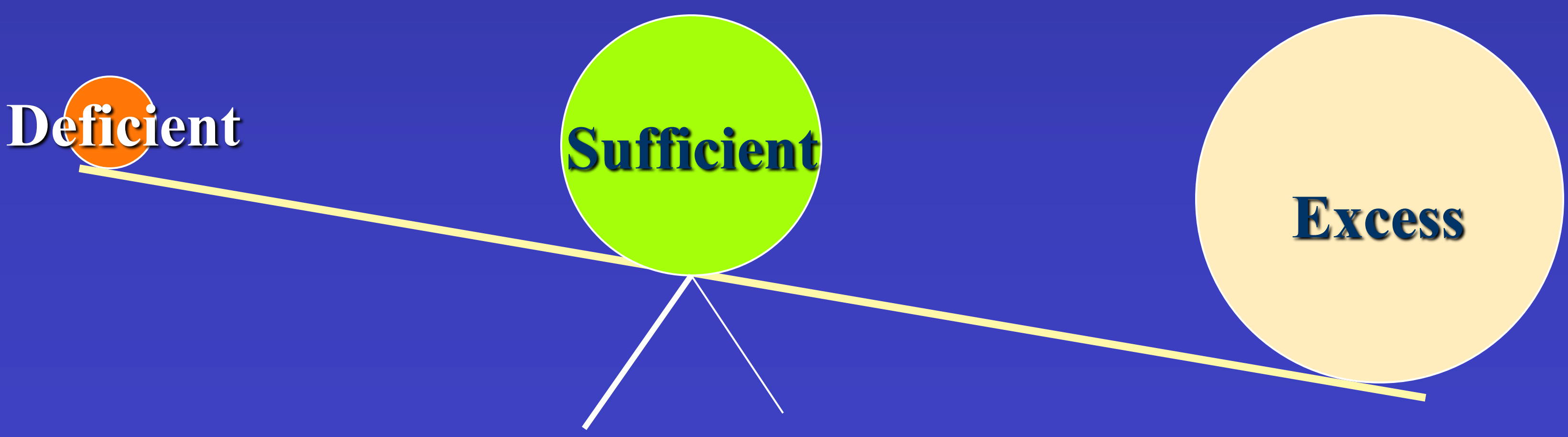
Effect of Inhibiting Nitrification on Scab of Potato

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

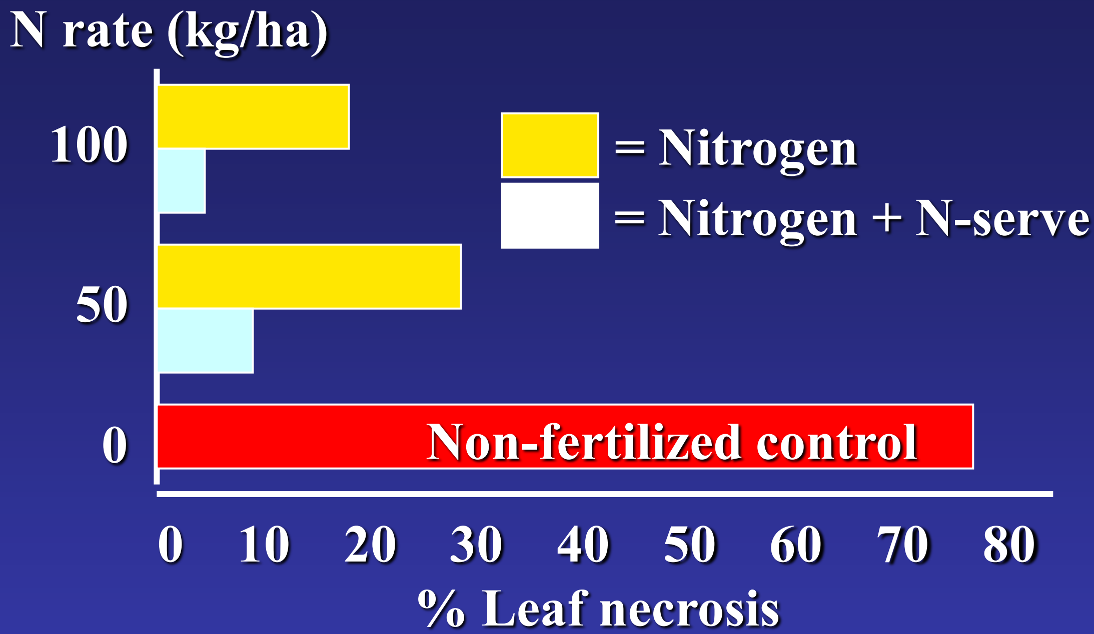
Relationship of Nutrition with Disease

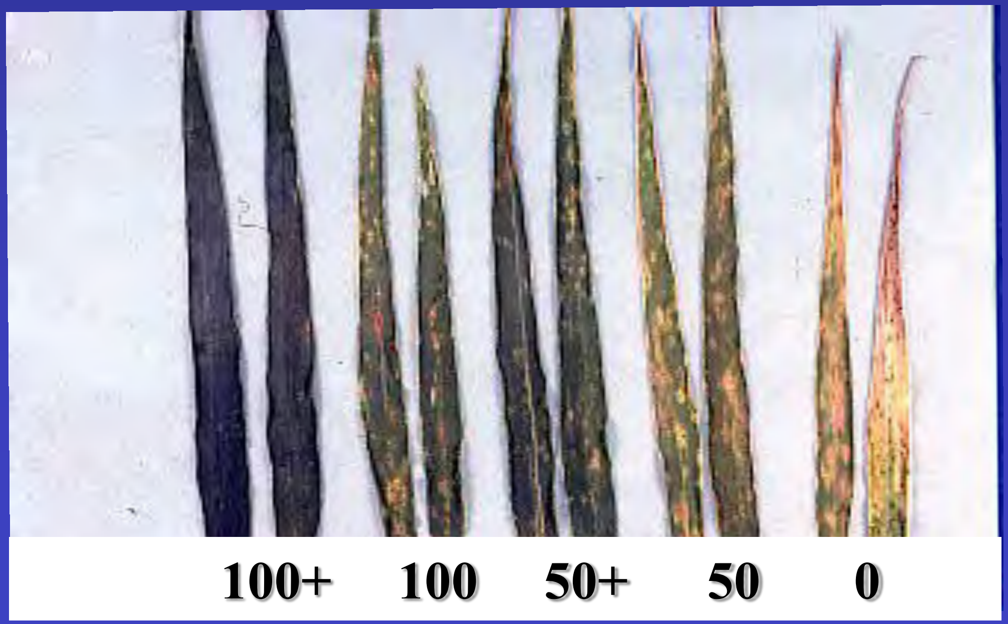
3. Rate Applied or Available

- Amount available
  - Deficiency to sufficiency versus
  - Sufficiency to excess for the particular plant
- Time available
- Nutrient balance



Effect of N Rate & Form on Tan Spot





Relationship of Nutrition with Disease

4. Method and Time Applied

Soil<-->Seed<-->Foliage, Side-dress<-->Band<-->Broadcast
Spring<-->Fall<-->Split

Susceptibility of Plant, Favorable Environment, Virulence of Pathogen

Effect of nitrogen source and time on *Rhizoctonia* "winter-kill" of winter wheat

N Treatment	Time	Percent Kill
NH3 + N-Serve	September	14
Urea Granuals	February	40
28% N Solution	February	60
Urea	April	14

Urea - Feb.   NH4 - Sept.

Time N Applied on Yield and Sharp-Eyespot of Wheat

N Applied	% Lodging	Disease Index*	kg/ha Yield
Fall	3	2.1	3036
Spring	73	3.2	2640

*Disease indexed on a 0 (healthy)-5 scale

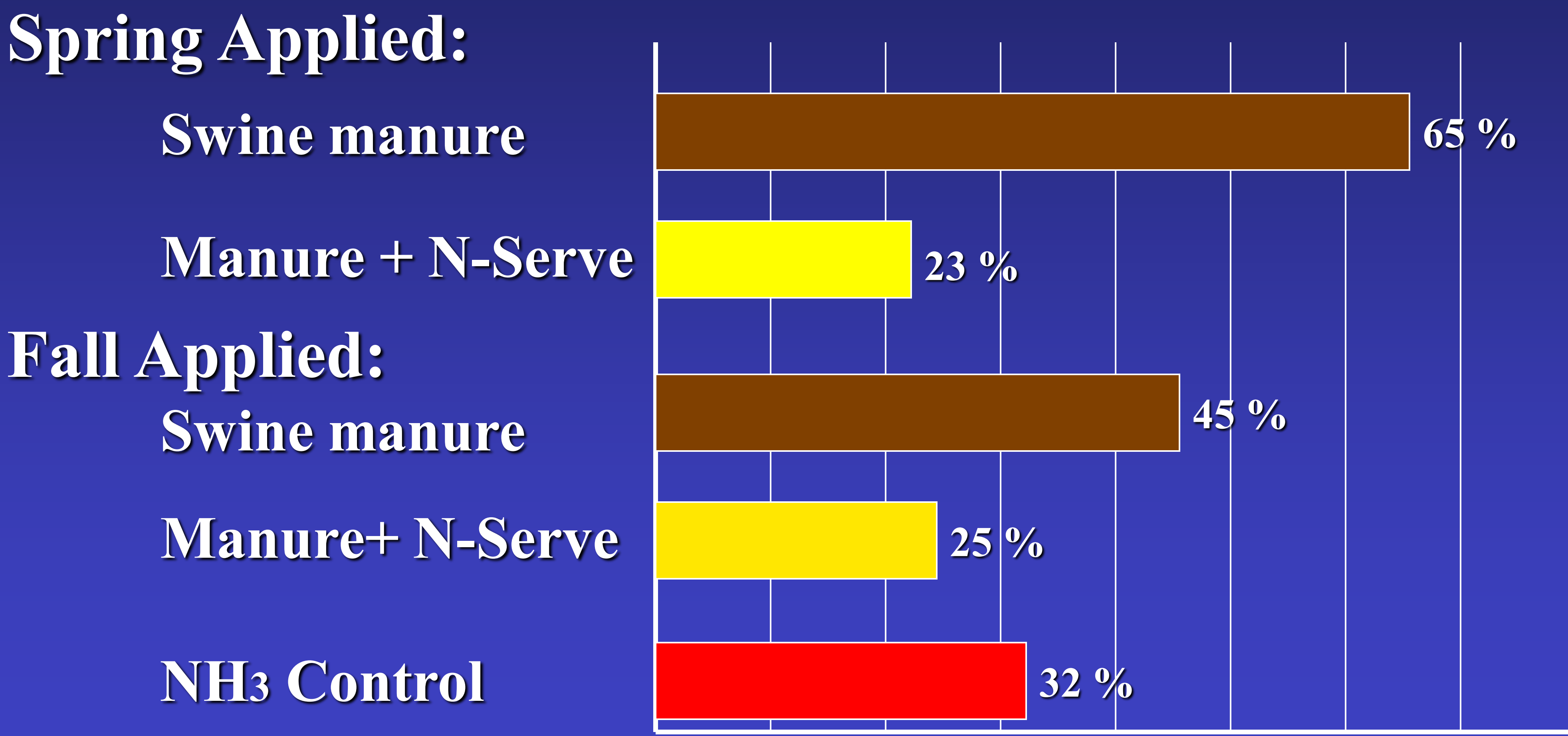
Relationship of Nutrition with Disease

5. Source and Associated Ions

Gas<-->Liquid<-->Granule, Anion<-->Cation (K_2SO_4/KCl)

Gibberella stalk rot of corn

Effect of N Source and Time Applied On Stalk Rot of Corn



Some Sulfur Compounds for Disease Control

- **Elemental sulfur**
  - Soil pH adjustment
  - Direct, combined, vaporization
- **Carbon disulfide**
  - Fumigation of fruits and soil
- **Sulfide salts**
  - K_2S, P_2S_5, etc.
- **Xanthates**
- **Thiosulfates**
  - Nitrification inhibitors, stabilizers, etc.
- **Sulfate nutrient salts**
  - Ca, K, Mn, N, P, etc.

Some Diseases Affected by Sulfur

Disease	Pathogen	Host	Effect
Bud death	Pycnostysanus azaleae	Rhododendron	Decrease
Canker	*Rhizoctonia solani*	Potato	Decrease
Club root	*Plasmodiophora brassicae*	Crucifers	Decrease
Common scab	*Streptomyces scabies*	Potato	Decrease
Powdery mildew	*Erysiphe graminis*	Cereals	Decrease
Root rot	Armillaria mellea	Fruit trees	Decrease
Late blight	*Phytophthora infestans*	Potato	Decrease
	Pyrenopeziza brassicae	Oil seed rape	Decrease
Leaf spot	Ramularia beticola	Sugar beet	Decrease
Mosaic virus	Tobacco mosaic virus	*Nicotiana glutinosa*	Decrease
Patch	*Fusarium nivale*	Turfgrass	Decrease
Powdery mildew	*Uncinula necator*	Grape	Decrease
Root rot	Rhizoctonia solani	Soybeans	Decrease
Rust (stem,stripe)	*Puccinia* spp.	Cereals	Increase
Snowmold	*Typhula idahoensis*	Cereals	Decrease
Stewarts wilt	Erwinia stewartii	Maize	Decrease
	Dothistroma	Pine	Decrease
Wilt	*Verticillium dahlia*	Potato	Decrease
[Bud mite	Cecidophyopsis ribis	Current	Decrease

Relationship of Nutrition with Disease

6. Integration with other practices

Rotation, Tillage, Seed rate, Herbicide, pH, Moisture

Severe take-all of wheat following glyphosate on soybeans (left), the non-treated control is right.

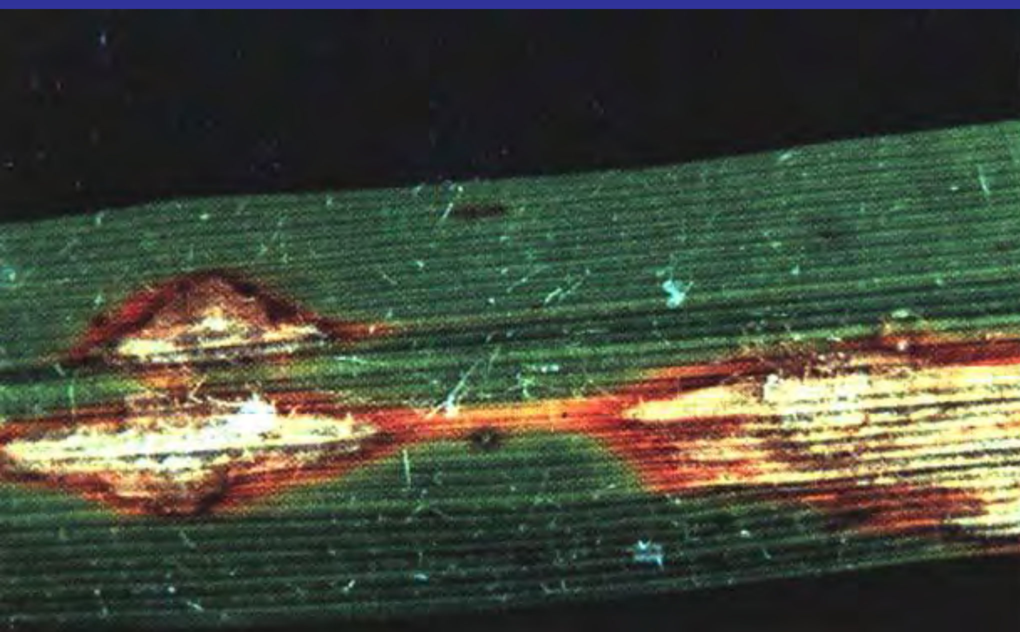
Less take-all of wheat in a firm (right) than loose seed-bed (left)

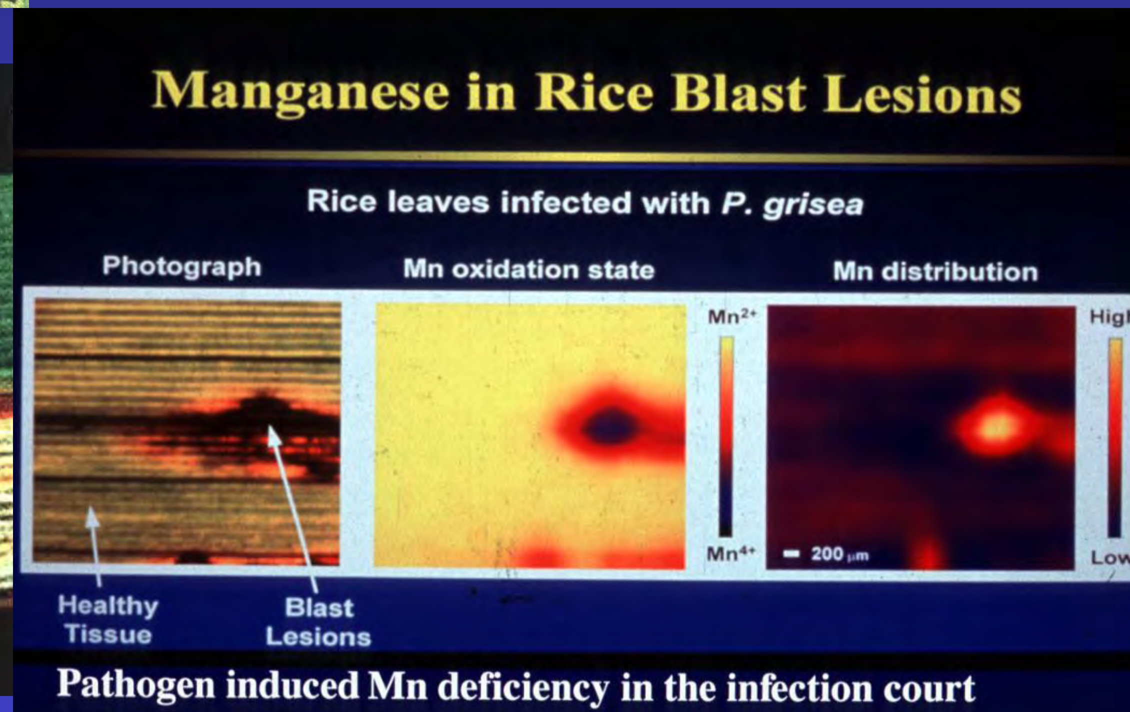
Effect of Crop Sequence & Tillage on Extractable Soil Mn*

Crop Sequence	AmAcetate	Quinol	Total
Continuous corn	25.4 a	104 a	130 a
Corn in corn-Sbean-wheat	14.5 b	77 b	91 b
Sbean in corn-Sbean-wheat	14.4 b	65 c	79 c
Wheat in corn-Sbean-wheat	13.6 b	67 c	81 bc
Continuous Soybeans	10.4 c	53 d	64 d
Tillage			
Fall Chisel	22.4 a	104 a	126 a
No-Till	16.9 b	63 b	80 b

* Data from sampling long-term rotations - Purdue IPM and Tillage Project

Rice blast, caused by *Pyricularia grisea* (*Magnaporthe grisea*)

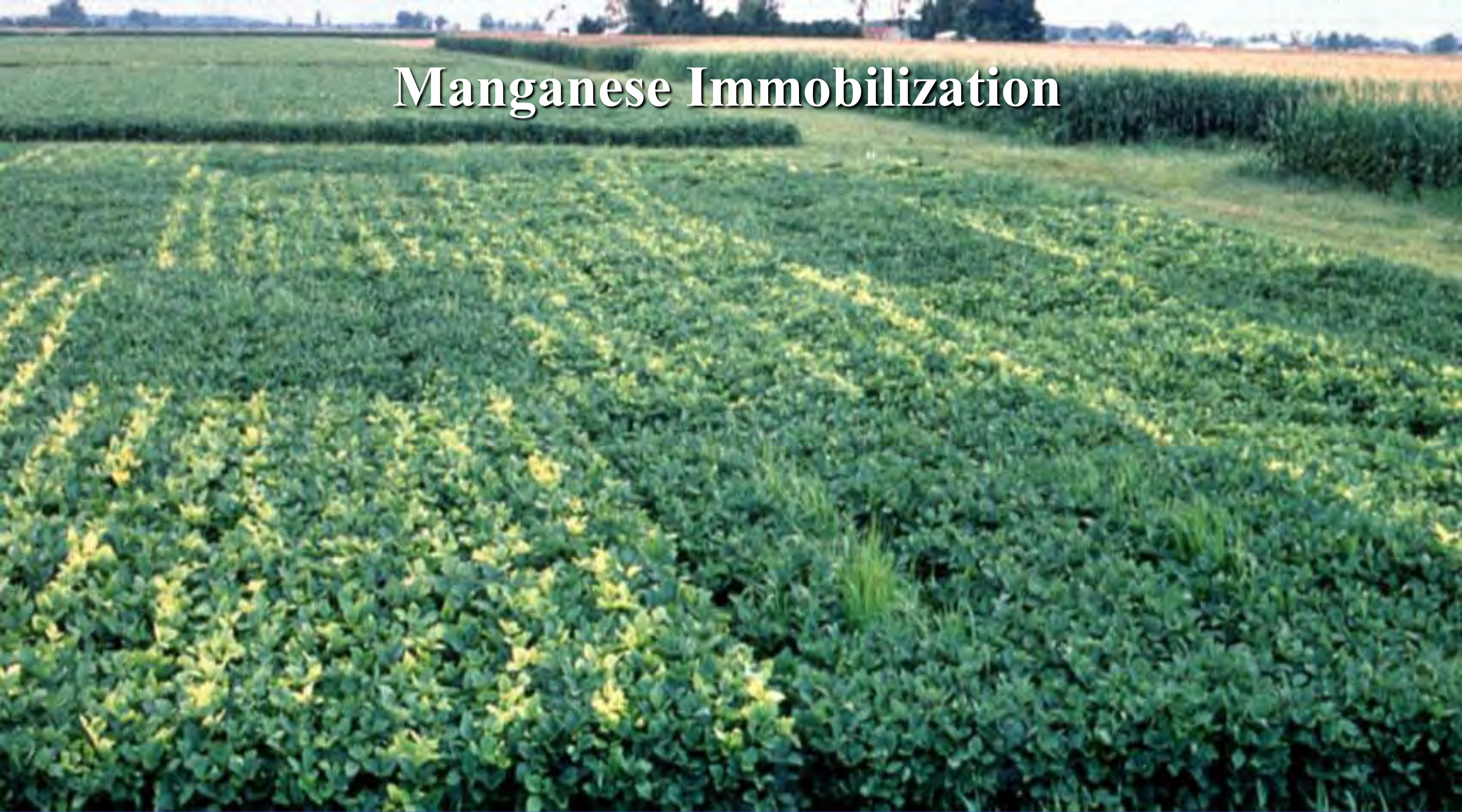




Effects of Cultural Conditions on Mn Availability & Blast

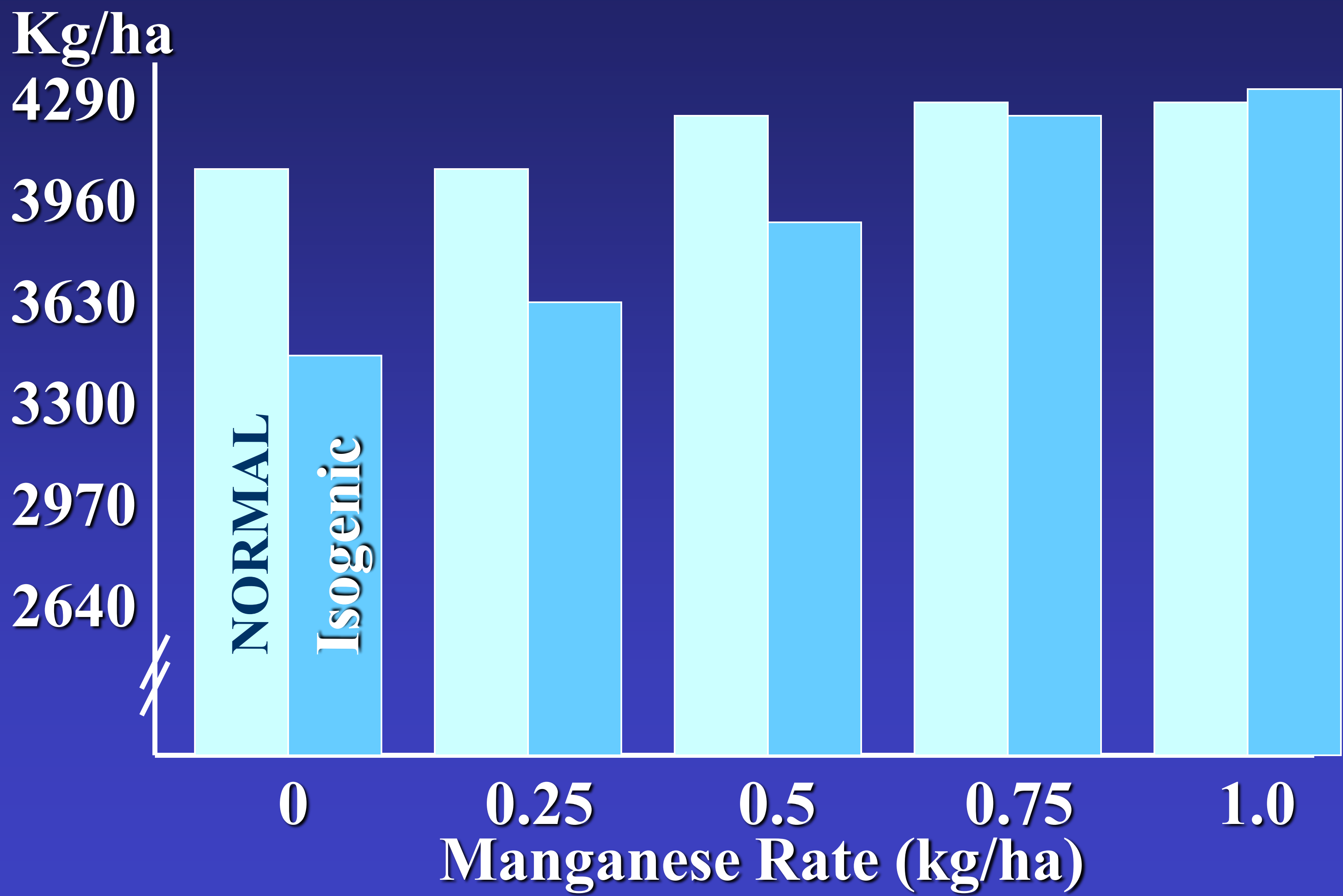
Condition	Manganese availability	Blast severity
Upland rice culture	Decrease	Increase
Alkaline soils	Decrease	Increase
Nitrate nitrogen	Decrease	Increase
Aerobic or dry soils	Decrease	Increase
"Low" temperatures	Decrease (uptake)	Increase
Sandy soil	Decrease	Increase
Manure	Decrease	Increase
High plant populations	Decrease	Increase
Paddy rice culture	Increase	Decrease
Acid soils	Increase	Decrease
Ammonium nitrogen	Increase	Decrease
Inhibiting nitrification	Increase	Decrease
Anaerobic soils	Increase	Decrease
"High" temperatures	Increase	Decrease
Silicon fertilization	Increase	Decrease
Clay & loam soils	Increase	Decrease

Manganese Immobilization



Transient foliage chlorosis of soybeans after applying glyphosate [banded to show effect]

Response of Soybeans to Manganese



“Engineering” a Glyphosate Mn Program

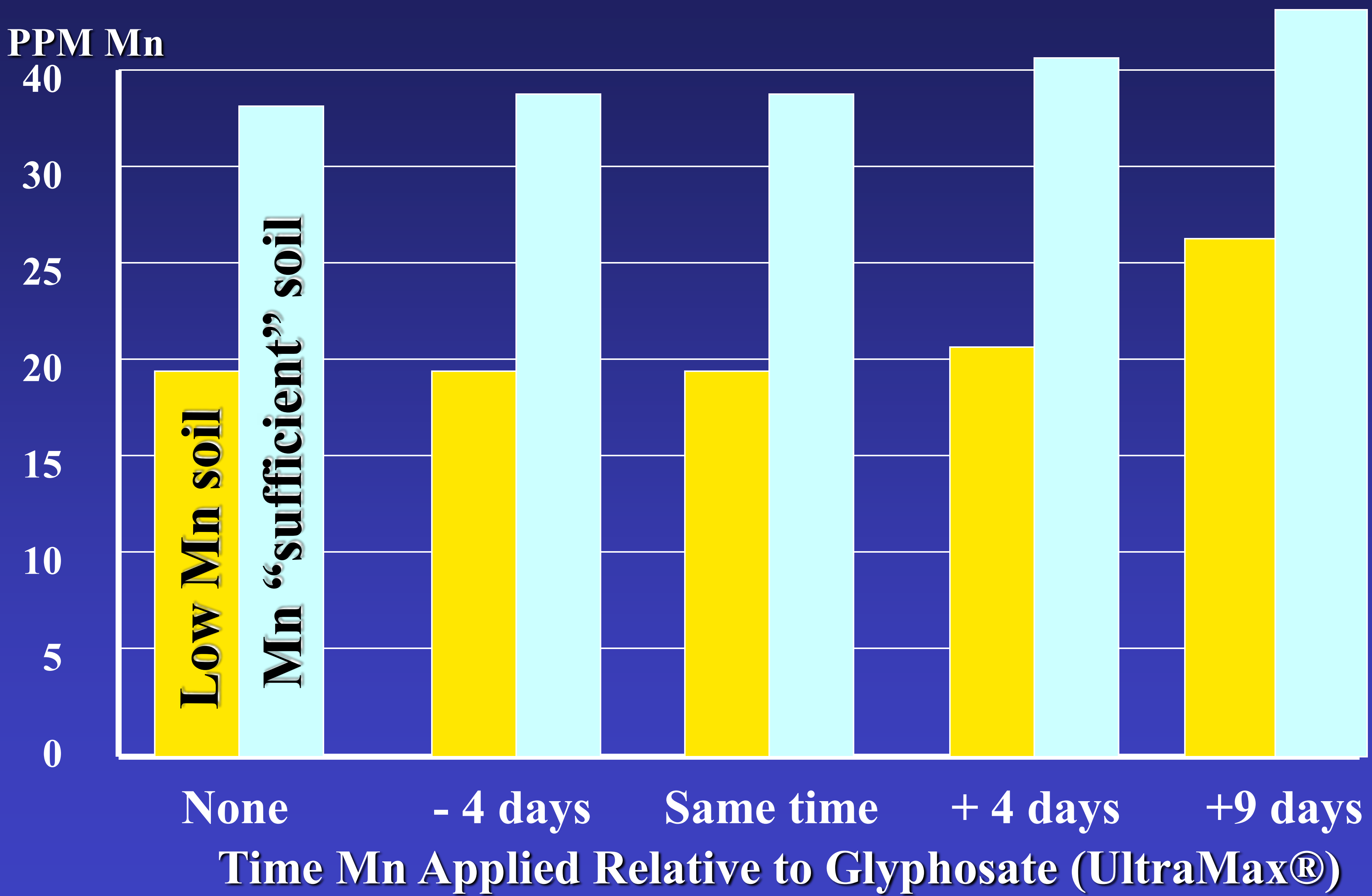
- ❑ **Micronutrients**
  - ✓ Copper - three sources
  - ✓ Manganese - six sources
  - ✓ Zinc - five sources
  - ✓ Combinations - factorial
- ❑ **Timing of micronutrient application**
  - ✓ Before glyphosate(4-6 days before)
  - ✓ At the same time as glyphosate
    - Concurrent
    - Tank-mix
  - ✓ 4 - 6 days after Glyphosate
  - ✓ 8 - 30 days after glyphosate
- ❑ **Glyphosate formulation**

Effect of Glyphosate & Mn Tank Mixes on Chlorophyll & Soybean Grain Yield*

Manganese Formulation	Rate	SPAD-502 reading	Yield
	kg/ha	11 DAT	kg/ha
Untreated	None	23.9 a	1584 a
Glyphosate only	None	25.9 a	2178 a
Mn-EAA	0.5	35.6 b	3168 b
Mn-EDTA	0.7	36.8 b	3300 b
Mn-LS	0.6	36.4 b	3828 b
MnSO4	2.5	37.1 b	3696 b

*From Bernards, Thelen, and Penner, 2004

Effect of Time of Mn Application on Tissue Mn



Herbicide-Nutrient Tank Mixes (WeatherMax®)

No herbicide control

Glyphosate + Zn tank mix

Glyphosate + Mn tank mix

Glyphosate Zn concurrent

Mechanisms by which Nitrogen and Sulfur Reduce Disease

- **Increased Plant Resistance**
  - Physiology - phytoalexin, CHO, phenolic production
  - Defense- callus, lignituber, cicatrix formation
- **Disease Escape, Increased Plant Tolerance**
  - Increased growth - roots, leaves
  - Shortened Susceptible stage
  - Compensation for disease damage
- **Modifying the environment**
  - pH, other nutrients
  - Rhizosphere interactions, nitrification, biological balance
- **Inhibited Pathogen Activity**
  - Reduced virulence
  - Direct effect on survival and multiplication
  - Biological control

Physiologic Roles of Manganese

Mn

CHO

Photosynthesis

Glycolysis (energy rections)

Mn

Shikimic Acid

Carbohydrate, hormone &

Amino Acid Synthesis

Mn

Root Growth

Amino Acids

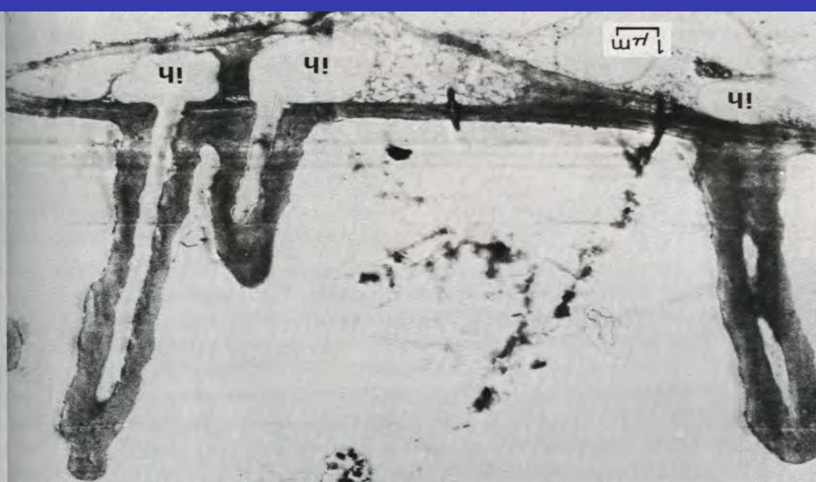
Cyanogenic Glycosides

Phenylalanine

ammonia-lyase

Mn

COUMARINS LIGNINS FLAVANOIDS = Defense materials

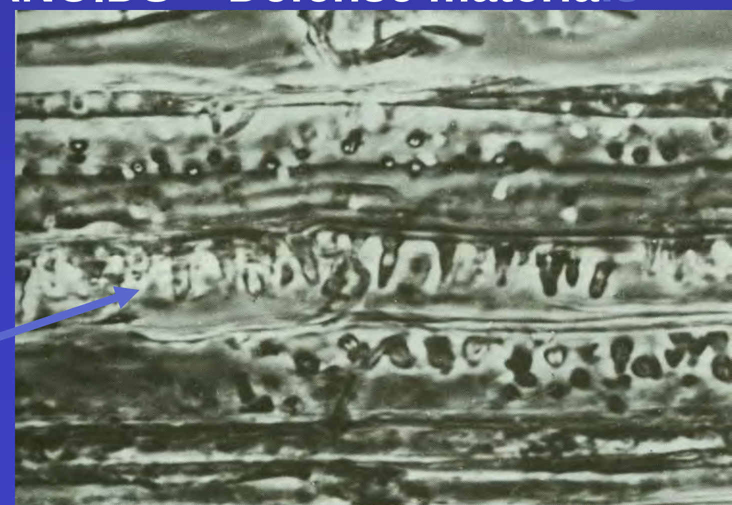


“Lignituber” formed in response to cell Penetration.

Wheat

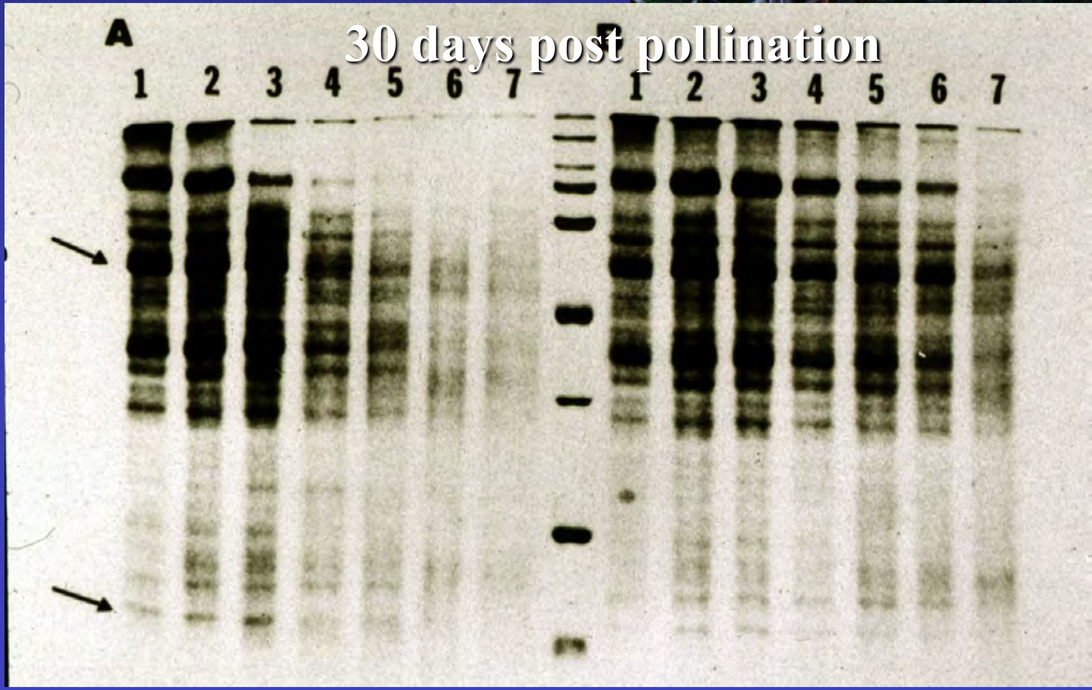
Triticale

(After Skou, 1975)



PREDISPOSITION TO STALK ROT: A NITROGEN; then a Carbon DEFICIENCY

- **Nitrogen:**
  - Rate response up to sufficiency
    - (Maintains photosynthesis)
  - Excess N increases stalk rot
  - Ammonium reduces (form effect)
  - "Stay green" hybrids are more tolerant
- **Tissue is cannibalized:**
  - Storage nitrogen (recycled)
  - Physiological N (enzymes; Rubisco)
  - Structural proteins
    - (stalk hydroxyproline)
- **Carbon:**
  - Senescence as photosynthesis stops
  - Low carbohydrate reserves increase



120 kg/ha N   120 kg N/ha+Nitrapyrin

Approaches to Improve Disease Control

Increase resistance/tolerance
Nutrient Seed Content
Nutrient Uptake Efficiency
Root Exudate Effects (siderophores/biological)

Plant

MICROBES

Mn Reducers/oxidizers
Inhibit Nitrifiers
Biological control / PGPR

ENVIRONMENT

Nutrient Amendment
Nutrient Seed Treatment
pH Adjustment
Cultural Modification (pH, water, organic matter, crop sequence)
Nutrient Balance
Biological amendment

REMEMBER

1. Nutrition is an integral part of efficient crop production
    - A. Crop quality and quantity
    - B. Disease control

2. No nutrient controls all diseases
    - A. Consider each nutrient-disease-environment interaction
    - B. Use nutrient form, rate, and time effectively

3. Cultural practices that reduce disease influence nutrition

4. Integrate nutrition and cultural practices for optimum yield and disease control.