Managing Nutrition to Control Plant Disease

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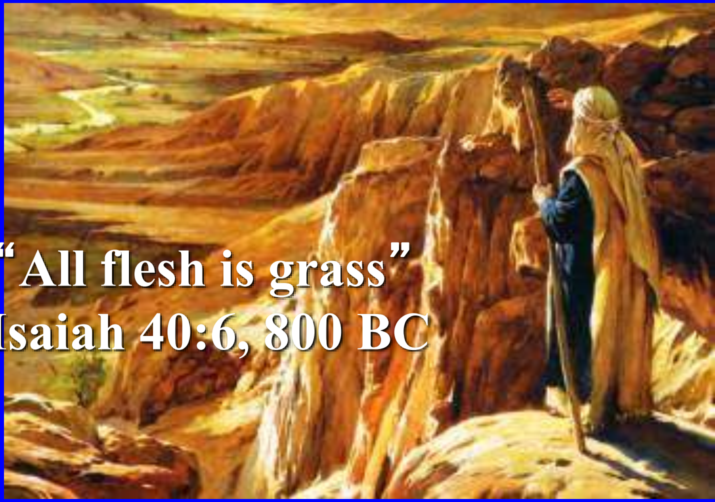
Nutrition and Plant Health

- **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**

The Plant Factory - Storing the Sun's Energy

Photosynthesis and N-fixation

Mn^{+2}

N, P, K, Ca, S, Co, Fe, Ni, B, Cu, Mo, Zn

$$6\ CO_2 + 12\ H_2O \rightarrow \underline{C_6H_{12}O_6} + 6\ O_2$$

Chloroplast

Mg^{+2}

The Harvest is <u>SUGAR</u>

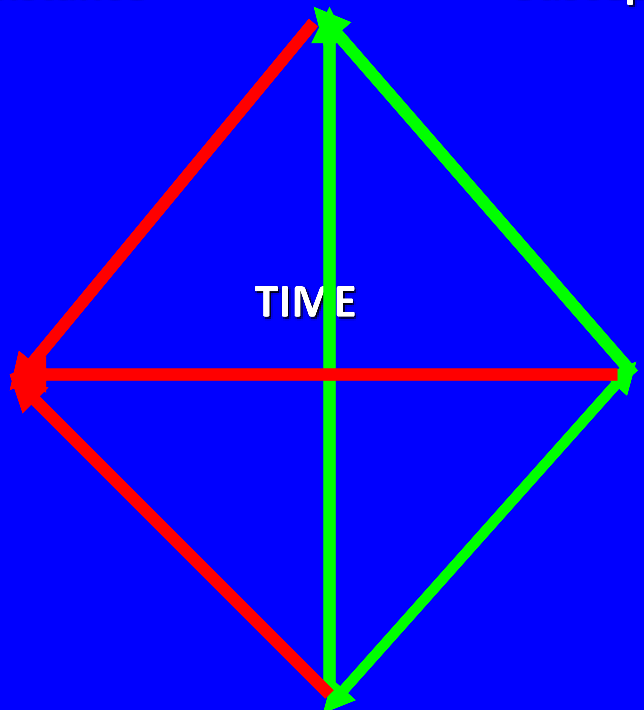
and <u>PROTEIN</u>

N_2

"Farming" is Managing the Ecology

Vigor, Stage of Growth, Root Exudates

Resistance **PLANT** Susceptibility



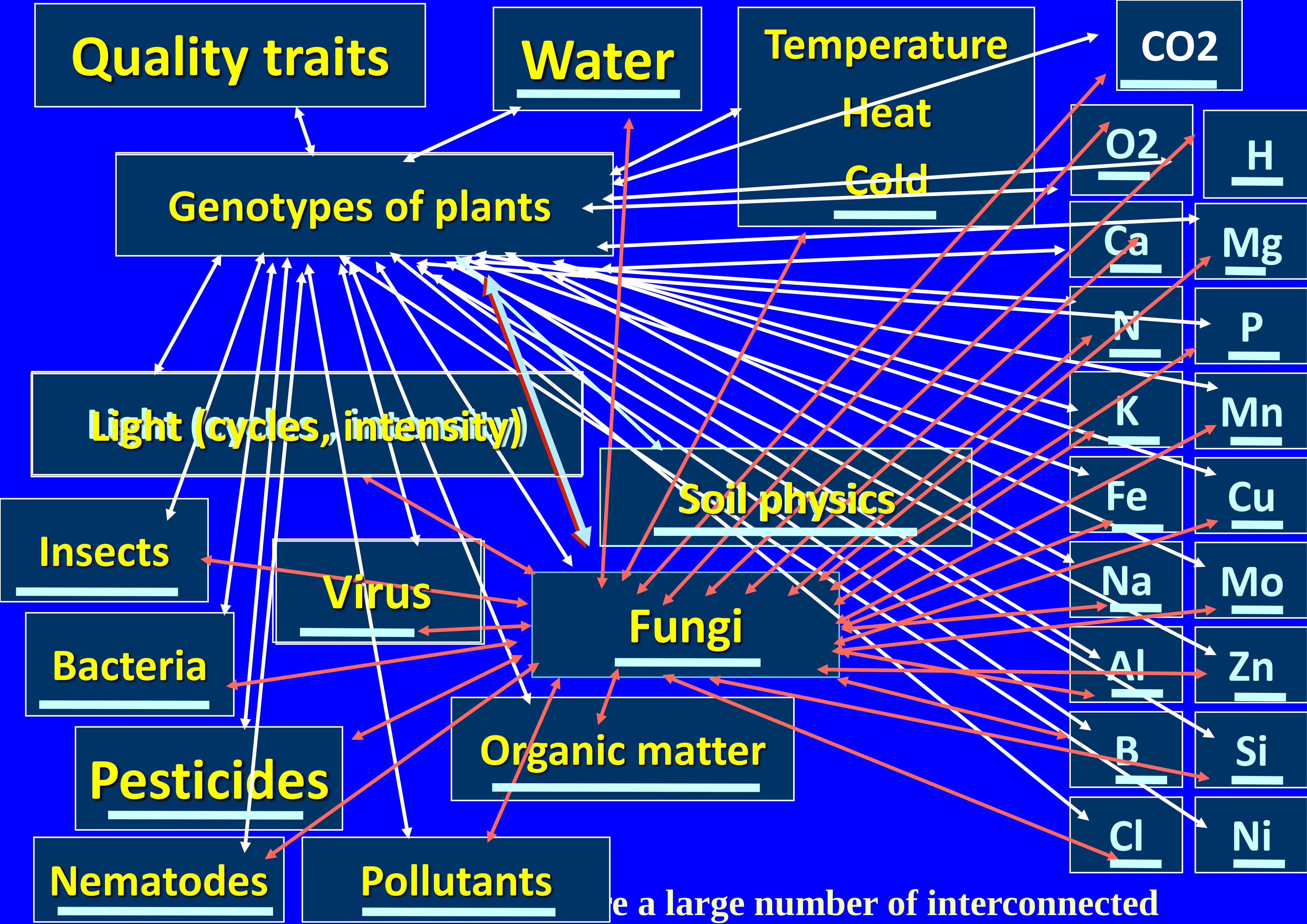
PATHOGEN
Population
Virulence
Activity

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

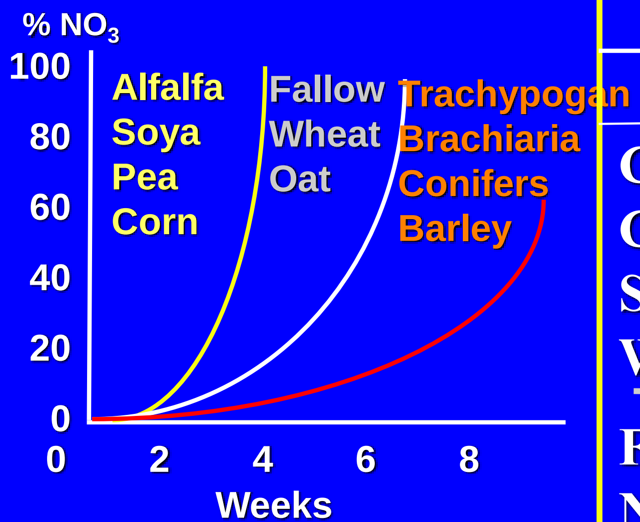


e a large number of interconnected plant properties and responses to physical and biological environmental factors.

Changes in Agricultural Practices Change the Interactions

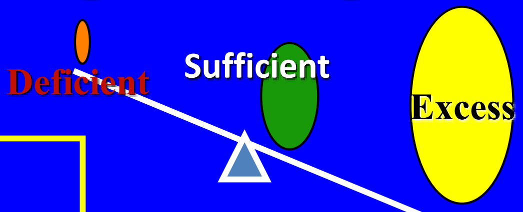
Crop Sequence	Tillage/No-till	Fertilization
Biotic environment	Residue break down	Rate/form
Nutrition	Soil density/aeration	Time applied
Nitrification	Pathogen survival	Source/assoc. ions
Organic matter	Nutrient distribution	Inorganic/Organic
Herbicide usage	Denitrification	

Effect of crop residue on nitrification

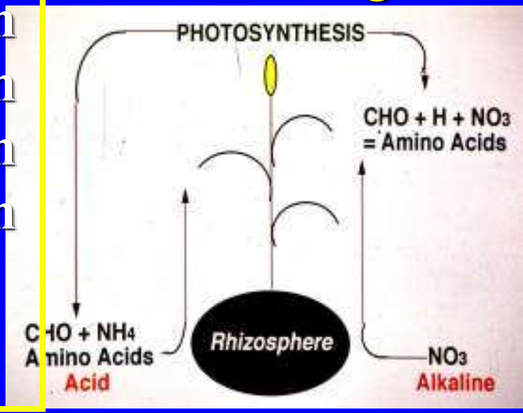


Crop sequence effect on Mn^{+2}

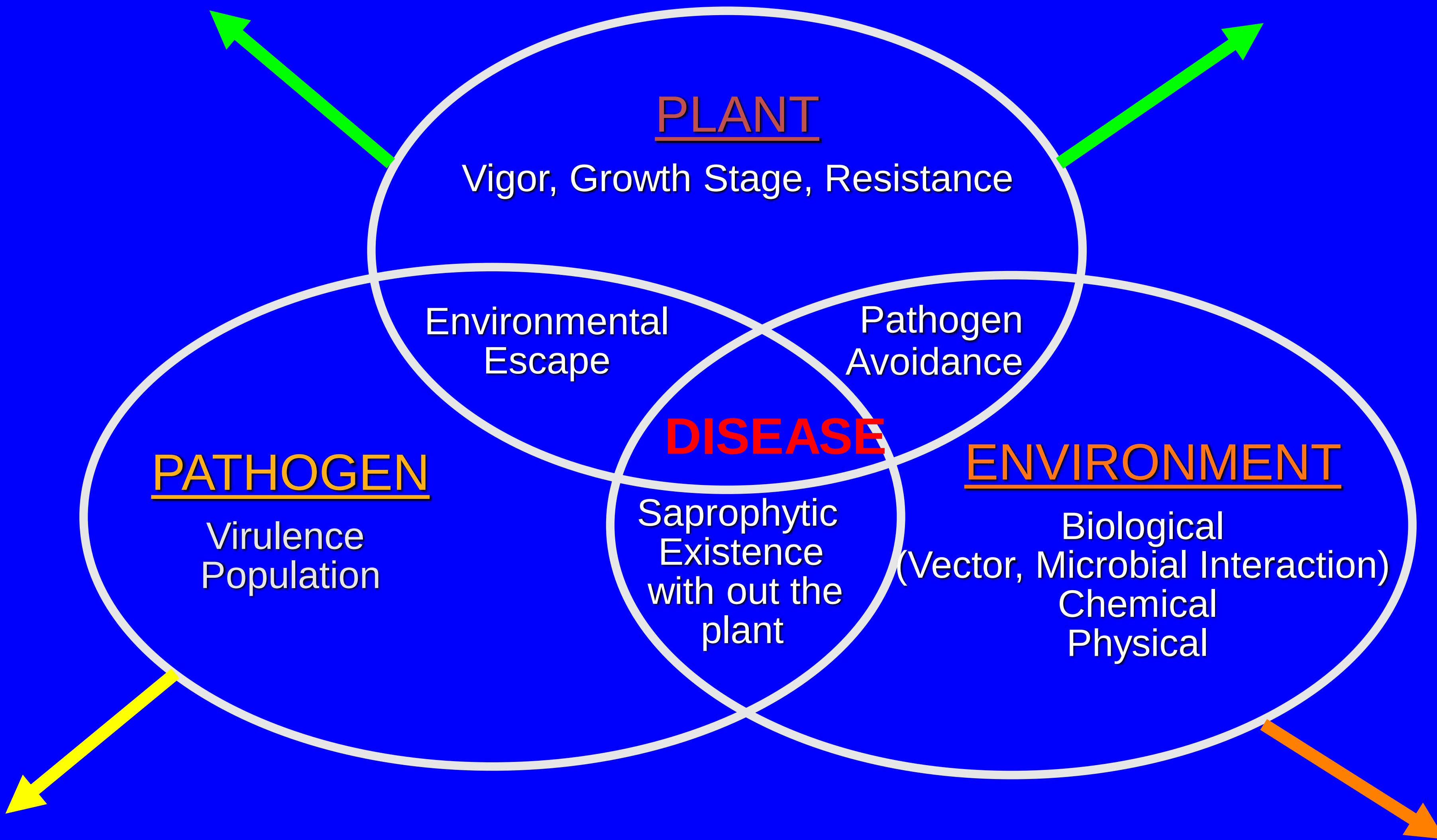
Rotation	Extractable Mn
Continuous Corn	130 ppm
Continuous soybeans	64 ppm
Soybean, wheat, corn	91 ppm
Wheat, corn, soybean	79 ppm
Fall chissel	126 ppm
No-till	80 ppm



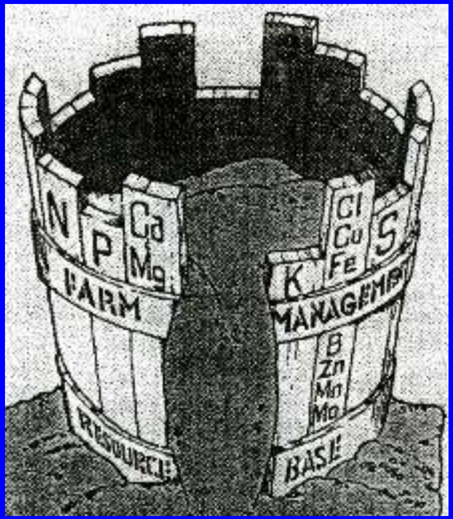
Metabolism of different forms of nitrogen



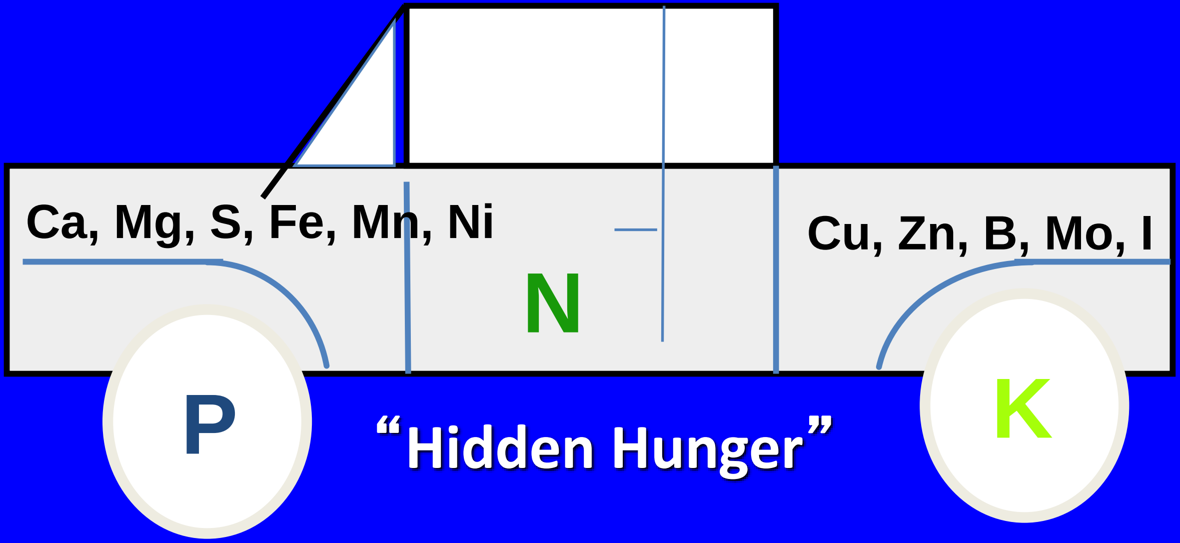
The Interaction of Three Factors Over Time Determines if a Disease will be Latent or Severe



NUTRIENT BALANCE IS IMPORTANT BECAUSE EACH ELEMENT FUNCTIONS AS PART OF A DELICATELY BALANCED, INTERDEPENDENT SYSTEM WITH THE PLANT'S GENETICS AND THE ENVIRONMENT



"Law of the minimum"



Nutrient *BALANCE* may be related to disease or <u>root function!</u>

"The roots may be the root of the problem!"

"The weak link may be underground!"

Nutrients are:

Components of plant parts as well as

Activators,

Inhibitors,

and Regulators

of Physiological Processes

Many herbicides and pesticides are nutrient chelators

Root exudation of organic compounds from cotton, wheat and apple with different Zn levels

Zn Treatment	Amino acids	Sugars	Phenolics
	($\mu g\ g^{-1}$ root $6h^{-1}$)		
		COTTON	
-Zn	165	751	161
+Zn	48	375	117
		WHEAT	
-Zn	48	615	80
+Zn	21	315	34
		APPLE	
-Zn	55	823	350
+Zn	12	275	103

Cakmak and Marschner, 1988, J. Plant Physiol.

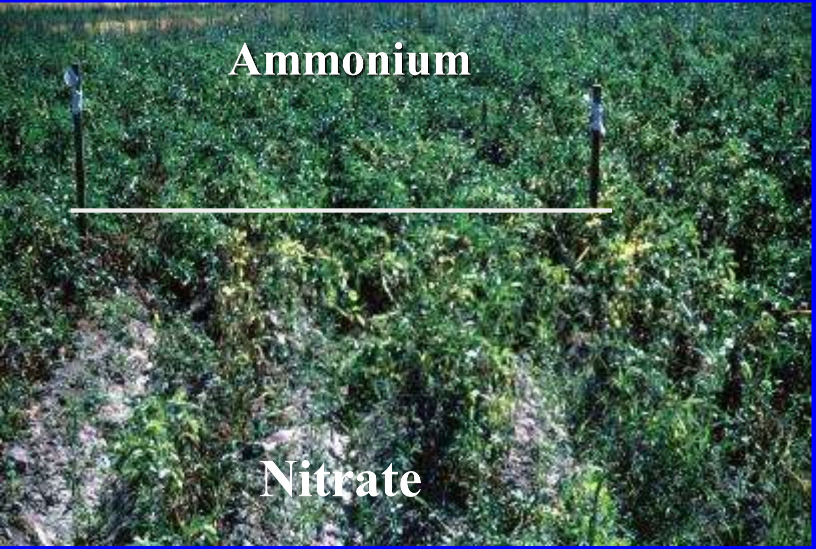
Reported* Effects of Nutrients on Disease

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

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

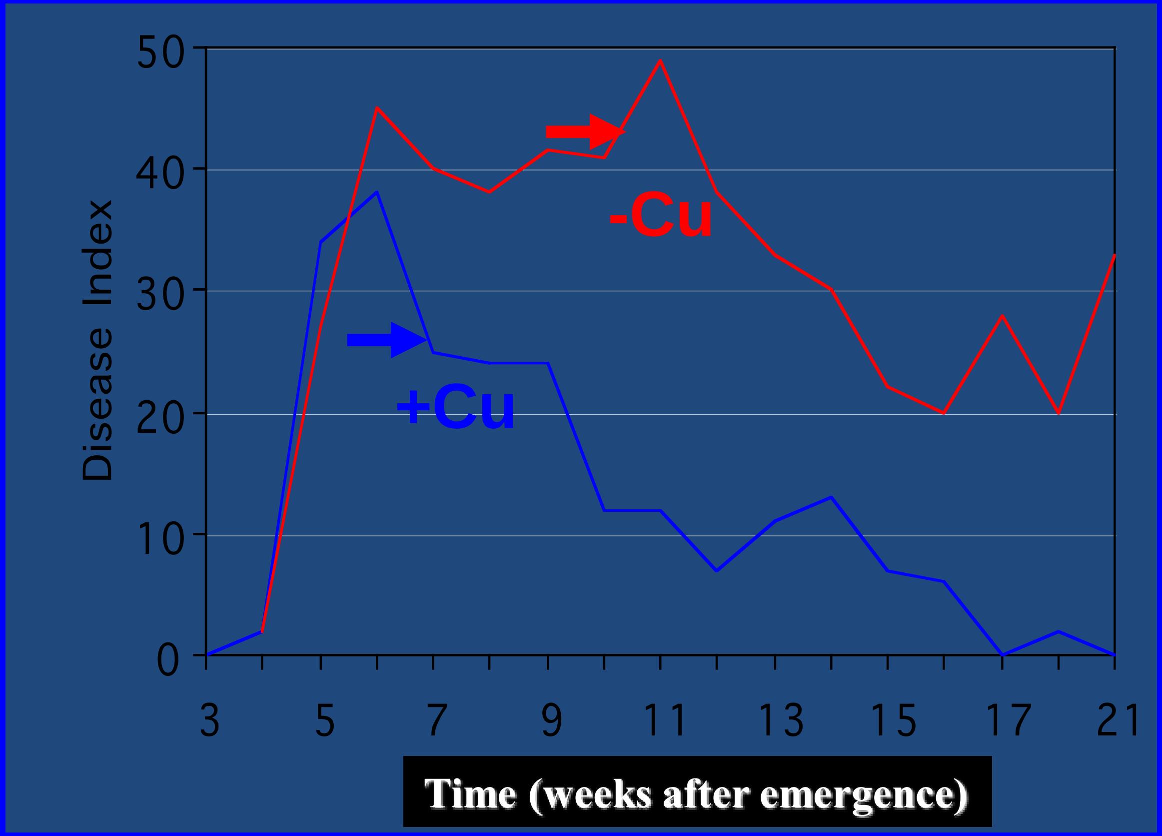
Effect of Copper on Two Wheat Diseases

Ergot sclerotia in wheat

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

CHO

Mn

Photosynthesis

Glycolysis (energy reactions)

Mn

Shikimic Acid

Root Growth

Carbohydrate, hormone &

Mn

Amino Acid Synthesis

Amino Acids

Cyanogenic

Mn

Glycosides

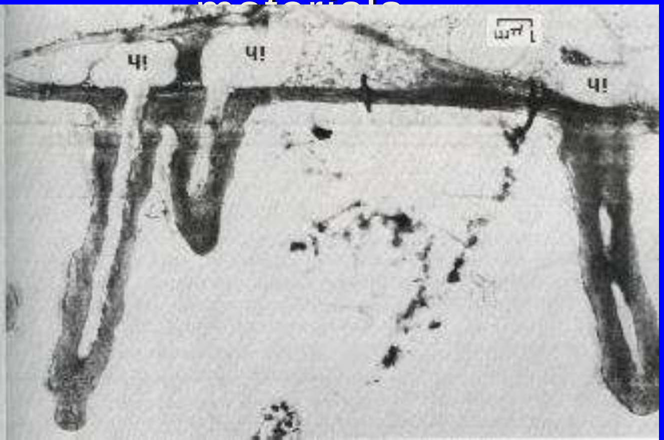
Phenylalanine

ammonia-lyase

Mn

Cu

COUMARINS LIGNINS FLAVANOIDS = Defense materials

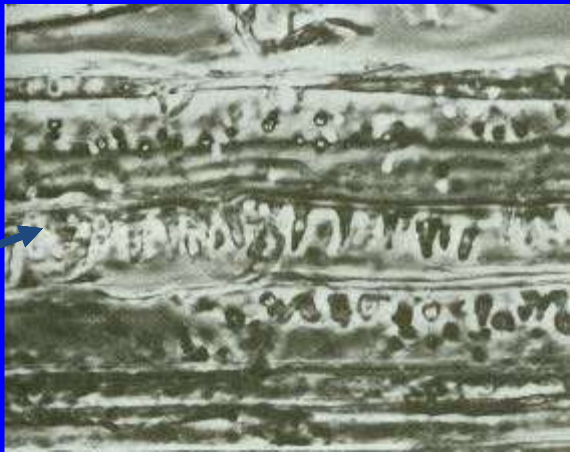


"Lignituber" formed in response to cell Penetration.

Wheat

Triticale

(After Skou, 1975)



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

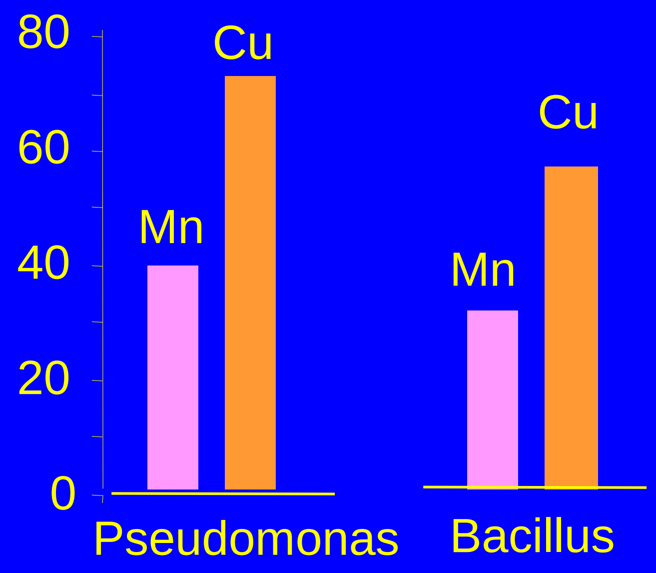
Anthracnose

Potato virus X

Maize stalk rot

Disease as a Symptom of Deficiency

- **Take-all:** **manganese, Cu, etc. (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**

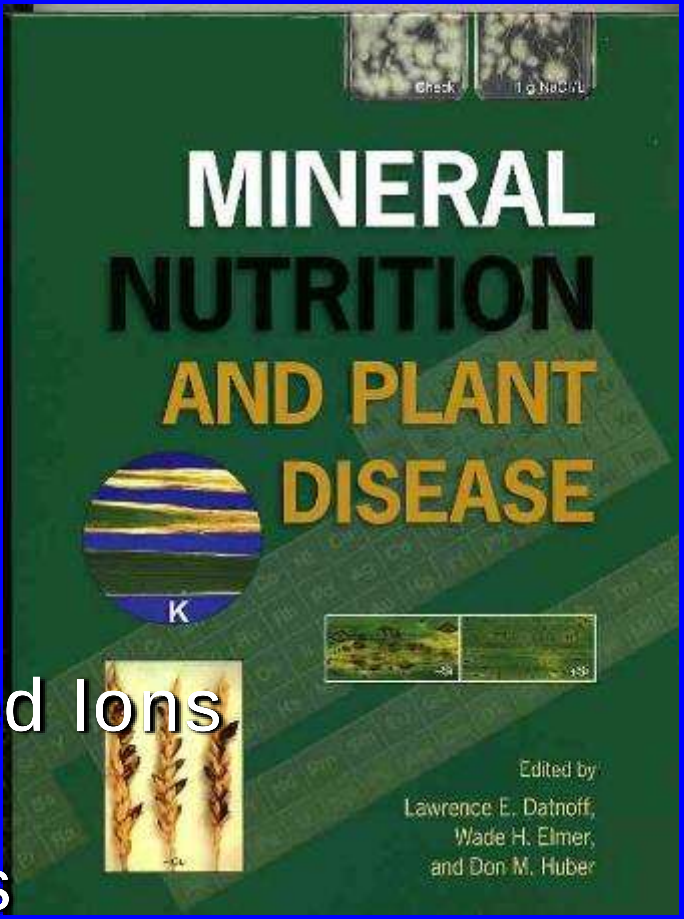


Taken up in 90 hours from hydroponics solutions by wheat rhizosphere bacteria

After Voss 2001

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



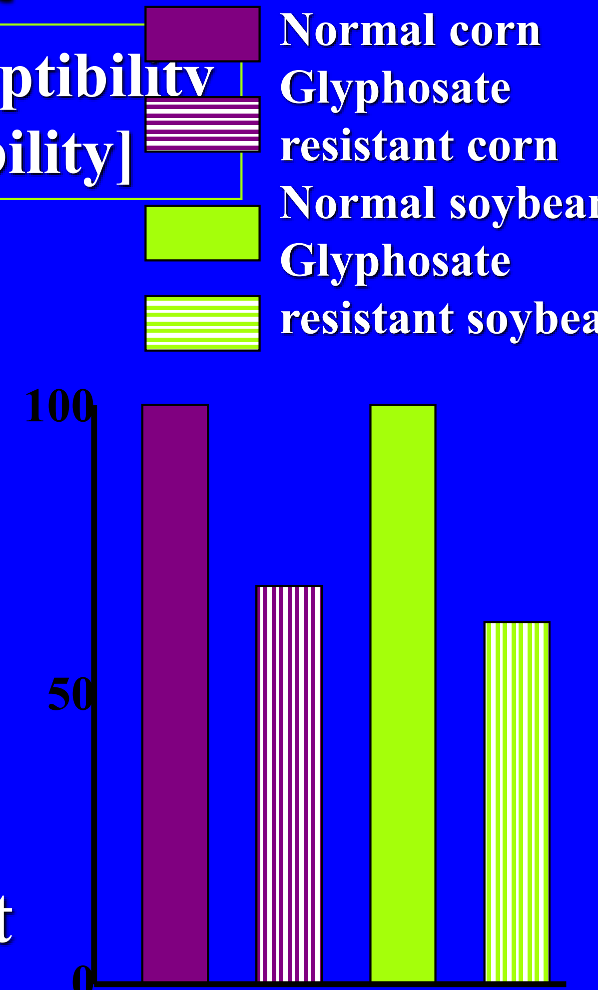
Keys to Using Nutrition to Manage Disease

1. Genetics of the Plant

Immunity<-->Resistance<-->Tolerance<-->Susceptibility

[Nutrient uptake efficiency, nutrient availability]

- **Stage of growth**
- **Age**
- **Health**
- **Environment**



Effect of the glyphosate resistance gene on Mn uptake efficiency

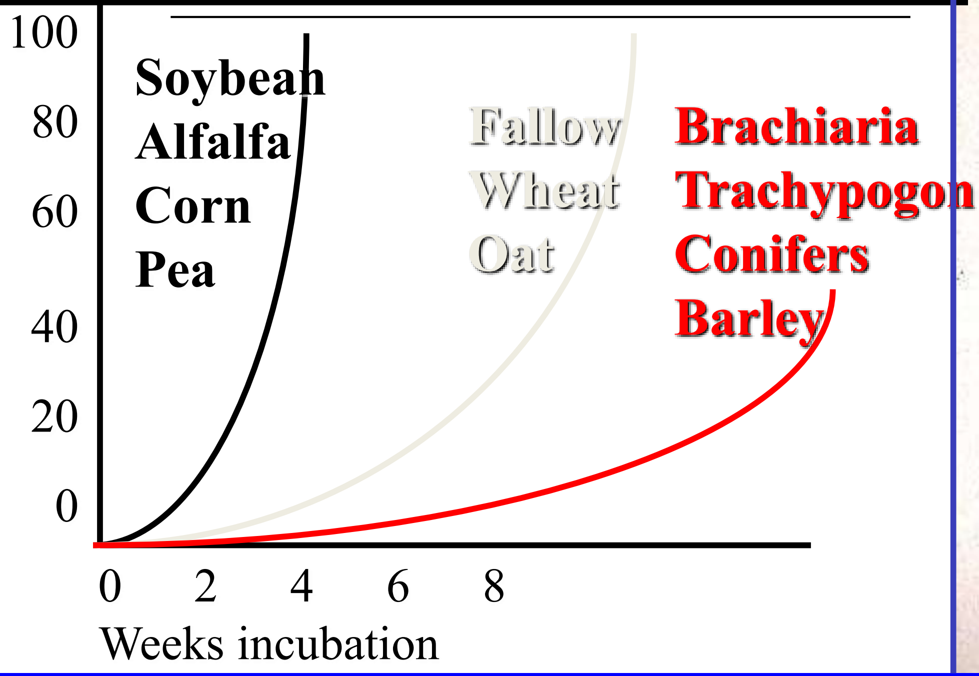
Keys to Using Nutrition to Manage Disease

2. Nutrient Form or Availability

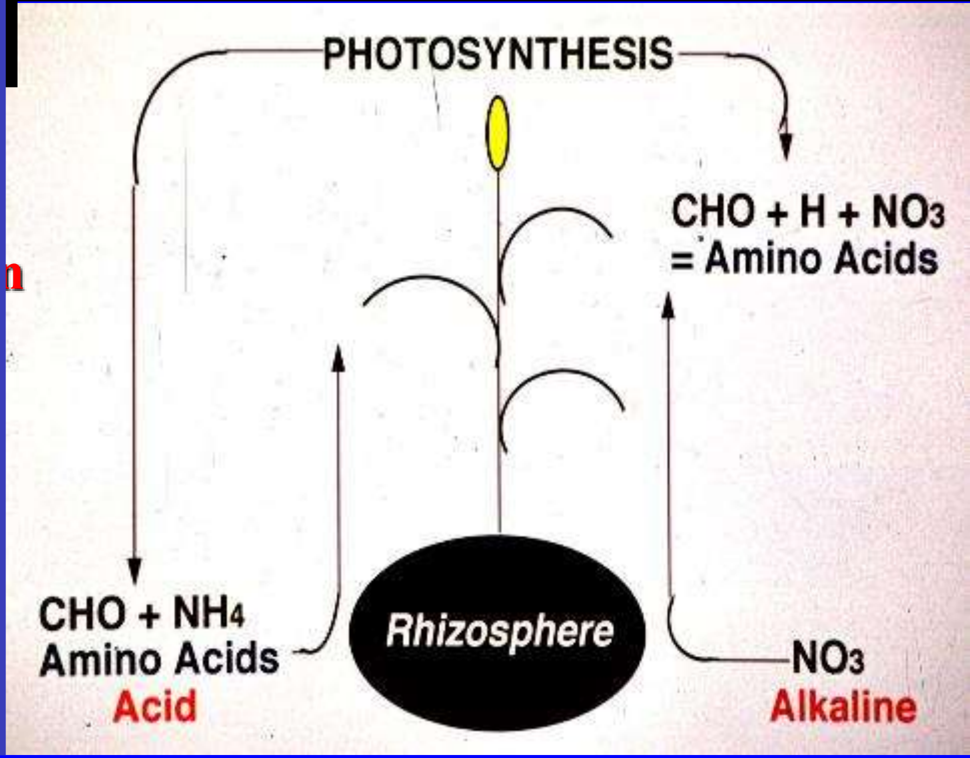
Oxidized<-->Reduced, Soluble<-->Non-soluble

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

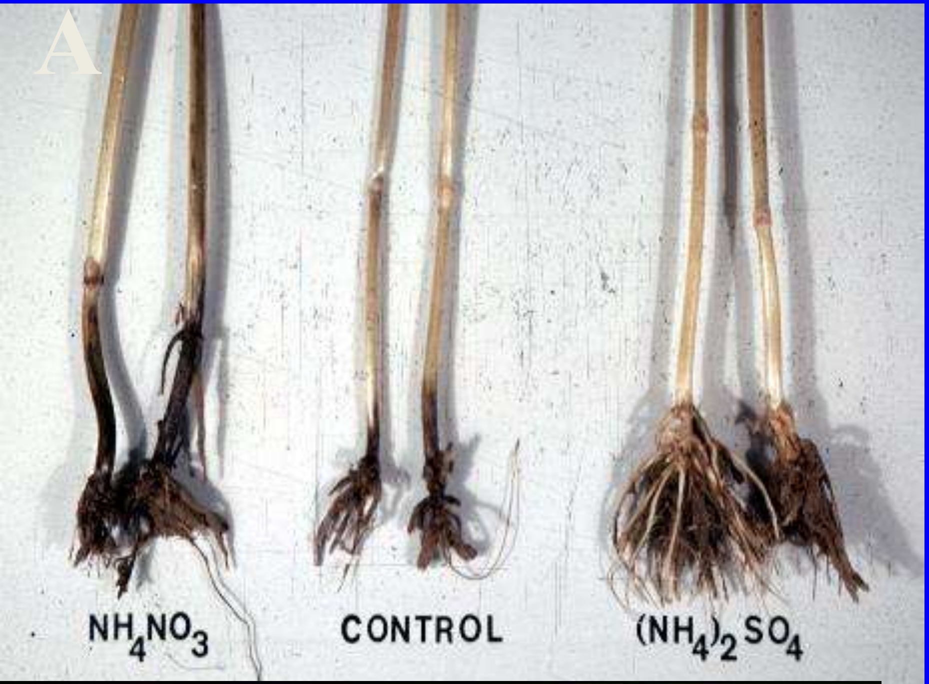
Crop	Disease	Pathogen
Bean *(P. vulgaris)*	Root rot	*Thielaviopsis basicola*
	Root knot	*Meloidogyne*
Carrot	Root rot	*Sclerotium rolfsii*
Corn	Stalk rot	*Gibberella zeae*
EggPlant	Wilt	*Fusarium oxysporum*
Onion	White rot	*Sclerotium rolfsii*
Pea	Root rot	*Pythium* spp.
Potato	Scab	*Streptomyces scabies*
	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*

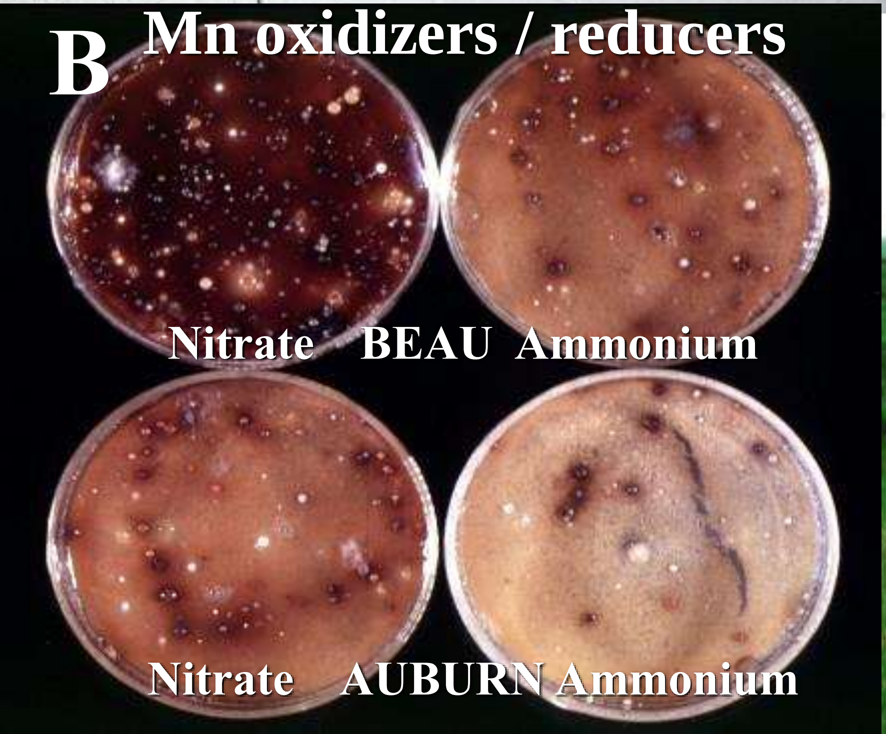
Effect of N form & inhibiting nitrification on Take-all and rhizosphere Mn oxidizers

A. N form on Take-all

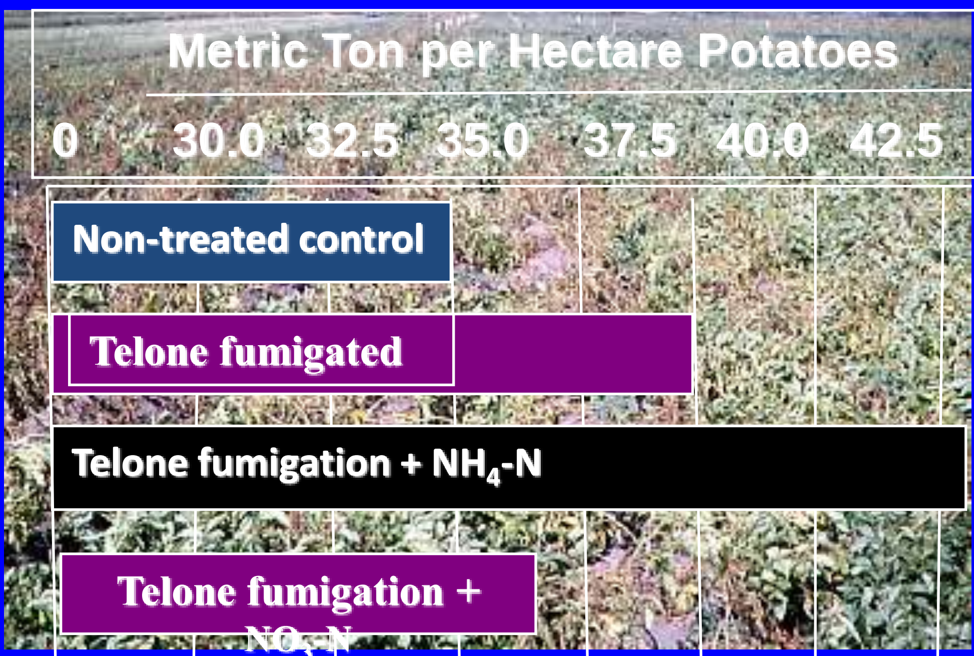
B. Manganese oxidizers

C. -/+ Nitrification inhibitor

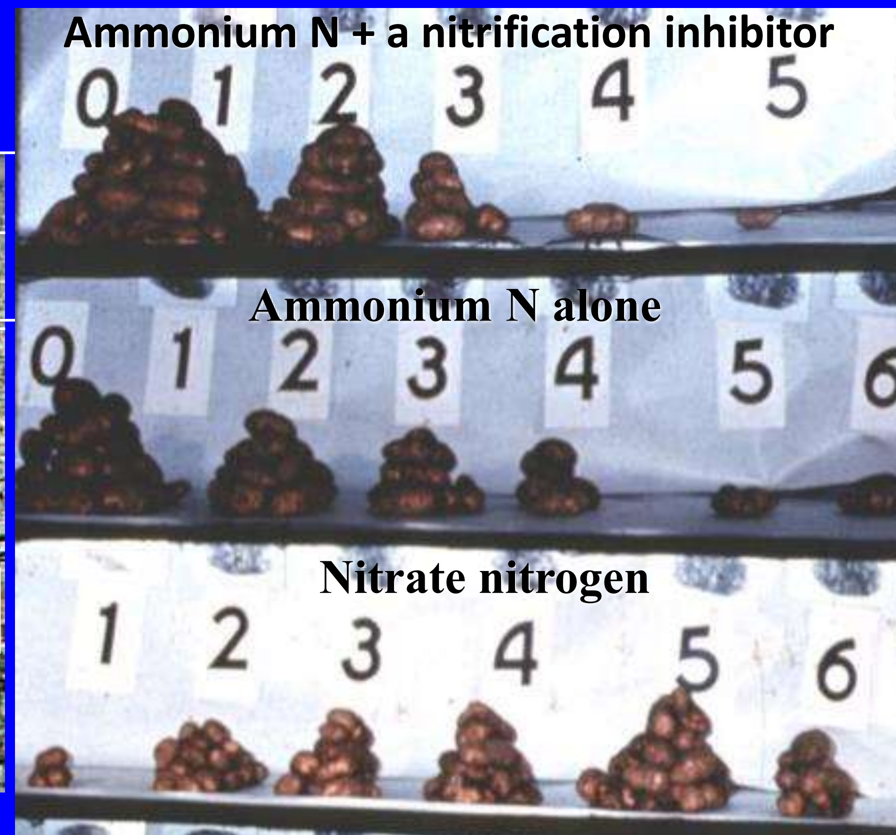




Effect of N Form on Yield of *Verticillium* Infected Potato



Effect of Inhibiting Nitrification on Potato Scab

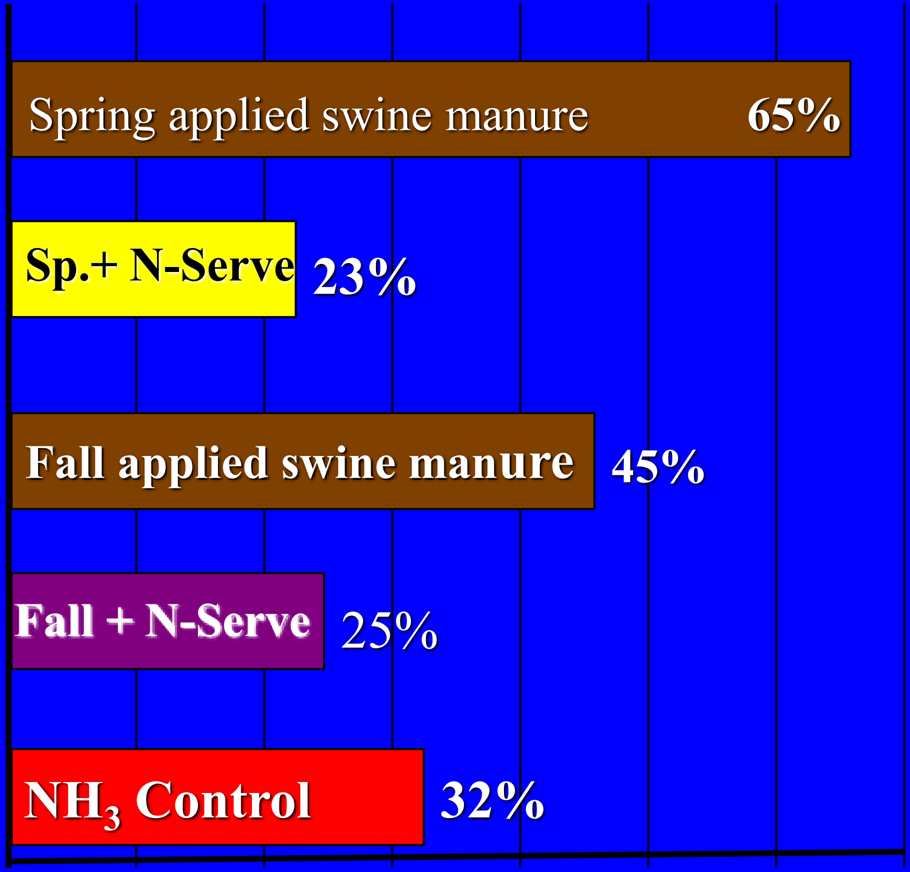


Disease scale: 0=no surface scab, 2=10% surface scab, 6=30% scab.

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

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

Spring versus Fall application of manure



Keys to Using Nutrition to Manage Disease

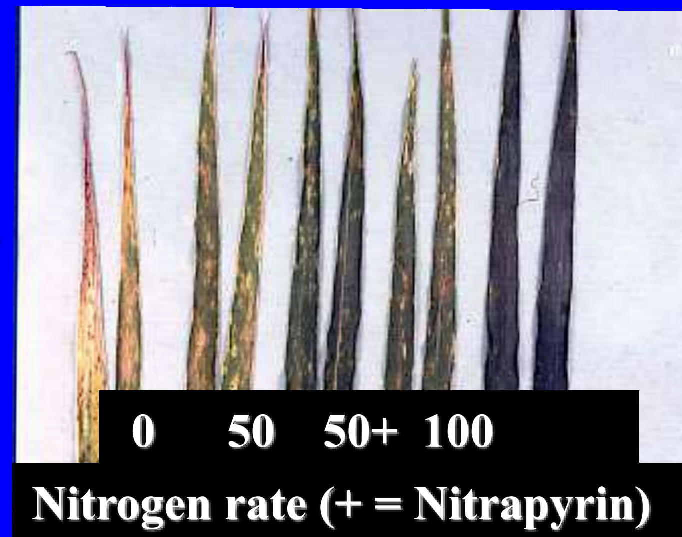
3. Rate Applied or Available

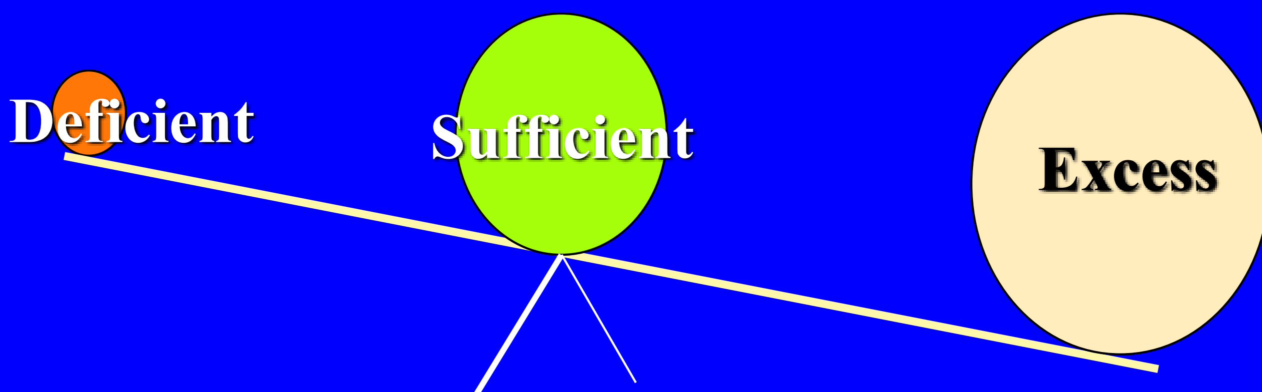
- **Amount available**

  Deficiency to sufficiency versus

  Sufficiency to excess for the particular

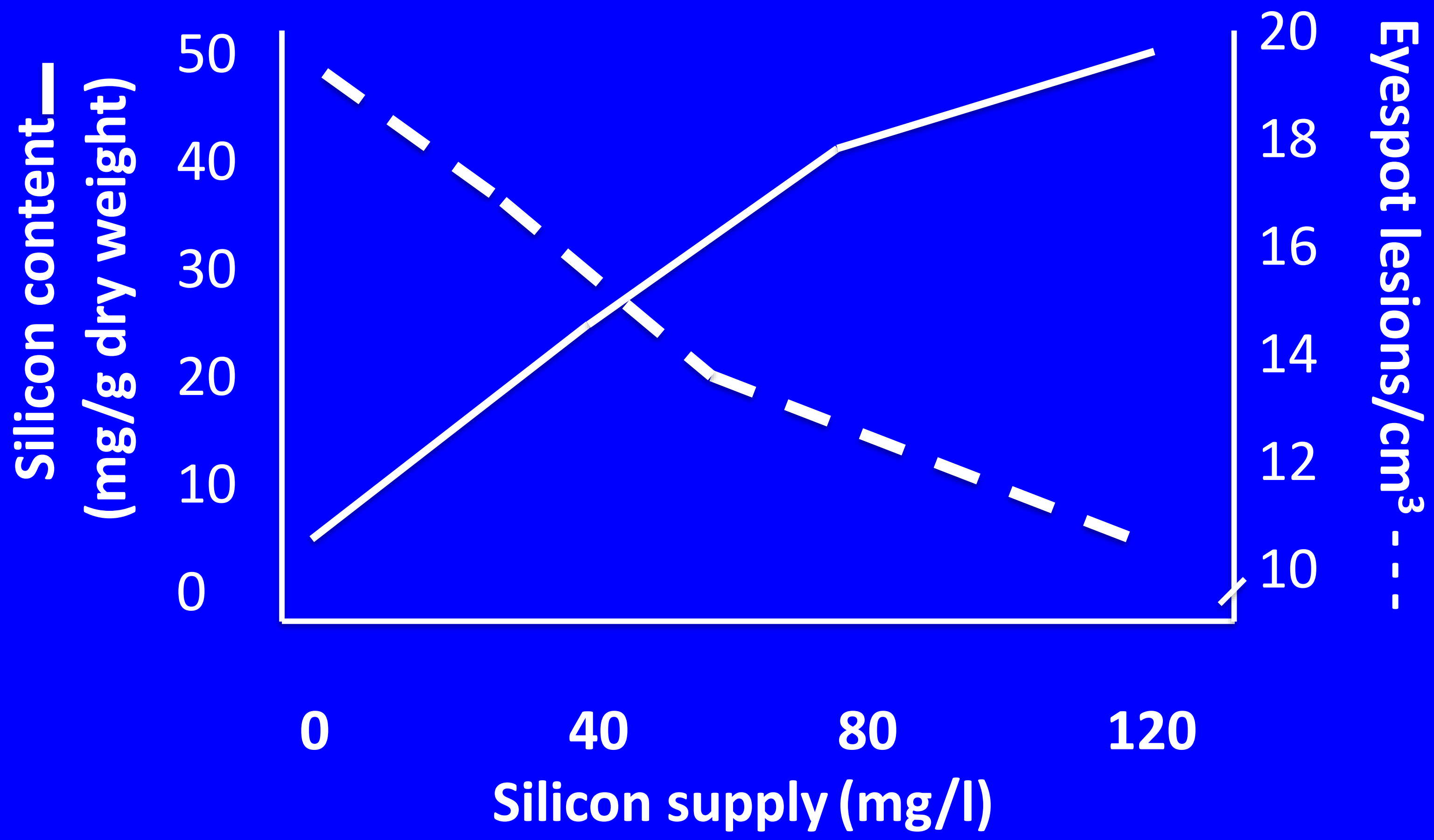
- **Time available**
- **Nutrient balance**





Corn is continuous; legumes have a ‘recovery’ window

Tissue Silicon and Blast Susceptibility (*Pyriculara oryzae; Magnaporthe grisea*)



Relationship of Calcium Rate to Pectolytic Enzymes and Soft Rot Caused by Erwinia carotovera

(after Platero and Tejerina, 1976)

Calcium content (mg/g dry wt)	Pectolytic activity (relative units)* Polygalturonase	Pectin transeliminase	Symptom severity
6.8	62	7.2	4
16.0	41	4.5	4
34.0	21	0	0

*0 = no decay; 4 = Complete decay within 6 days

Relationship of B Rate to Red Spider Mite Severity

B supply (mg/l)	Mites (No/m^2)	Feeding holes No./cm^2)	Tissue Cyanidin (ug/g)
0	1.8	67	2-5
0.5	1.7	60	10-18
5.0	1.2	30	
50	1.0	20	20-32
500	0.9	17	
1000	0.9	12	

Keys to Using Nutrition to Manage 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	% Kill
NH3 + N-Serve	September	14
Urea Granuals	February	40
28% N Solution	February	60
Urea	April	14

Time N applied on yield & sharp eyespot

N	% lodging	Index	Yield (kg/ha)
Fall	3	2.1	3036
Early spring	73	3.2	2640

Urea - Feb. NH4 - Sept.

Mobility of Nutrients in Plants

Very mobile		Moderately	Somewhat Poorly
N	Mg	Fe	Ca
P	S	Cu	Mn
K	Mo	Zn	
Ni		B	
Cl		Co	
Na		Si	

Keys to Using Nutrition to Manage Disease

5. Source and Associated Ions

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

Gibberella stalk rot of corn

Effect of KCl on the incidence of take-all in wheat (+ NH_4-N)

KCl (kg/ha) Autumn	Spring	% infected roots	Grainyield (t/ha)
0	0	45	5.3
56	0	34	5.7
56	185	11	6.5

Christensen et al., Agron, J. 73: 1053-1058; 1981

Effect of copper on wheat melonosis (*Pseudomonas cichorii*). After Mahli et al, 1989

Treatment	Rate (kg Cu/ha)	Application Method	Percent disease	Grain yield (kg/ha)
Control	Nil	None	92	294
CuSO4	10	Banded	76	511
CuSO4	10	Incorporated	34	2016
CuSO4	10	Foliar spray	6	2116
Cu-Chelate	2	Foliar spray	7	2505

Nutrient Interactions – (Plant, rate, pH effect)

Element	Decreases uptake	Increases uptake
NH_4	K, Ca, Mg, Cu	Fe, Mn, P, Ni, Zn
NO_3	P, S, Cl, Fe	K, Cu, Mn
Mo	Fe	Mn, (Fe), NO_3 utilization
P	Cu, Fe, Mn, Ni, Zn	Ca, Mn, Mo
K	Mo, Ca, Mg, NH_4, B, Cu	NO_3, Fe
S	Mg, Mo	K, Ca, NH_4
Ca	Al, Cu, K, Mg, Fe, Mn, B, Zn	P, B
Mg	K, Ca, Mn, Fe, Ni	P
B	Ca	Mn
Co	Ni	
Cu	Fe, P, Ca, Mo, K, Mg, Ni, Zn	Mn
Fe	P, Ca, Mn, Ni	
Mn	P, Ca, Fe, (Zn)	B, Mo, (Zn)
Zn	P, Ca, Fe, Ni	NH_4
Cl	NO_3	Mn, NH_4
Si		Mn, P

Keys to Using Nutrition to Manage 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 soybean control is right.

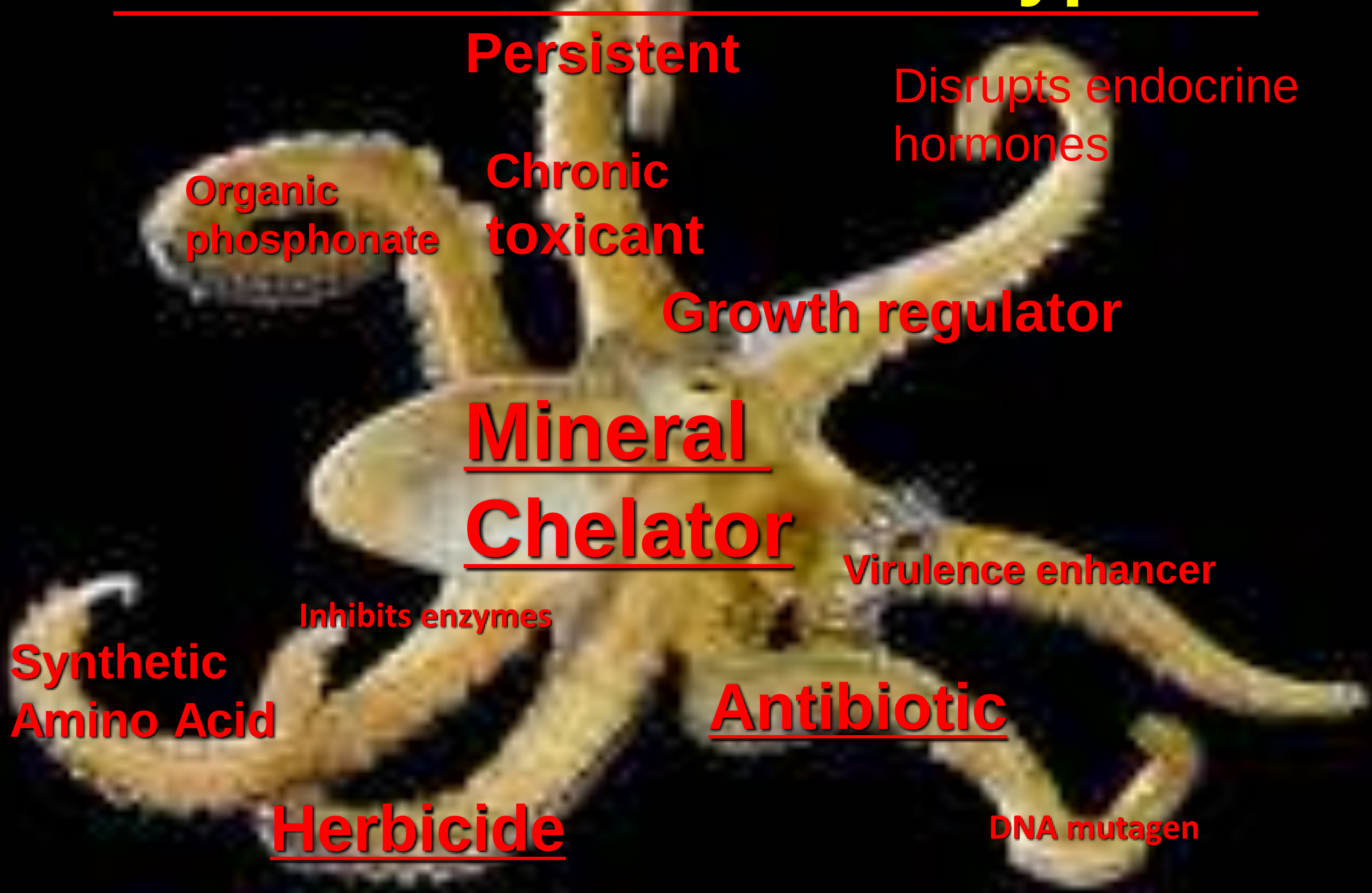
Less take-all of wheat in a Firm (right) than loose seed-bed (left)

Pesticide Interactions with Nutrition

- **Many pesticides are mineral chelators**
  - ‘Immobilize’ (or enhance) critical mineral co-factor for enzymes
  - Organic phosphates, amino-phosphonates, dithiocarbamates, etc.
- **Herbicides - specific ion or general immobilization**
  - Cu examples: Puma Gold (fenoxyprop); Tordon
  - General: Glyphosate, Glufosinate
  - Others: Zn, Fe, Co, Ni, B, etc.
- **Environmentally influenced** (activity, stability, persistence)
  - pH, moisture, temperature, microbial activity, soil type


Compensate for Reduced Availability if using the Tool!

Some Characteristics of Glyphosate



Immobilizes B, Ca, Co, Cu, Fe. K, Mg, Mn, Ni, Zn

% Mineral Reduction in Roundup Ready® Soybeans Treated with Glyphosate

Plant tissue	Ca	Mg	Fe	Mn	Zn	Cu
Young leaves	40	28	7	29	NS	NS
Mature leaves	30	34	18	48	30	27
Mature grain	26	13	49	45		

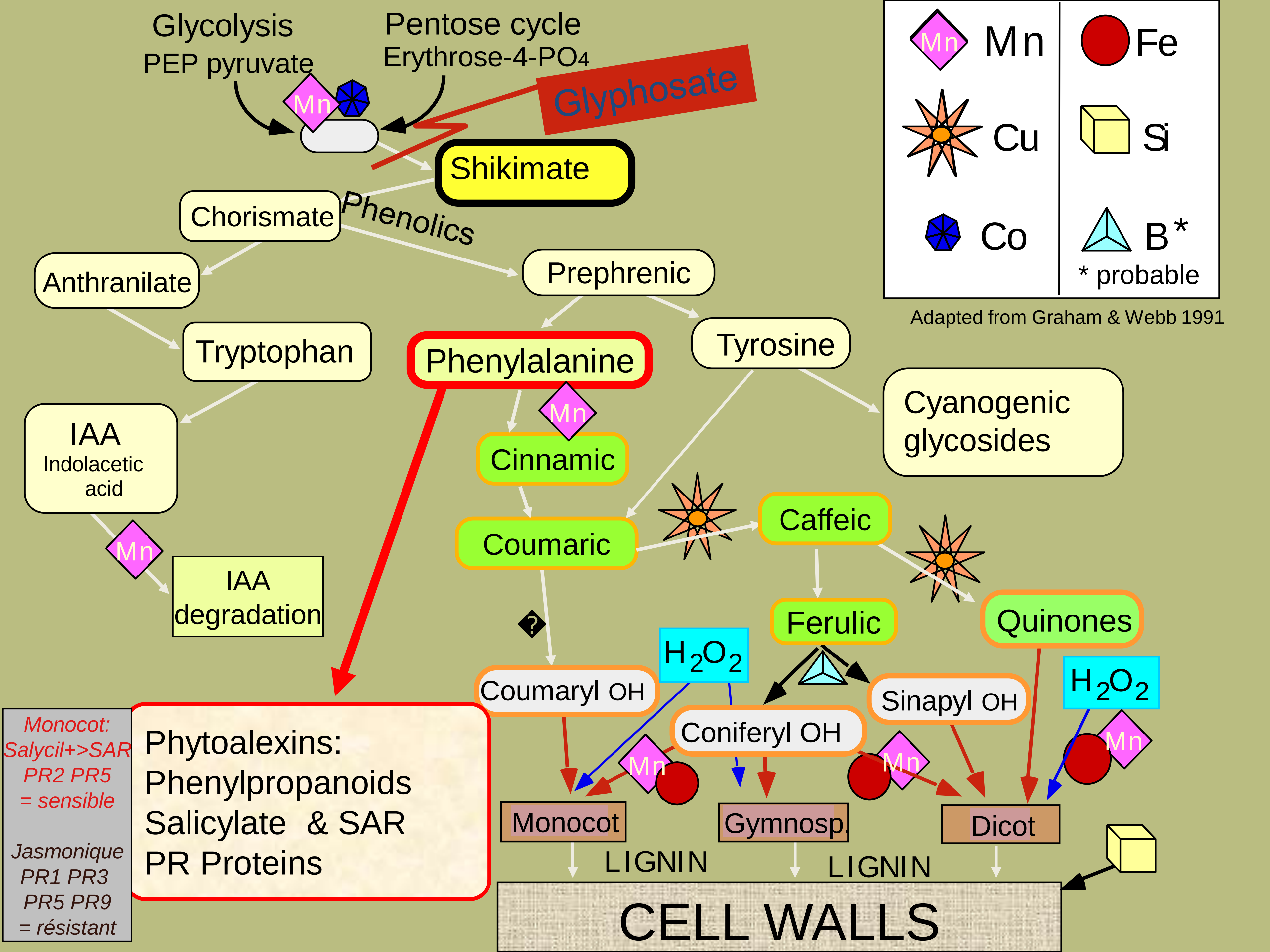
Residual glyphosate?

Reduced:	
Yield	26%
Biomass	24%

After Cakmak et al, 2009

Some of the 291 Enzymes Glyphosate Down Regulates

Enzyme	-Fold change
Taurine ATP-bindingsystem	11.07
Glutamate synthase	6.06
Aminomethyl transferase	5.58
Tyrosine aminotransferase	4.36
Thioredoxin reductase	4.20
NADH dehydroenase	4.04
Riboflavin synthase	3.57
3-phosphoadenosine-5-phosphosulfte reductase	3.75
Membrane bound ATP synthase	3.67
Acetolactate synthase	3.59
Pyridine nucleotide transhydrogenase	3.50
Shikimate kinase	3.36
3-deoxy-D-arabino-heptulosonate-7-phosphatase	3.38
Sulfite reductase	3.19
RNAase	3.18
Glutathione S-transferase	3.04
D-amino acid dehydrogenase	3.00
Glucose-6-phosphate dehydrogenase	2.67
ATP sulfurulase	2.65
5-enolpyruvylshikimate-3-phosphate synthetase (EPSPS)	2.62


Glycolysis
PEP pyruvate
Pentose cycle
Erythrose-4-PO4
Glyphosate
Mn
Fe
Cu
Si
Co
B*
* probable
Adapted from Graham & Webb 1991
Shikimate
Chorismate
Phenolics
Anthranilate
Prephrenic
Tryptophan
Phenylalanine
Tyrosine
Cyanogenic glycosides
IAA
Indolacetic acid
Cinnamic
Caffeic
Coumaric
IAA degradation
Ferulic
Quinones
H_2O_2
Coumaryl OH
Sinapyl OH
Coniferyl OH
Monocot: Salycil+>SAR PR2 PR5 = sensible
Jasmonique PR1 PR3 PR5 PR9 = résistant
Phytoalexins:
Phenylpropanoids
Salicylate & SAR
PR Proteins
Monocot
Gymnosp.
Dicot
LIGNIN
LIGNIN
CELL WALLS

Reduced Nutrient Efficiency of Isogenic RR Soybeans

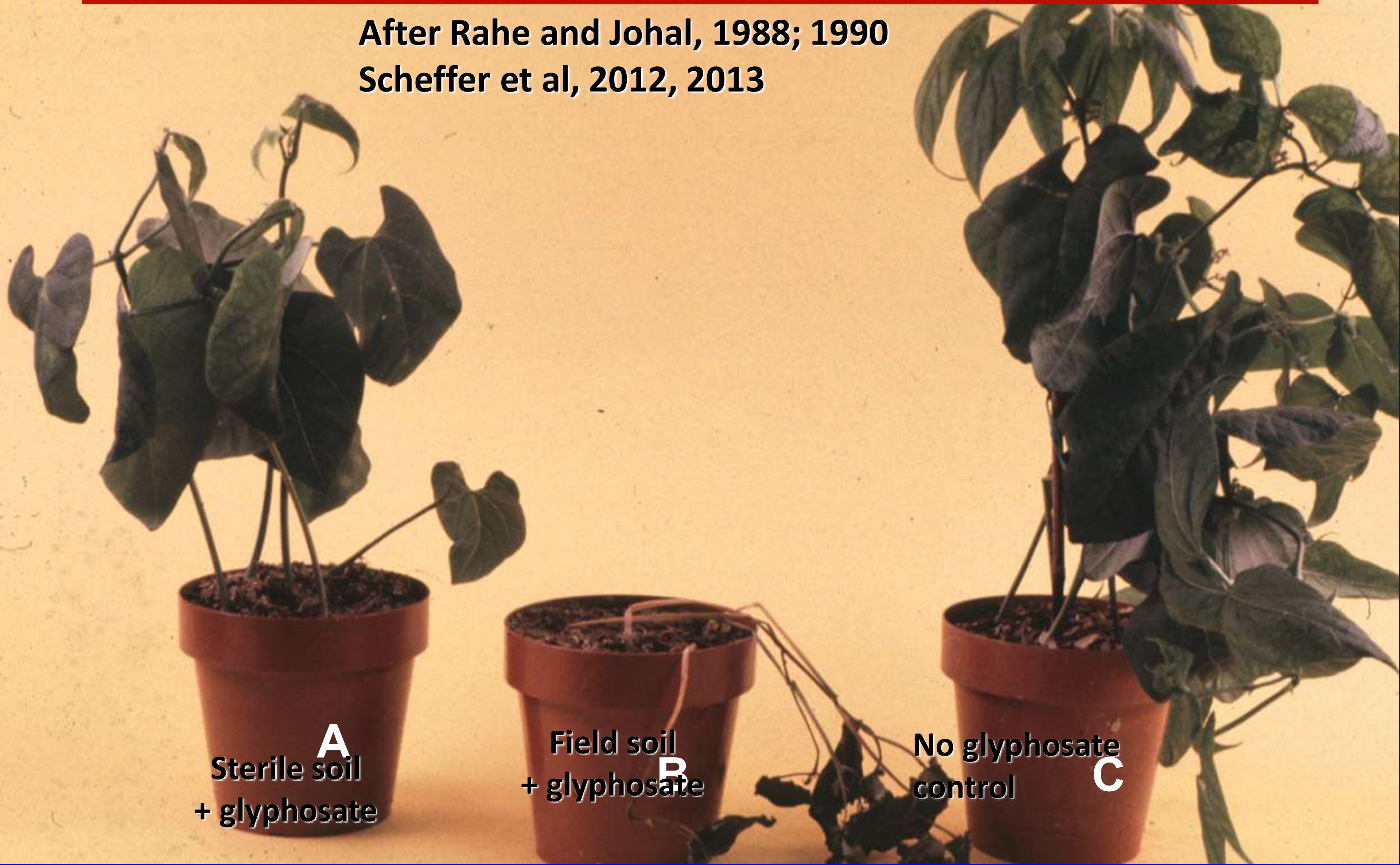
Tissue: Isoline	Mn %	Zn %
Normal	100	100
Roundup Ready®	83	53
RR + glyphosate	76	45

Copper, iron, and other essential nutrients were also lower in the RR isoline and reduced further by glyphosate!

After Zobiole et al., 2008, 2009

Herbicide action is by soil-borne fungal pathogens

Glyphosate Increases Disease Susceptibility



Some Plant Pathogens Increased by Glyphosate

Corynespora cassicola
Fusarium spp.
Phytophthora spp.
Pythium spp.
Rhizoctonia solani
Thielaviopsis bassicola
Xylella fastidiosa
Myrothecium verucaria
F. solani f.sp. Pisi
Gaeumannomyces graminis
Magnaporthe oryzae

("Emerging" and "reemerging diseases")

Fungal Mn oxidation in soil (increased virulence)

Abiotic: Nutrient deficiency diseases; bark cracking, mouse ear, 'witches brooms', drought stress, chill damage

Foliar application of glyphosate

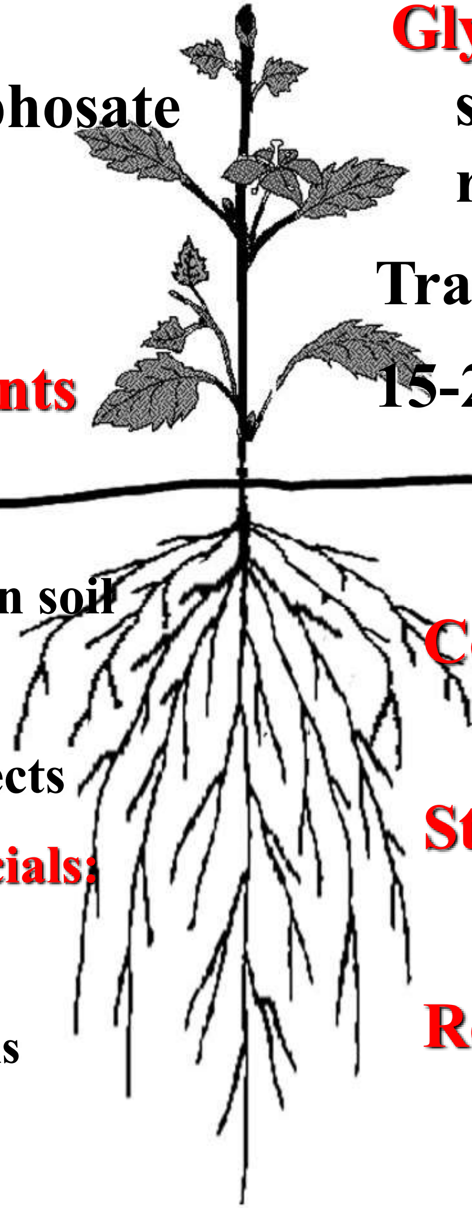
Systemic movement throughout the plant

Chelation of micronutrients

Glyphosate accumulates in shoot, root and reproductive tissues

Translocated to roots

15-20% released into soil



Glyphosate can accumulate in soil (slow to little degradation)

Residual soil and residue effects

Glyphosate is toxic to beneficials:

- N-fixing microbes
- Mycorrhizae
- Biological control organisms
- Earthworms
- PGPR organisms

Compromises plant disease resistance

Stimulates soilborne diseases

Reduces nutrient uptake

Schematic of glyphosate interactions in soil

Nutrient Management for Citrus Disease Control

Principle	Implementation	Nutrients
Time	Latent periods Flush periods	N, P, K, B, Ca, Fe, Mg, Cu*, Mn*, Zn*, Mo, Co, Ni
Method	Soil (Latent eriod) Foliar (Flush period)	
Form	NH_4, NO_3, PO_3*, PO_4, SO_4	
Rate	Compensation, Maintenance	Tissue test
Integration	Weed control	No glyphosate/Liberty

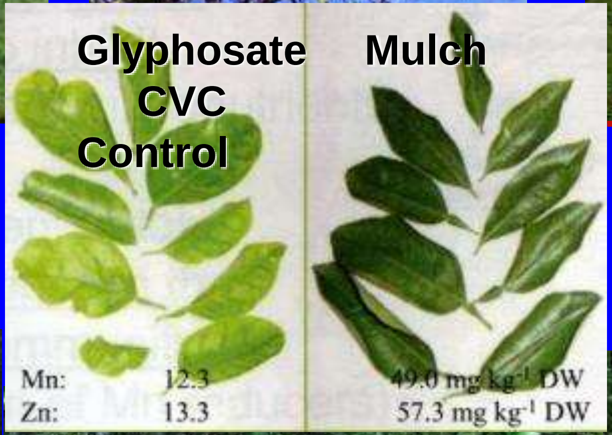
Multi-component Approach for CVC/HLB

Item	CVC	HLB
Target tissue	Xylem	Phloem
Time	All	Flushes
N Form	NH_4	NO_3
Strategy 1*	Resistance <u>and</u> Compensation	
(Plant)	Root/soil	Foliar (Phosphites)
	NH_4, Cl, Mn	Mn, Zn, Mo, Cu, Co, B, Mg
Strategy 2	Modify	Modify
(Environment)	Weed Control	Block N-source, weeding
	Inhibit nitrification	Shade, Mo, Mn, Co
Strategy 3	Inhibit	Suppress
(Pathogen)	Shikimate	NO_3, Cu-I

*Strategies: 1=plant, 2= environment, 3=pathogen

Citrus Variegated Chlorosis

Predisposition to CVC (*Xylella fastidiosa*) by glyphosate



Nutrient Management of HLB
(Boyd, Yamada, AgSpectrum, Dean, etc.)

Nutrient Program:

1. Compensate for nutrient disruption – N, K, Mn, Zn, Mo, Co
2. Optimize general nutritional needs
3. Timing, form, frequency, rate re infection cycle

REMEMBER

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

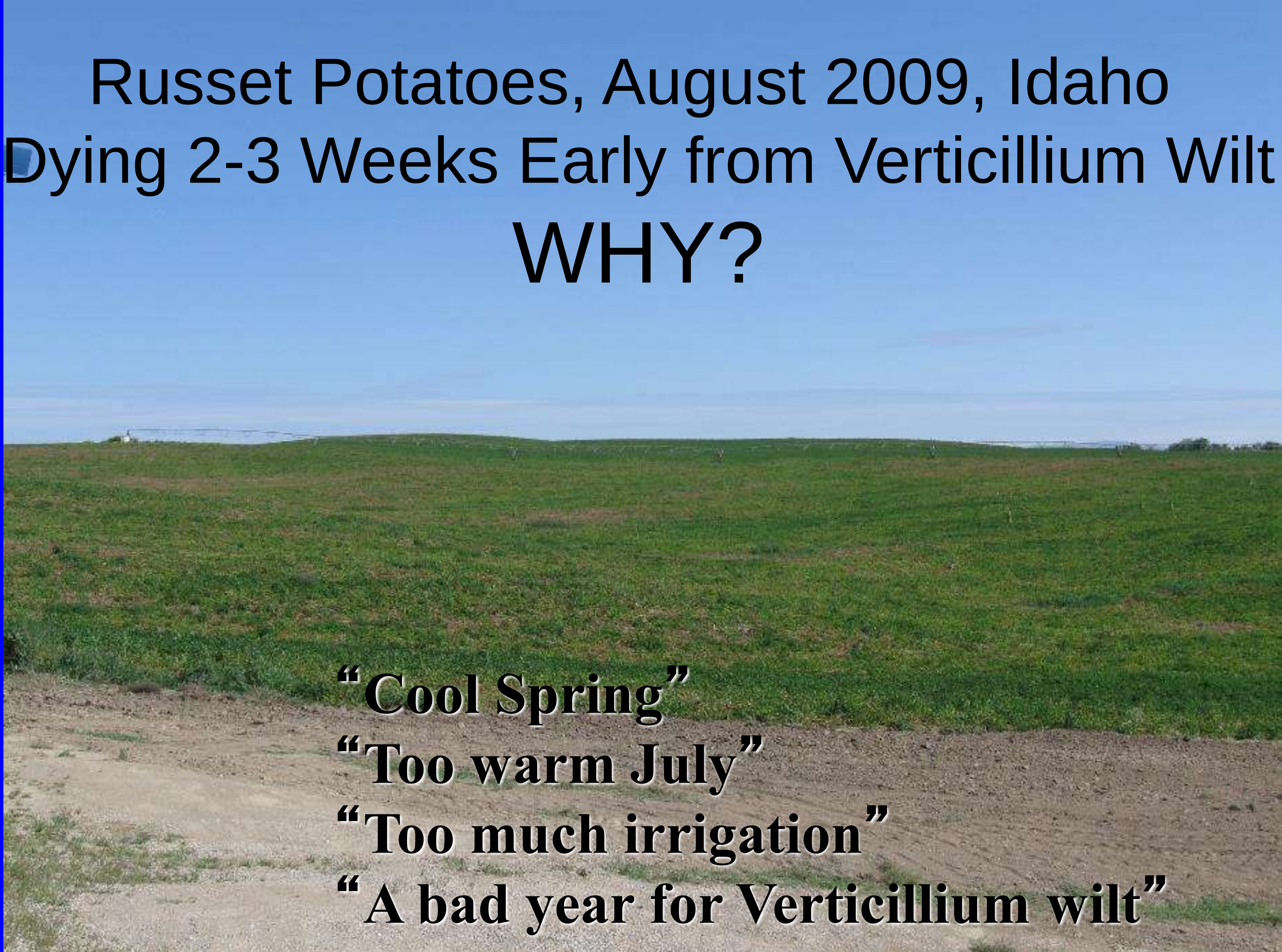
2. Changes in the nutrient related interactions of the plant - environment - and pathogen affect disease
   A. Increase plant resistance and defense response
   B. Make the environment less conducive for pathogenesis
   C. Reduce virulence or survival of the pathogen

3. Nutrient rate, form, time, source and method of application are important principles for disease control

4. Integrate nutrition and cultural practices for optimum yield, disease control, over-all plant health and nutrient quality

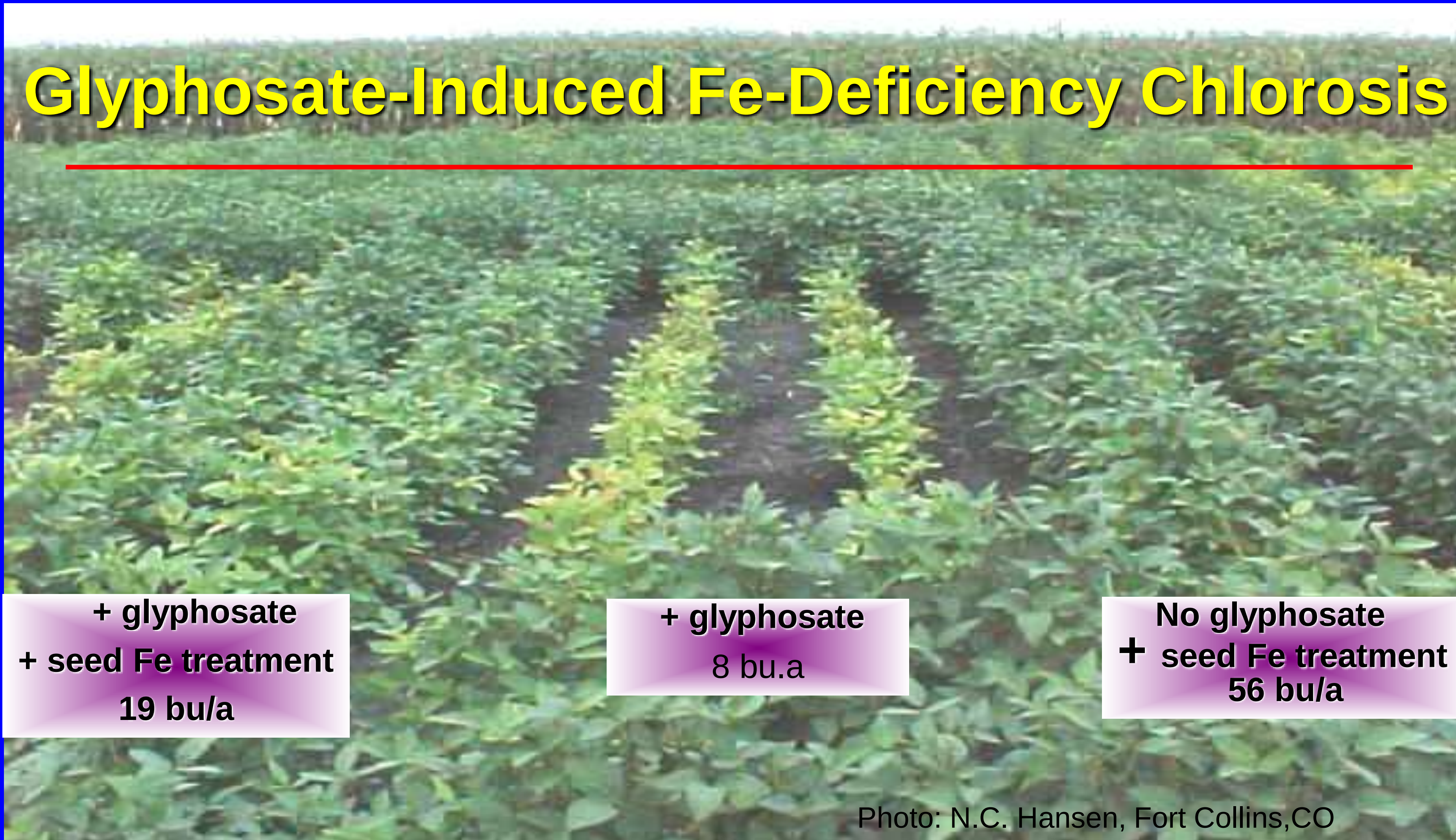
Russet Potatoes, August 2009, Idaho
Dying 2-3 Weeks Early from Verticillium Wilt

WHY?



"Cool Spring"
"Too warm July"
"Too much irrigation"
"A bad year for Verticillium wilt"

Glyphosate-Induced Fe-Deficiency Chlorosis



Interaction of seed-applied Fe and glyphosate application on Fe deficiency chlorosis in soybeans; Minnesota, USA

Jolley et al., 2004, Soil Sci. and Plant Nutrition 50:973-981

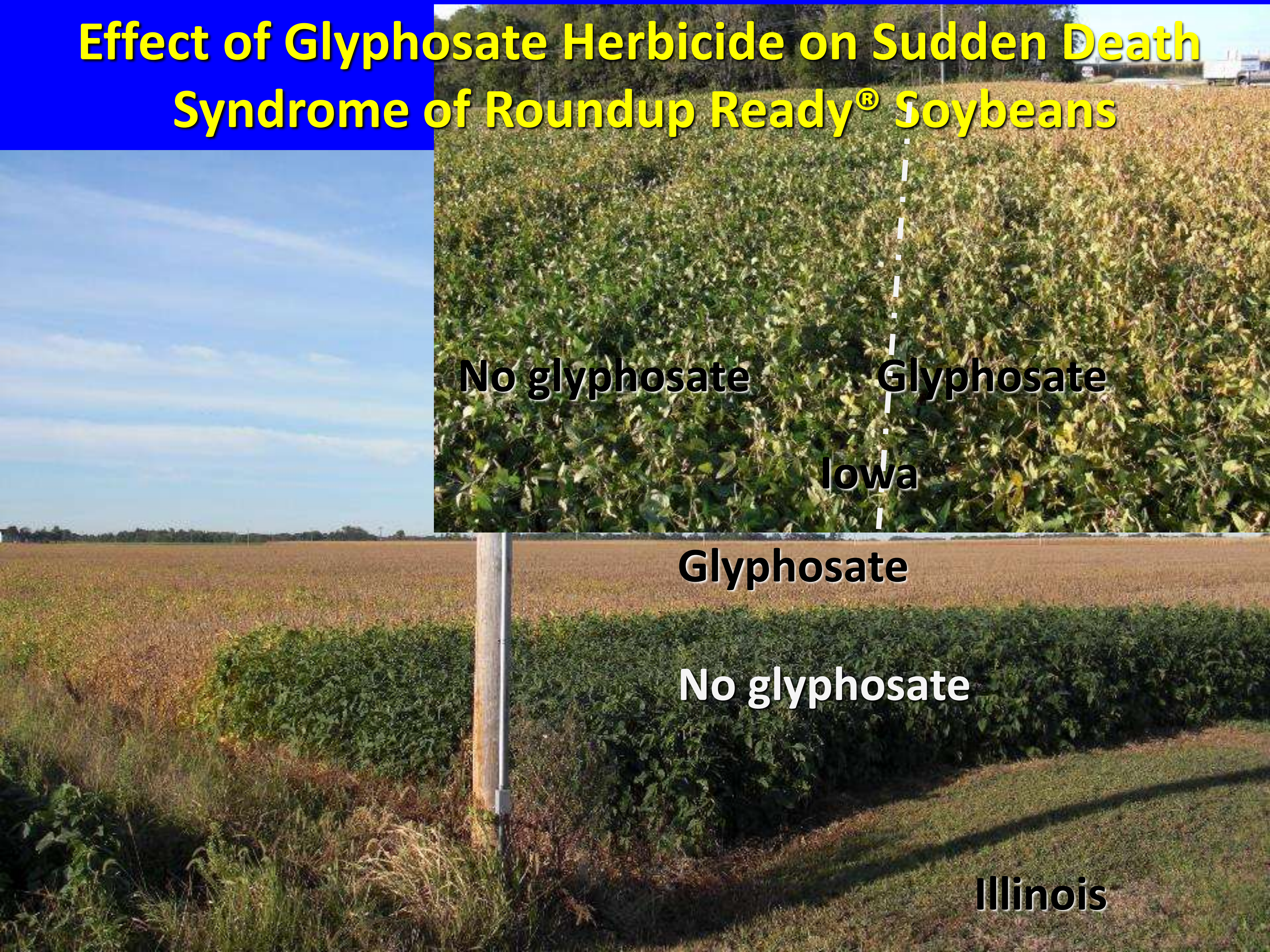
% Reduced Nutrient Density in RR versus Non-RR*

Nutrient	Alfalfa	Soy Beans**
Nitrogen	13 %	40 %
Phosphorus	15 %	------
Potassium	46 %	16 %
Calcium	17 %	26 %
Magnesium	26 %	30 %
Sulfur	52 %	------
Boron	18 %	------
Copper	20 %	27 %
Iron	49 %	18 %
Manganese	31 %	48 %
Zinc	18 %	30 %

*Third year, alfalfa, second cutting analysis; Glyphosate applied one time in the previous year

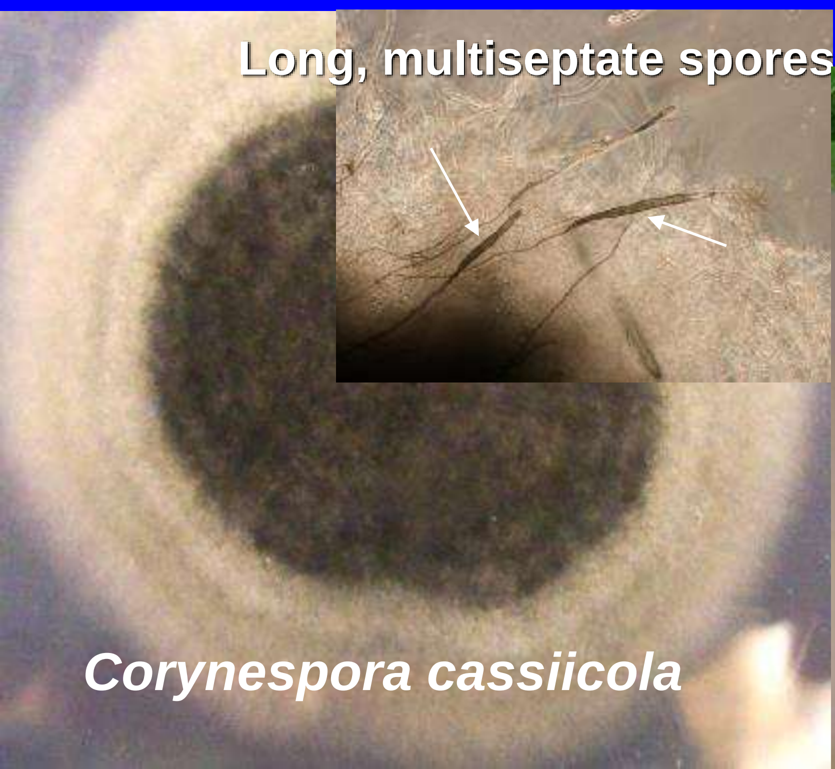
**Youngest mature leaf

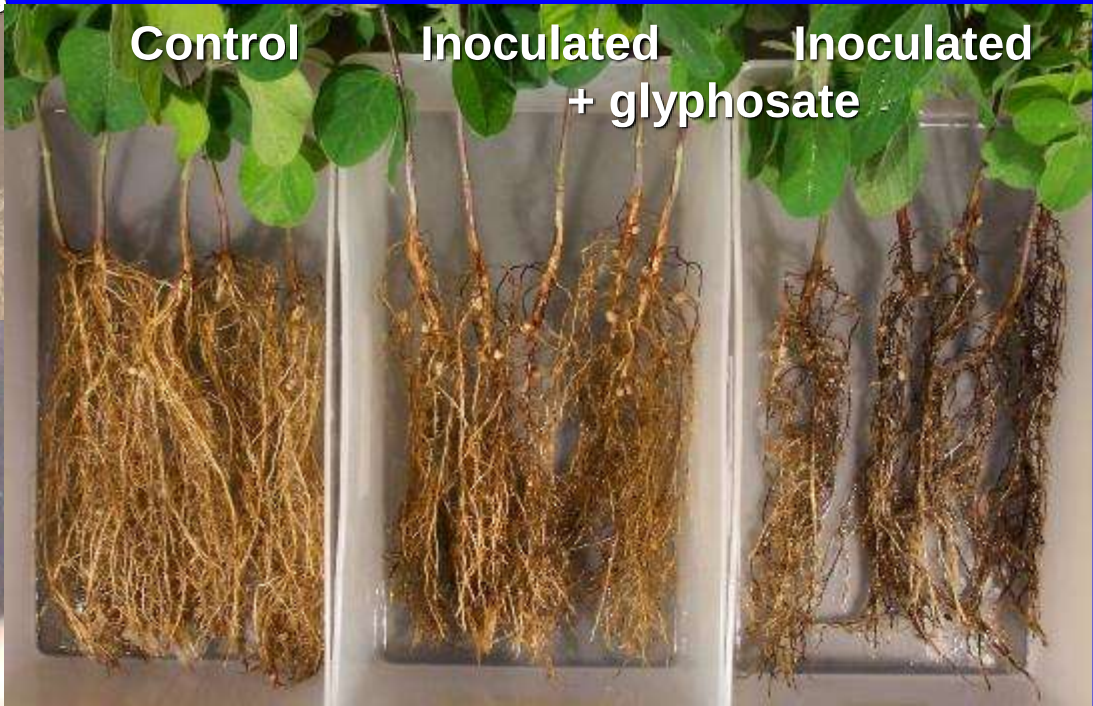
Effect of Glyphosate Herbicide on Sudden Death Syndrome of Roundup Ready® Soybeans



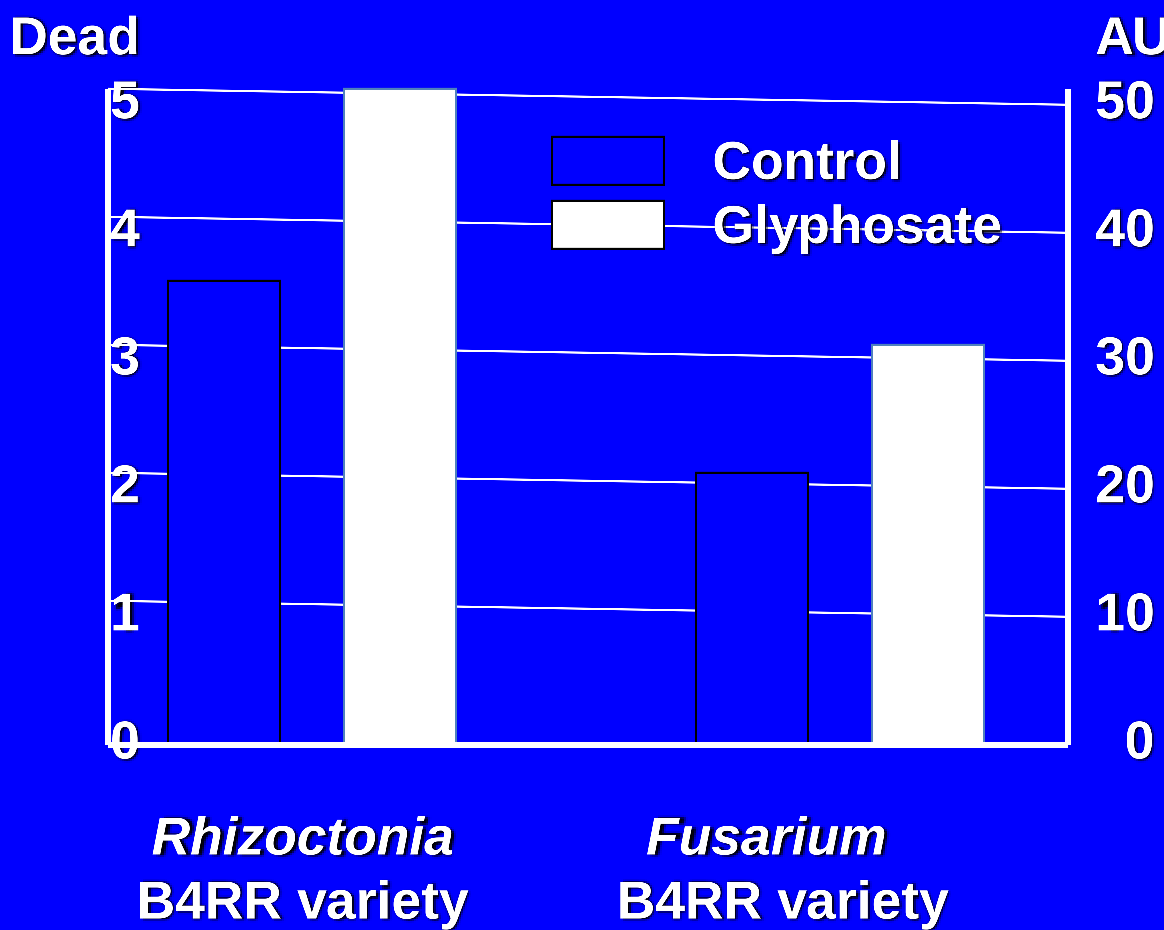
Corynespora Root Rot

- An extensive dark brown to black rotting of small lateral roots
- Generally considered a root "nibbler"
- Especially severe when glyphosate is applied to near-by weeds
- Especially severe when glyphosate is applied to the plant





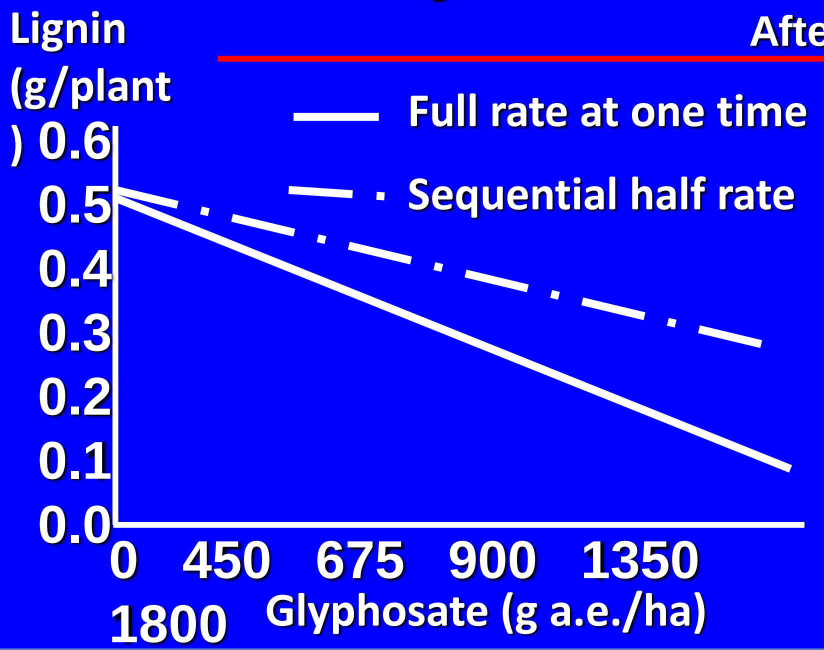
Impact of Glyphosate on Sugar Beet

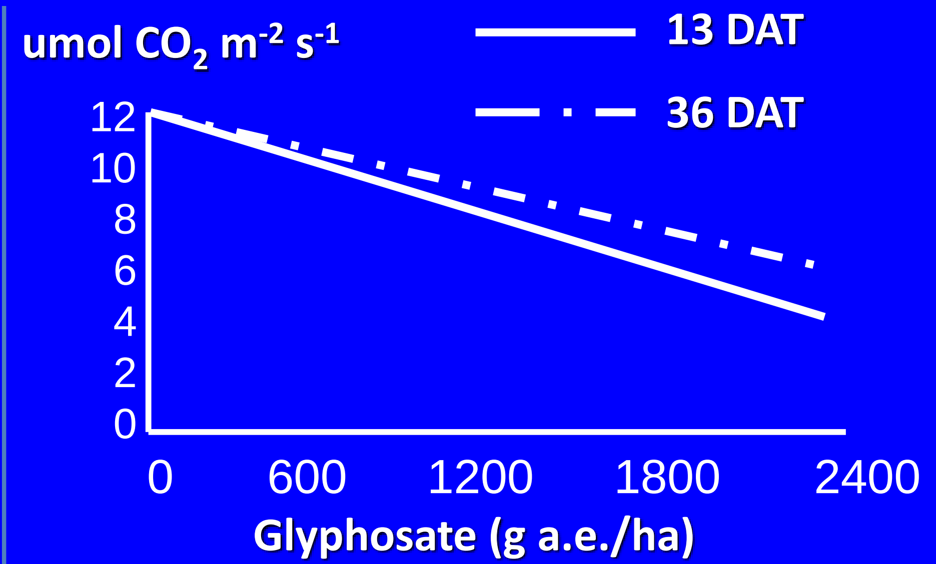


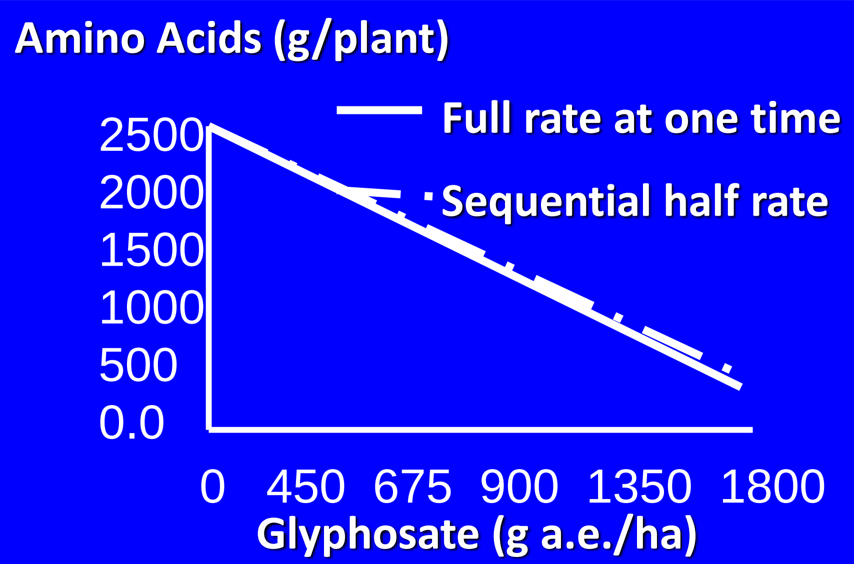
"Precautions need to be taken when certain soil-borne diseases are present if weed management for sugar beet is to include post-emergence glyphosate treatments." Larson et al., 2006

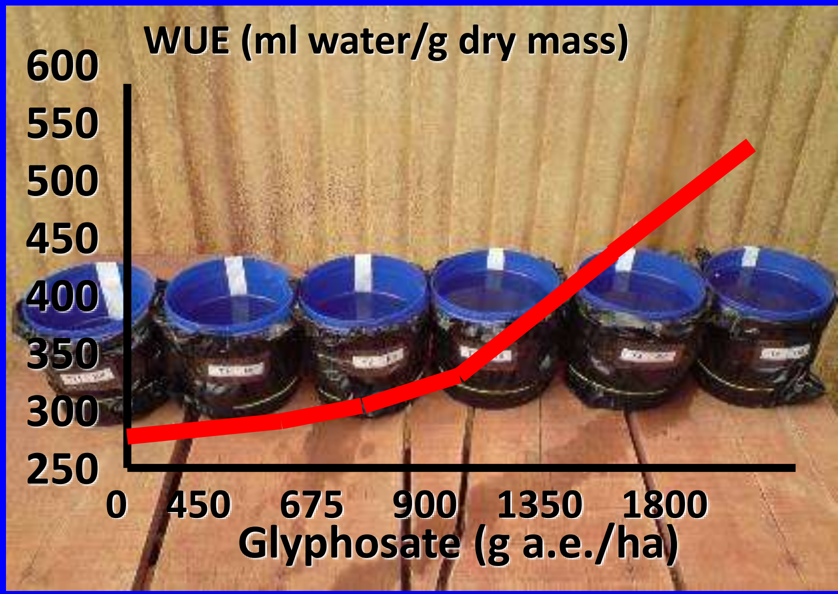
Effect of Glyphosate on Lignin, AA, Water Use Efficiency, and Photosynthesis of Glyphosate-Resistant Soybeans

After Zobiole, 2009









Herbicide Affects on RR Corn Yield Indiana, 2010

Herbicide	RR Corn Hybrid 6733HXR	6179VT3	5442VT3	5716A3
Surestart (11")	266*	216	223	219
Cadet (V6)	227	219	219	213
Laudis (V6)	224	218	214	214
Integrity (pre-E)	231	217	215	204
Glyphosate (V6)	212	207	206	210
Steadfast (V6)	207	204	201	196
Status (V6)	187	195	193	192

*125.6 % of glyphosate yield (yields in bu/a - rounded)

All plots were hand weeded

Special Considerations in Fertilizing RR Crops

Two factors: 1) Chemical; 2) gene

1. Providing nutrient availability for yield and quality

- Compensate for reduced plant efficiency
- Compensate for reduced soil availability
- [Timing and formulation are important]

2. Detoxifying residual glyphosate

- In meristematic root, stem, flower tissues, etc.
- In soil [Ca, Co, Cu, Mg, Mn, Ni, Zn]

3. Restoring soil microbial activity

- Nutrient related (N-fixation, Fe, Mn, Ni, S, Zn, etc.)
- Disease control related (nutrition, pathogen antagonists, etc.)
- Biological amendment (N-fixers, PGPRs, etc.)

4. Judicious use of glyphosate

Yield Response of Roundup Ready® Soybeans to Micronutrients

Treatment	Indiana	Michigan	Kansas	Wisconsin
	---------------Yield (bu/a)-------------------			
Untreated	46	24	77	33
Glyphosate only	57	33	65	8
Glyphosate + Micronutrient	75 Mn	56 Mn	78 Mn	19 Fe

Effect of Glyphosate on Roundup Ready® Corn

Colorado State University, 2007

Mike Bartolo, Sr. Res. Scientist

Treatment	% grain moisture	Yield (bu/a)	% of control
Untreated*	15.6	234 a	100
Glyphosate**	15.6	195 d	83
Glyphosate + Zn, Mn	15.6	221 b	94
Glyphosate + Mn, Zn, Fe, B	15.6	208 c	89

*Hand weeded, **1 lb a.i. + 1 pt AMS per acre

Notes: UTC = genetic potential (with RR gene)

Glyphosate reduces genetic potential 39 bu/a

Application of high Mn & Zn recovers some genetic potential, lower Mn & Zn recovers less

Response of Roundup Ready® Corn to Zn & Mn, 2007*

NDSU Carrington

Treatment	Yield (bu/a)
Glyphosate control	144
Zn seed Treatment	156
Foliar applied Zn	158
Foliar applied Zn+Mn	173
Seed + Foliar Zn	175
Soil granular Zn sulfate	167

* All treatments received glyphosate

Glyphosate & Manganese Effects on Cotton

Glyphosate @ 22 oz/ac plus ammonium sulfate (AMS)

Glyphosate @ 22 oz/ac plus AMS + Manganese

Untreated Check (conventional herbicide)

Effect of glyphosate and Manganese on Cotton Yield (Texas)

Treatment	% chlorotic plants	# seed cotton
Conventional herbicide	5	4885
Glyphosate	97	2237
Glyphosate + Mn	2	4693

after Ronnie Phillips, 2009

Effect of Tillage on Glyphosate Injury & Yield

Field History: 8 years Conservation Reserve Program

2 qt blyphosate burndown 2008

1 qt glyphosate on RR corn 2009

1 qt glyphosate burndown 2010

Increasing Nutrient Uptake Efficiency

Shallow, Compact Root System in RR Soybeans

Isogenic Normal

Isogenic Roundup Ready

An Epidemic of Roundup Resistant Weeds

REMEMBER

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   A. Crop quality and quantity
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   A. Increase plant resistance and defense response
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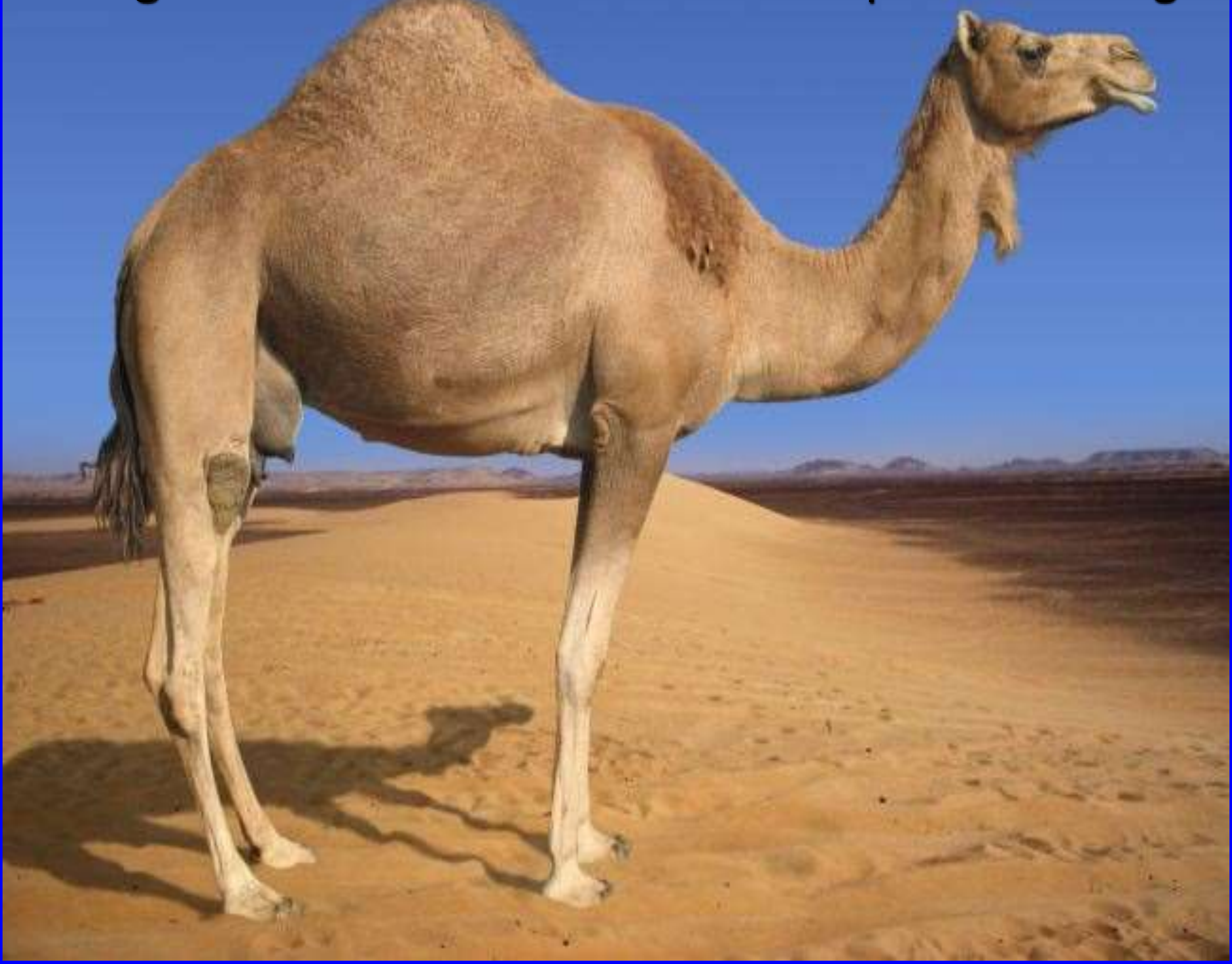
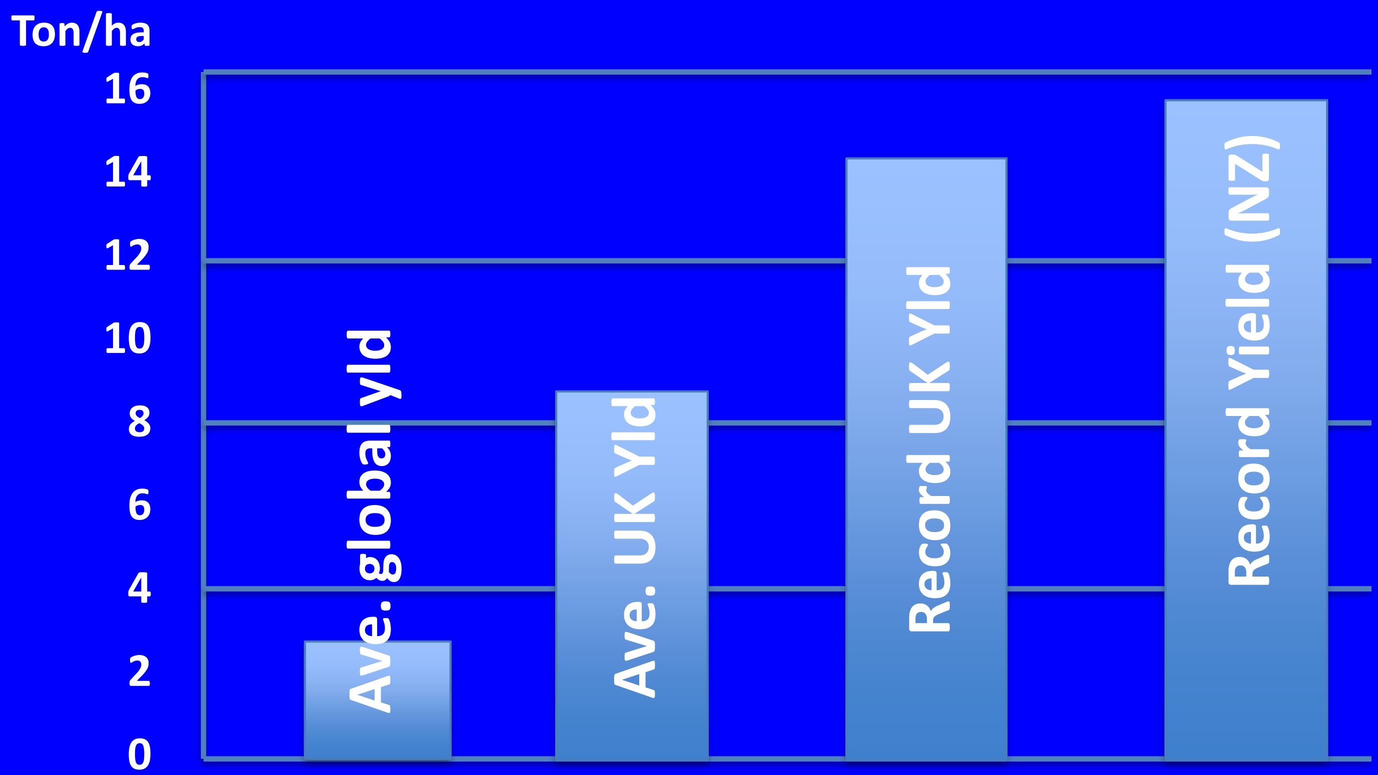
In Agriculture We Are Asked to Do Impossible Things



Average and Record Wheat Yields



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

Infection

Direct, natural opening, vector, wound

Disease development & Reproduction

Source

Survival

Dissemination

spread

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 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