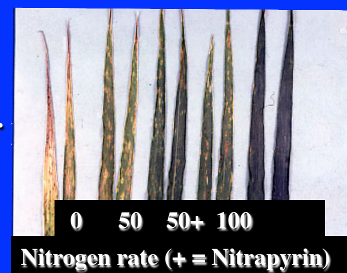
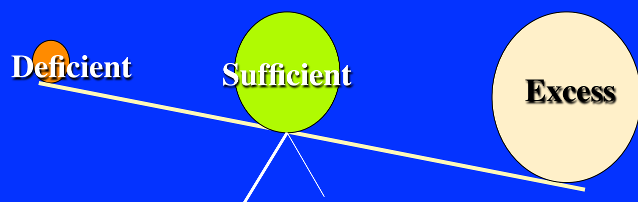
Keys to Using Nutrition to Manage Disease

3. Rate Applied or Available

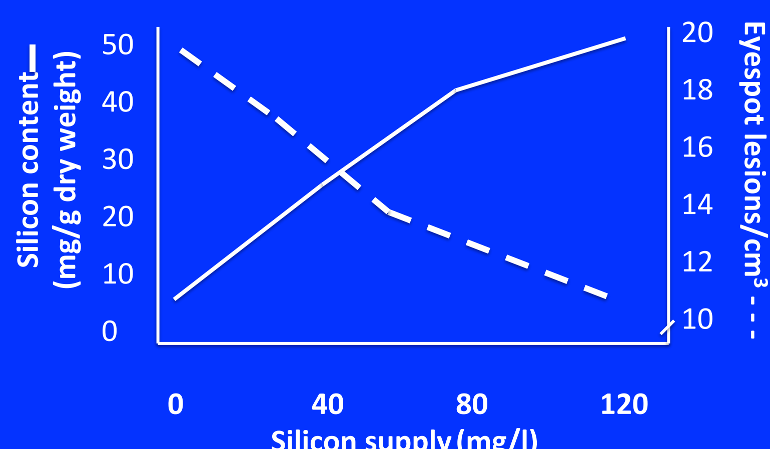
- Amount available
  - Deficiency to sufficiency versus
  - Sufficiency to excess for the particular
- Time available
- Nutrient balance



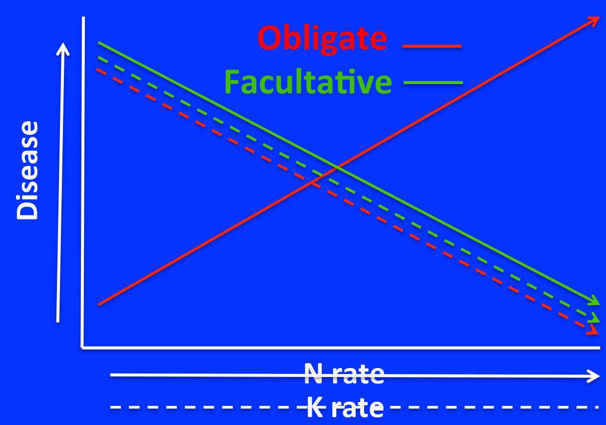


Corn is continuous; legumes have a 'recovery' window

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



Effect of N Rate on Obligate (Wheat Rusts, P. graminis) and Facultative (Tomato Bacterial Spot, X. vesicatoria) Fungi (after Volk et al, 1958)



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/m²)	Feeding holes No./cm²)	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.

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

Keys to Using Nutrition to Manage Disease

6. Integration with other practices

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

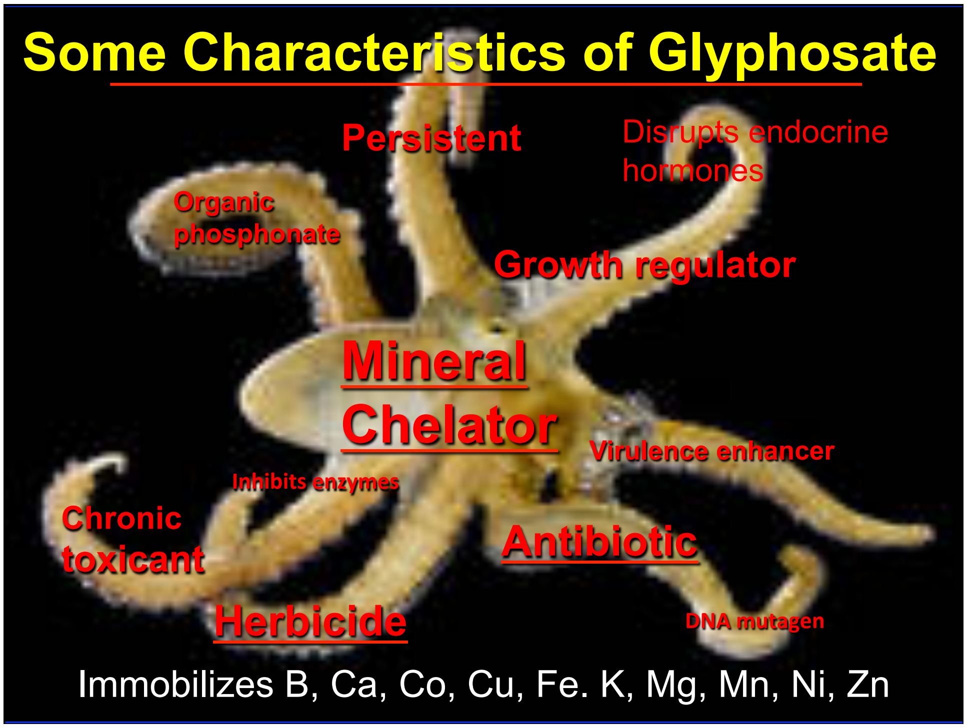
Severe take-all of wheat following glyphosate on soybeans (left), the non-treated soybean control is right.

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

Pesticide Interactions with Nutrition

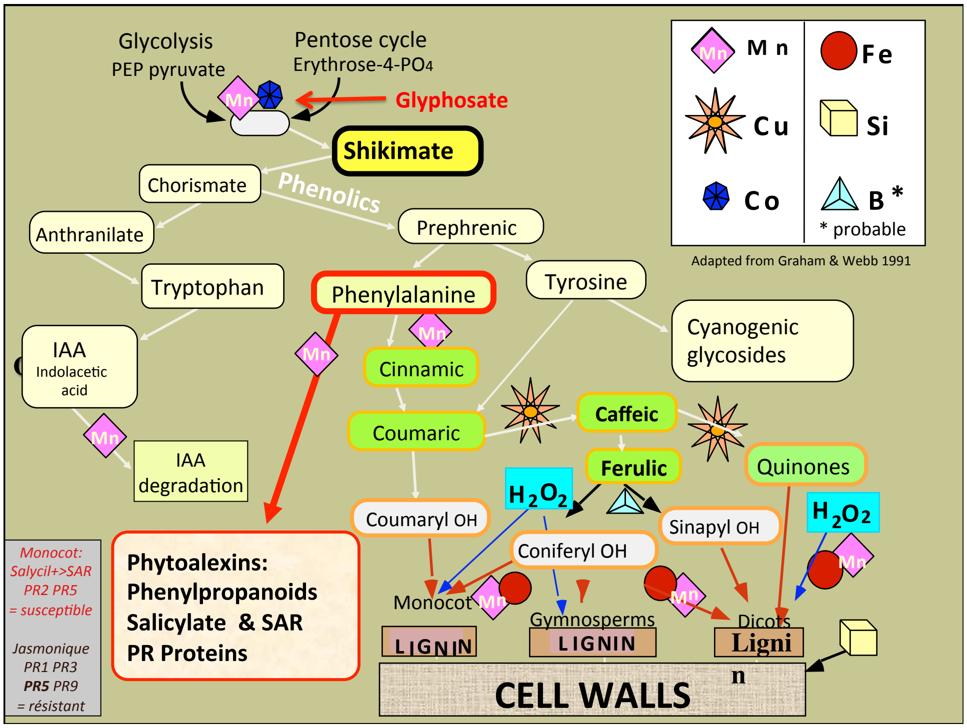
- **Many pesticides are mineral chelators**
  - 'Immobilize' (or enhance) critical mineral co-factor for enzymes
  - Organic phosphates, amino-phosphonates, dithiocarbamates, etc.
- **Herbicides - specific ion or general immobilization**
  - Cu examples: Puma Gold (fenoxyprop); Tordon
  - General: Glyphosate, 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 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

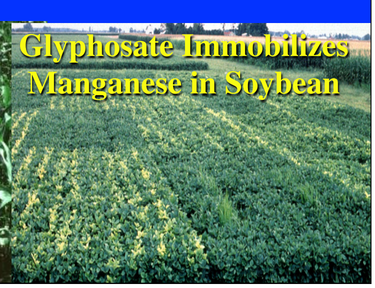


Understanding the Characteristics of Glyphosate
Glyphosate has Changed Agriculture for 30+Years

- **A strong chemical chelator**
  - Chelates minerals in the spray tank
  - Chelates minerals in the plant
  - Chelates minerals in the soil
  - Reduces: B, Co, Cu, Fe, K, Mg, Mn, Ni, Zn

Chelating stability constants of glyphosate

Metal ion	[ML] [M][L]	[MHL] [M][H][L]	[ML2] [M][L2]
Mg^{2+}	3.31	12.12	5.47
Ca^{2+}	3.25	11.48	5.87
Mn^{2+}	5.47	12.30	7.80
Fe^{2+}	6.87	12.79	11.18
Cu^{2+}	11.93	15.85	16.02
Fe^{3+}	16.09	17.63	23.00



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

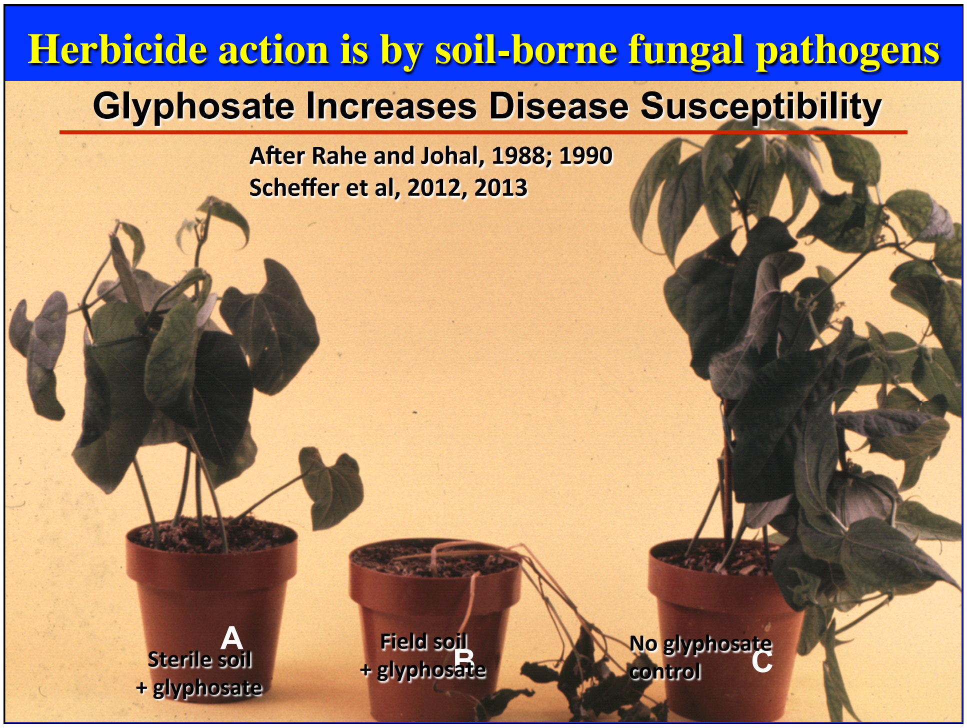
Some Plant Pathogens Increased by Glyphosate

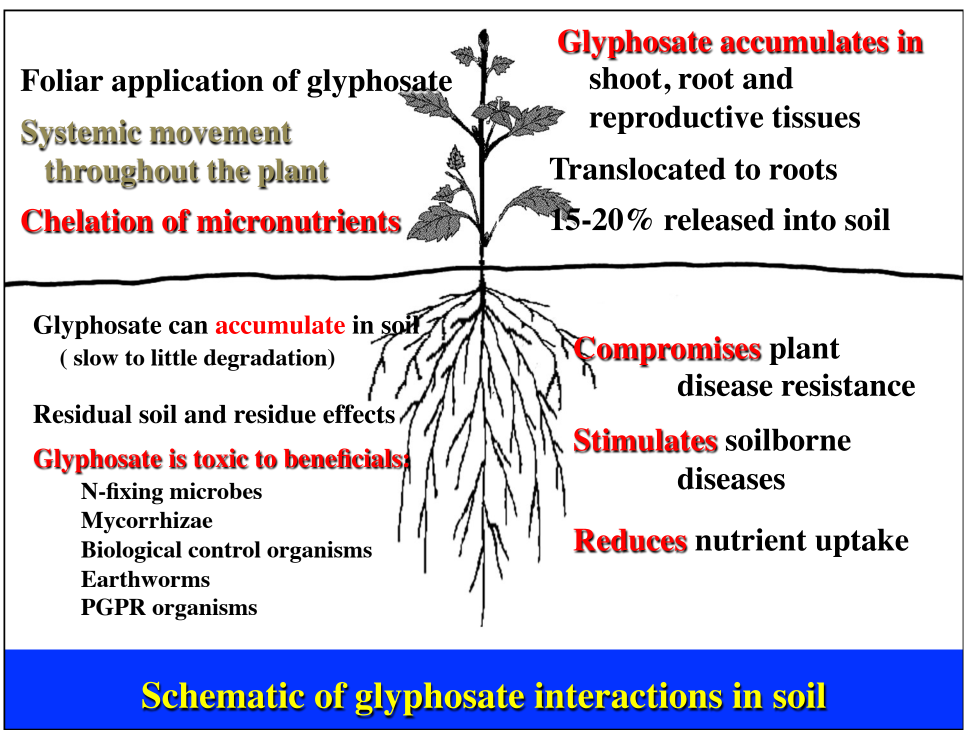
Corynespora cassicola
Fusarium spp.
Phytophthora spp.
Pythium spp.
Rhizoctonia solani
Thielaviopsis bassicola
Xylella fastidiosa
Myrothecium verucaria
F. solani f.sp. Pisi
Gaeumannomyces graminis
Magnaporthe oryzae

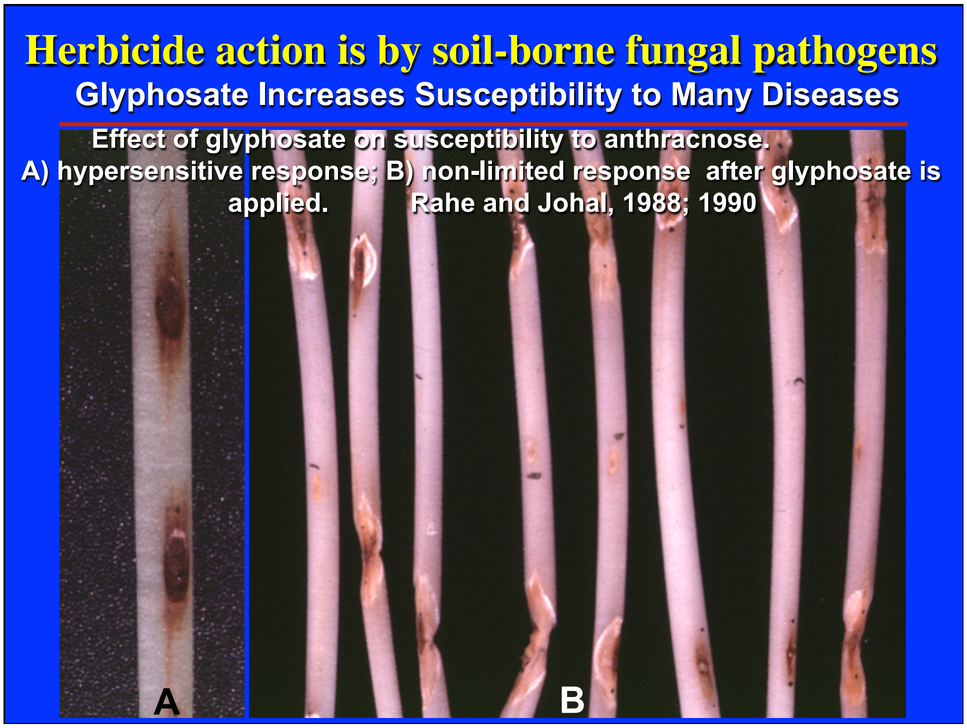
("Emerging" and "reemerging diseases")

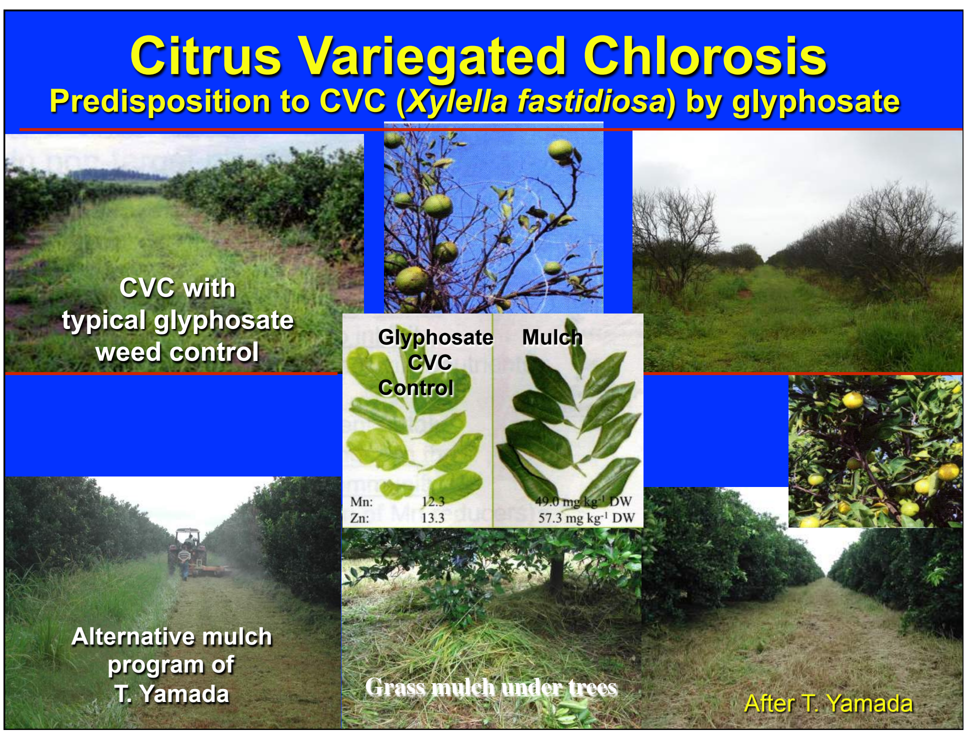
Fungal Mn oxidation in soil (increased virulence)

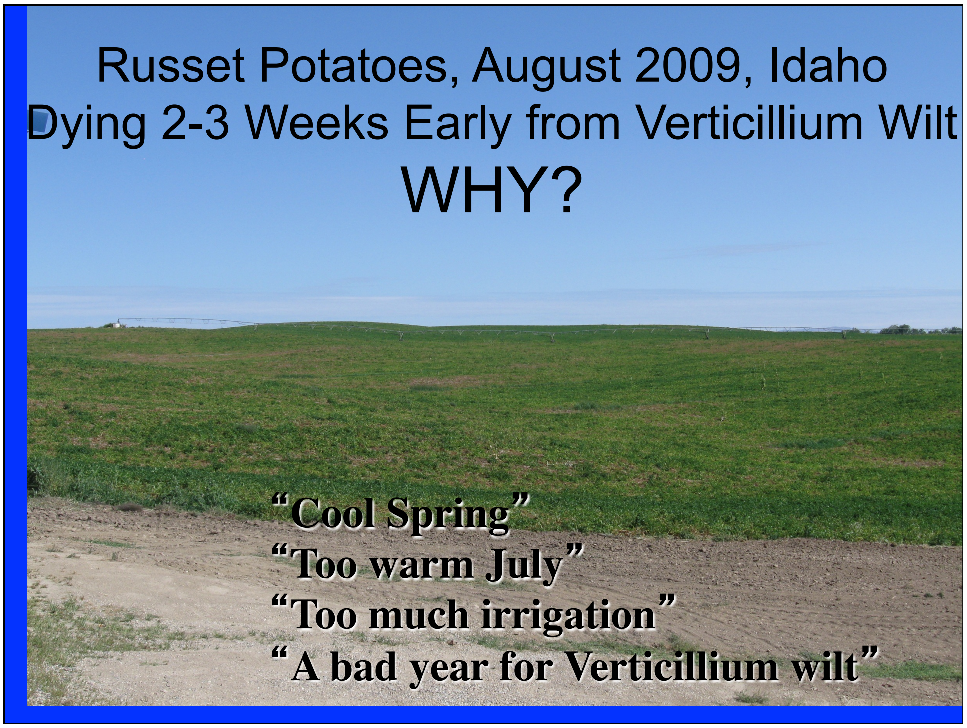
Abiotic: Nutrient deficiency diseases; bark cracking, mouse ear, 'witches brooms', drought stress, chill damage

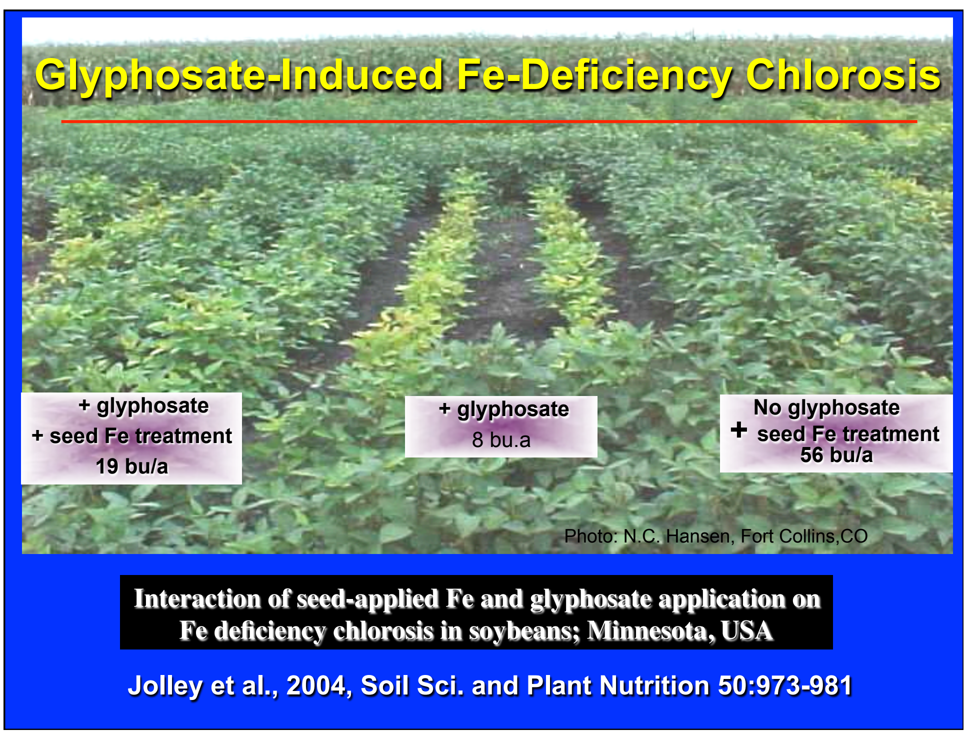

Herbicide action is by soil-borne fungal pathogens
Glyphosate Increases Disease Susceptibility
After Rahe and Johal, 1988; 1990
Scheffer et al, 2012, 2013
A
Sterile soil
+ glyphosate
Field soil
+ glyphosate
B
No glyphosate
control
C


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


Herbicide action is by soil-borne fungal pathogens
Glyphosate Increases Susceptibility to Many Diseases
Effect of glyphosate on susceptibility to anthracnose.
A) hypersensitive response; B) non-limited response after glyphosate is applied.
Rahe and Johal, 1988; 1990
A
B


Citrus Variegated Chlorosis
Predisposition to CVC (Xylella fastidiosa) by glyphosate
CVC with typical glyphosate weed control
Glyphosate CVC Control
Mulch
Mn: 12.3
Zn: 13.3
49.0 mg kg-1 DW
57.3 mg kg-1 DW
Alternative mulch program of T. Yamada
Grass mulch under trees
After T. Yamada


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
+ glyphosate
+ seed Fe treatment
19 bu/a
+ glyphosate
8 bu.a
No glyphosate
+ seed Fe treatment
56 bu/a
Photo: N.C. Hansen, Fort Collins,CO
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

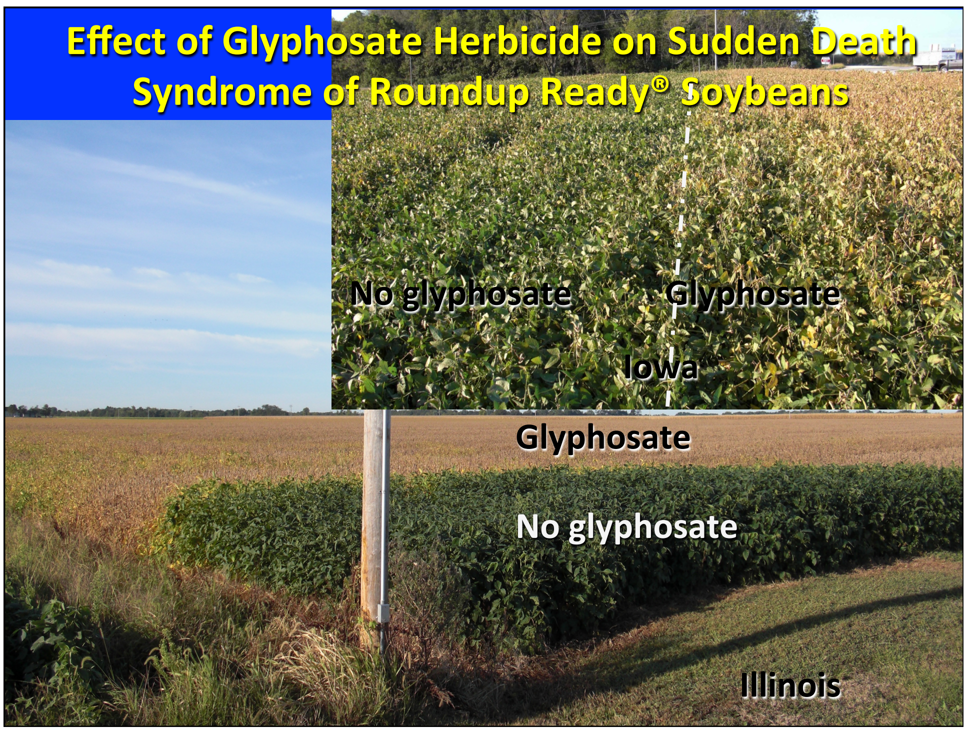
% Reduced Nutrient Density in RR versus Non-RR*

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

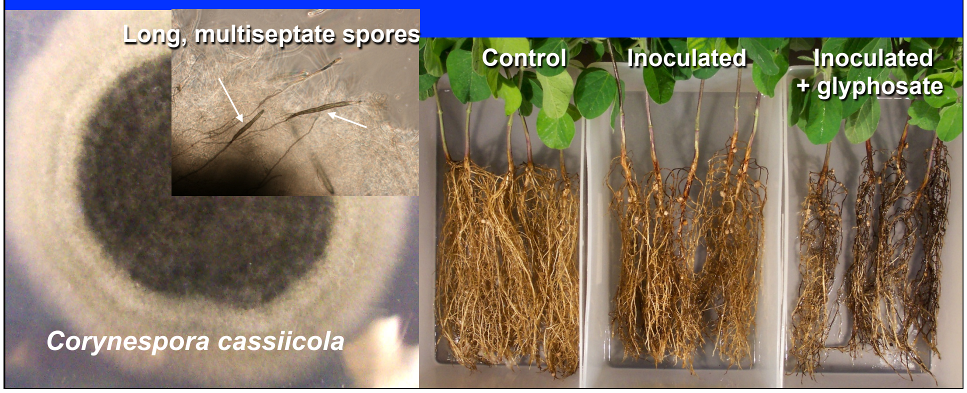
**Youngest mature leaf

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

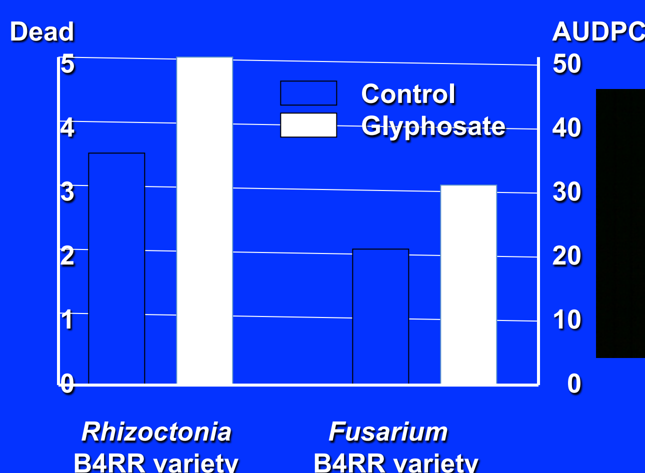


Corynespora Root Rot

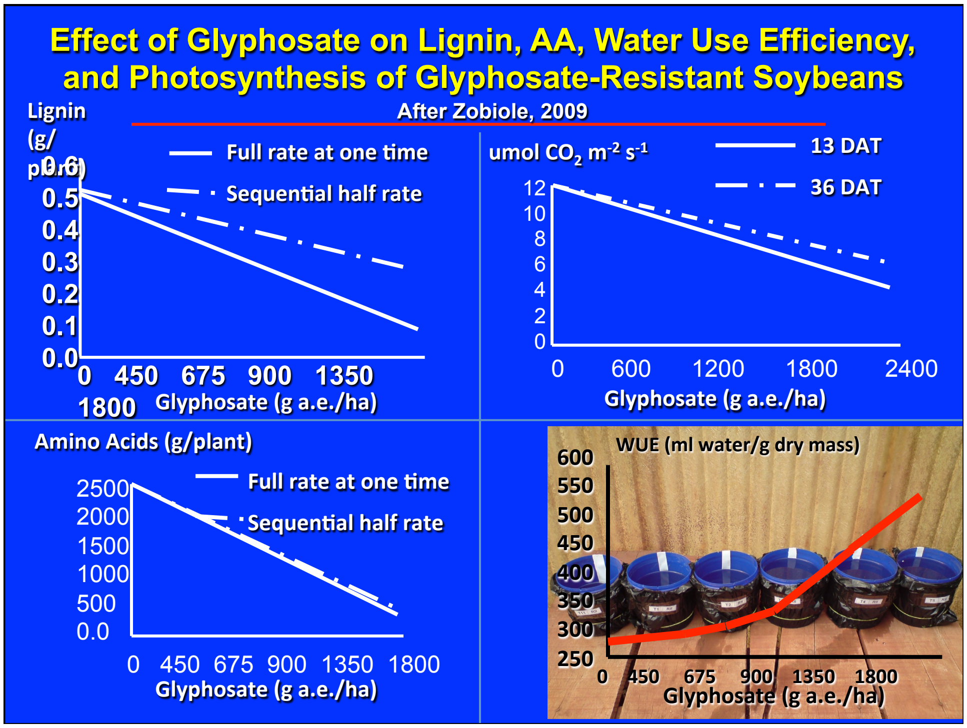
- An extensive dark brown to black rotting of small lateral roots
- Generally considered a root "nibbler"
- Especially severe when glyphosate is applied to near-by weeds
- Especially severe when glyphosate is applied to the plant



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



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

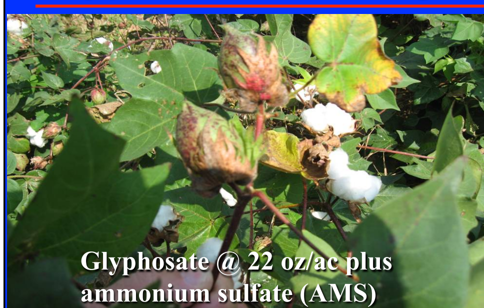
Response of Roundup Ready® Corn to Zn & Mn, 2007*

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



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

An Epidemic of Roundup Resistant Weeds

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 affects 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


In Agriculture We Are Asked to Do Impossible Things

Failed Promises of Touted Benefits

- ✓ Higher yields
- ✓ Fewer pesticides
- ✓ Less post-harvest loss
- ✓ Improved N-fixation
- ✓ Drought and salt tolerance
- ✓ Increased photosynthesis
- ✓ Greater root growth & function
- ✓ Disease resistance
- ✓ Lower risks (economic)
- ✓ Lower cost
- ✓ Greater safety
- ✓ Simpler management – resistant weeds & pests

BETRAYAL OF THE PUBLIC TRUST