Understanding Glyphosate and Glyphosate-resistance on Nutrient Sufficiency, Disease and Agricultural Sustainability

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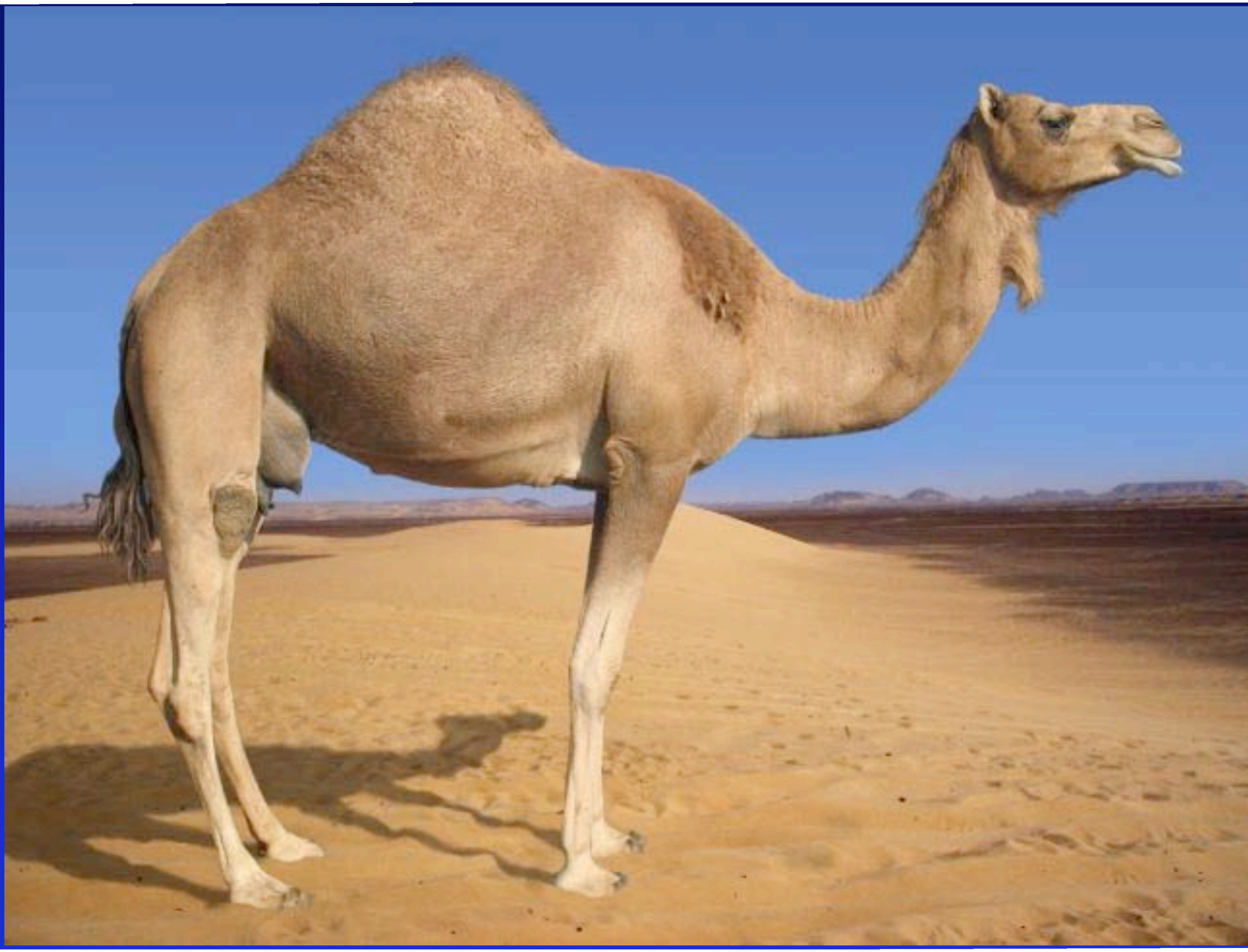


Parenting skills

Look back and take inventory once in a while!

Anticipate!

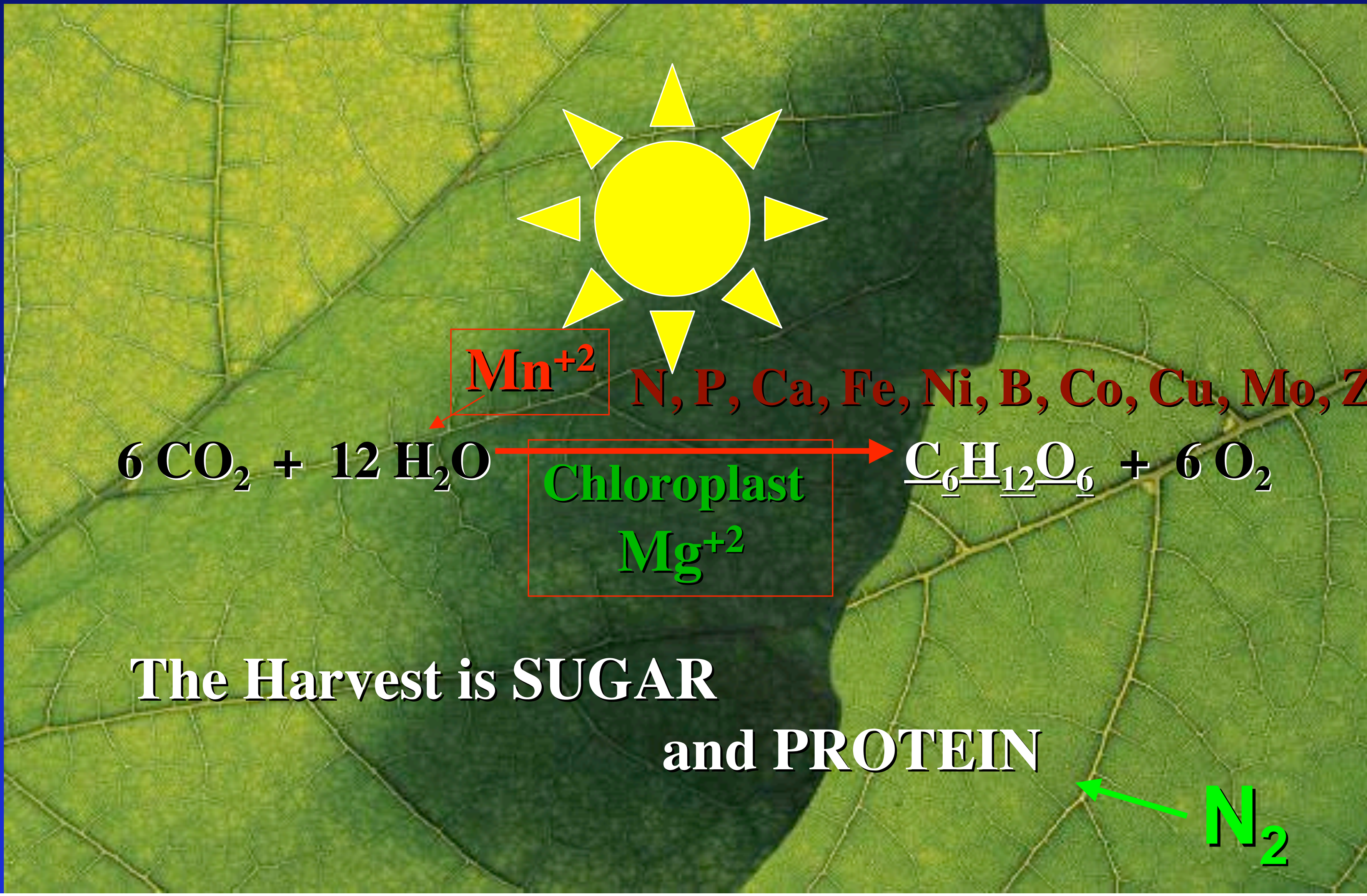
Hesitate!

AVOID HAZARDS
Bad Parenting!

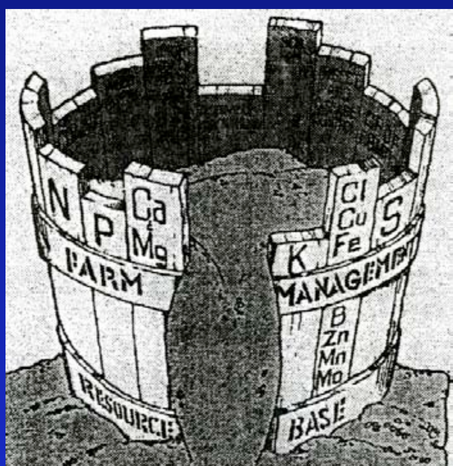
Understanding Glyphosate and Glyphosate-resistant Crops Impact on Nutrition, Disease & Sustainability

- Background
- Understanding glyphosate
  What it is and how it works
- Understanding glyphosate-resistance
  - What it is and what it doesn't do
- Recognizing the interactions
  - Symptoms - nutrition, disease
- Fertilization of corn, soybeans, and cereals in a glyphosate weed management program
- The bigger picture

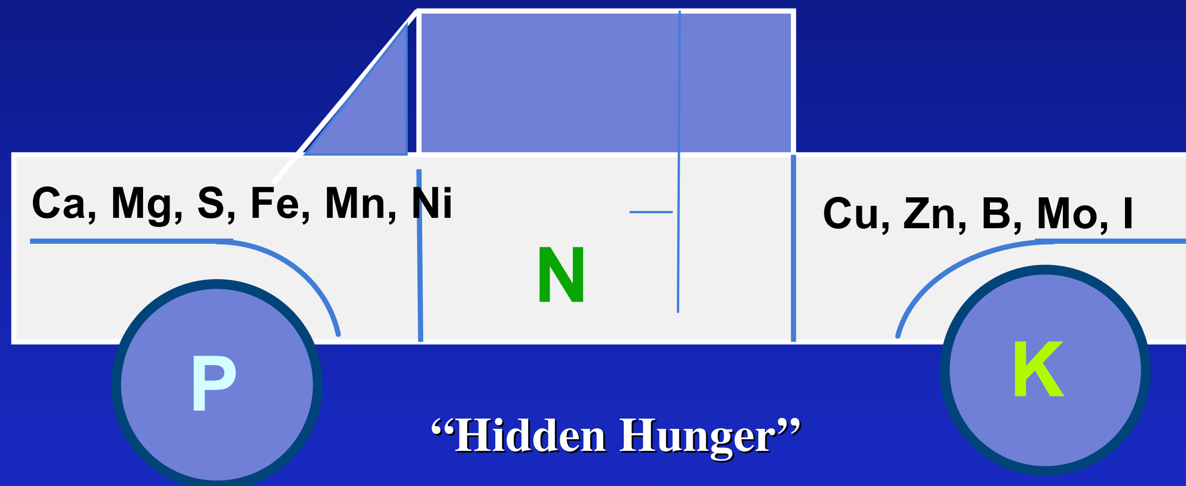
Photosynthesis and N-fixation



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"



"Hidden Hunger"

Nutrient *BALANCE* may be a matter of <u>root function!</u>

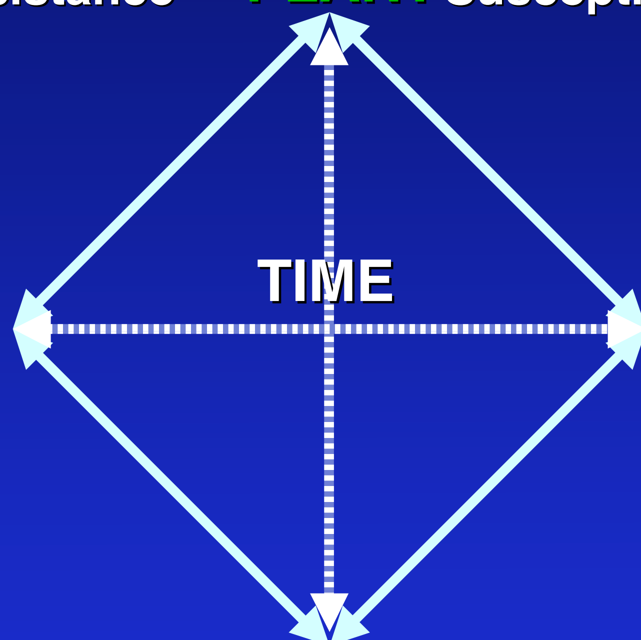
"The roots may be the root of the problem!"

"The weak link may be underground!"

Interacting Factors Determining Nutrient Availability and 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
- Ag Chemicals

BIOTIC ENVIRONMENT

Antagonists, Synergists

Oxidizers, Reducers

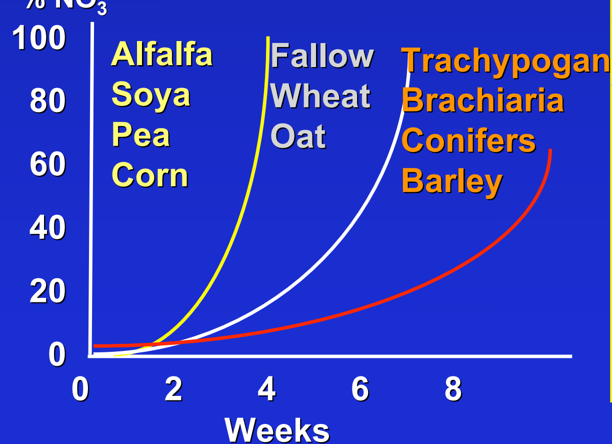
Competitors, Mineralizers

[Cu, Fe, K, Mn, N, S, Zn]

Changes in Agricultural Practices Change the Interactions

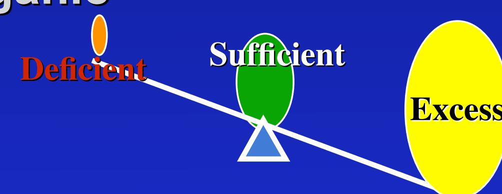
Crop Sequence	Tillage/No-till	Fertilization
Biotic environment	Residue break down	Rate/form
Nutrition	Soil density/aeration	Time applied
Nitrification	Pathogen survival	Source/assoc. ions
Organic matter	Nutrient distribution	Inorganic
	Denitrification	Organic
	Herbicide usage	

Effect of crop residue on nitrification

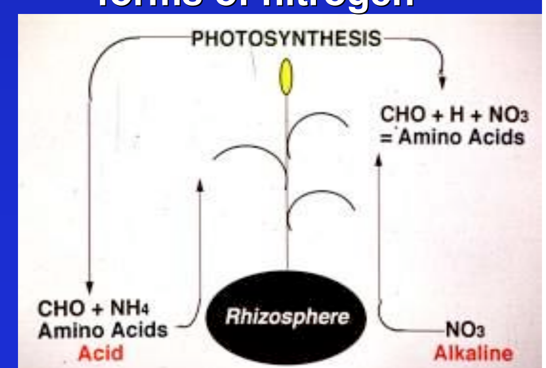


Crop sequence effect on Mn^{+2}

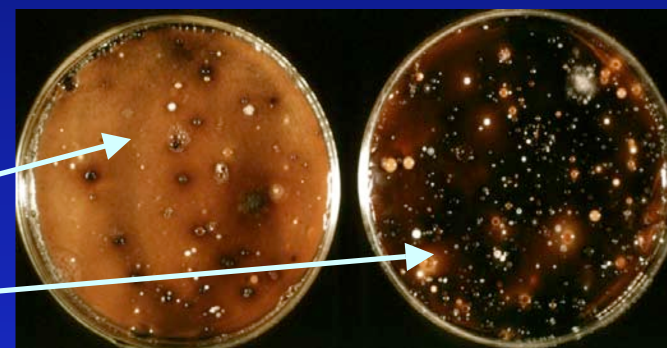
Rotation	Extractable Mn
Continuous Corn	130 ppm
Continuous soybeans	64 pp,
Soybean, wheat, corn	91 ppm
Wheat, corn, soybean	79 ppm
Fall chissel	126 ppm
No-till	80 ppm



Metabolism of different forms of nitrogen



Take-all and Populations of Mn-oxidizing Rhizosphere Bacteria



Mn Availability & Biological Activity

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

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
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

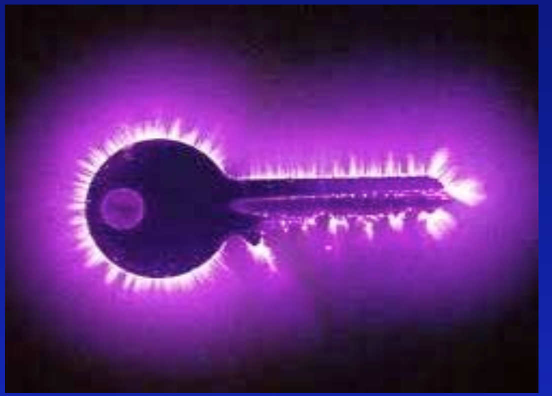
*Potato scab, Rice blast, Take-all, Phymatotrichum root rot, Corn stalk rot

Nutrients are:

Components of plant parts as well as

Activators,

Inhibitors,



and Regulators

of Physiological Processes

Many herbicides and pesticides are chelators

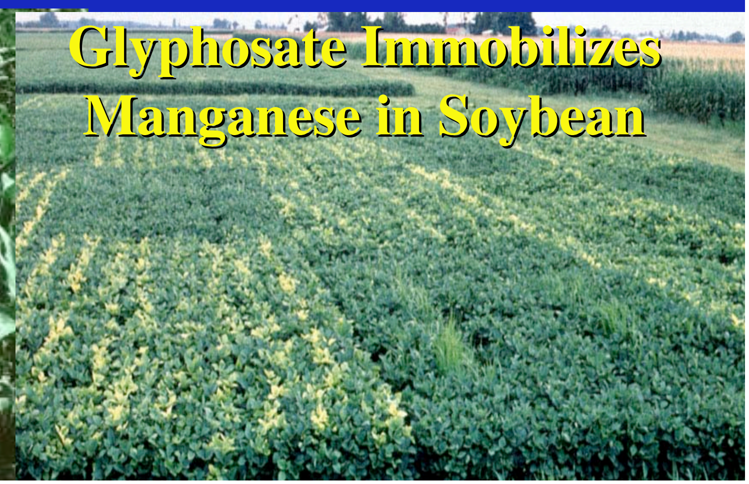
Understanding the Characteristics of Glyphosate

Glyphosate has Changed Agriculture for 30+Years

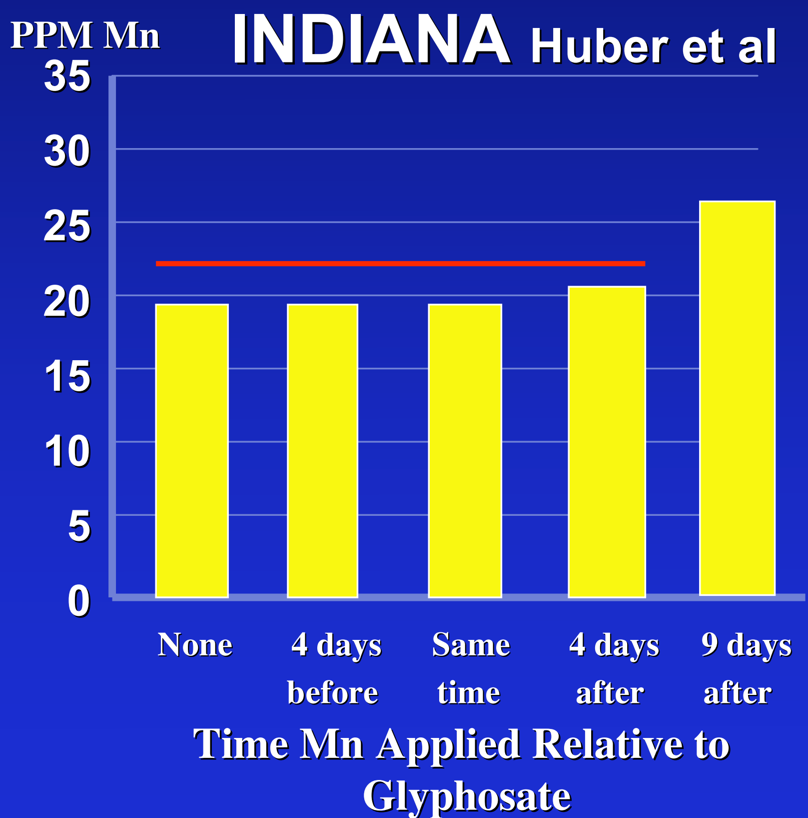
- **A strong chemical chelator**
  - Chelates minerals in the spray tank
  - Chelates minerals in the plant
  - Chelates minerals in the soil
  - Reduces: B, Ca, Co, Cu, Fe, K, Mg, Mn, Ni, Zn
- **Non-specific herbicidal effect**

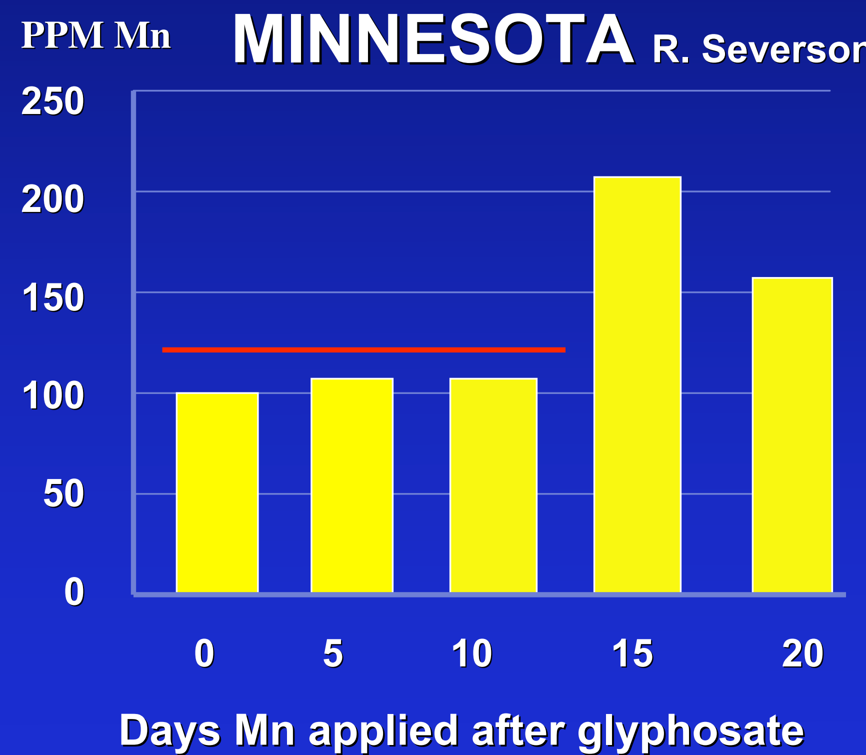
Chelating stability constants of glyphosate

Metal ion	$\frac{[ML]}{[M][L]}$	$\frac{[MHL]}{[M][H][L]}$	$\frac{[ML_2]}{[M][L_2]}$
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



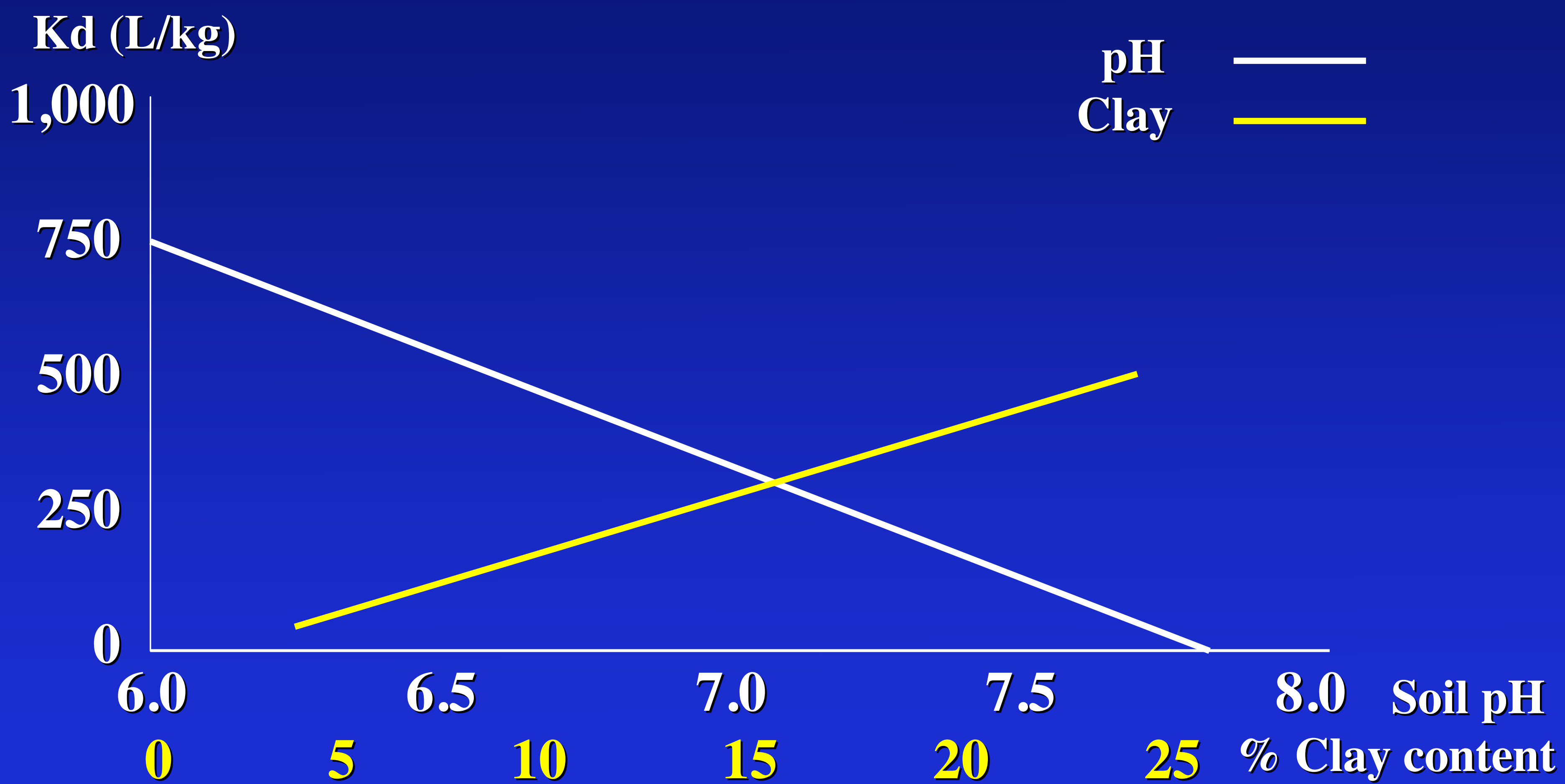
Effect of Time of Mn Application AFTER Glyphosate on Tissue Mn





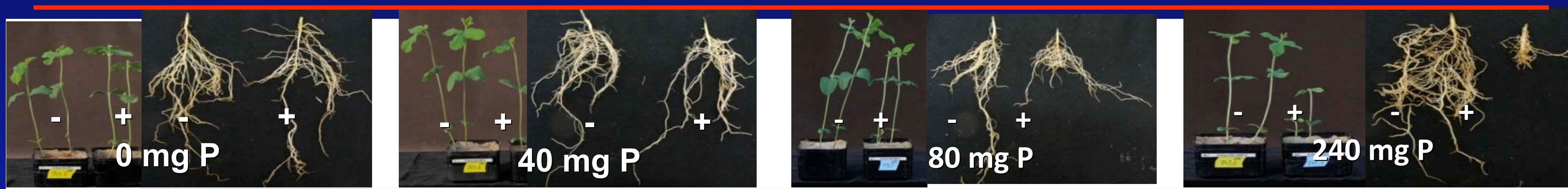
Effect of pH on Soil Sorption of Glyphosate

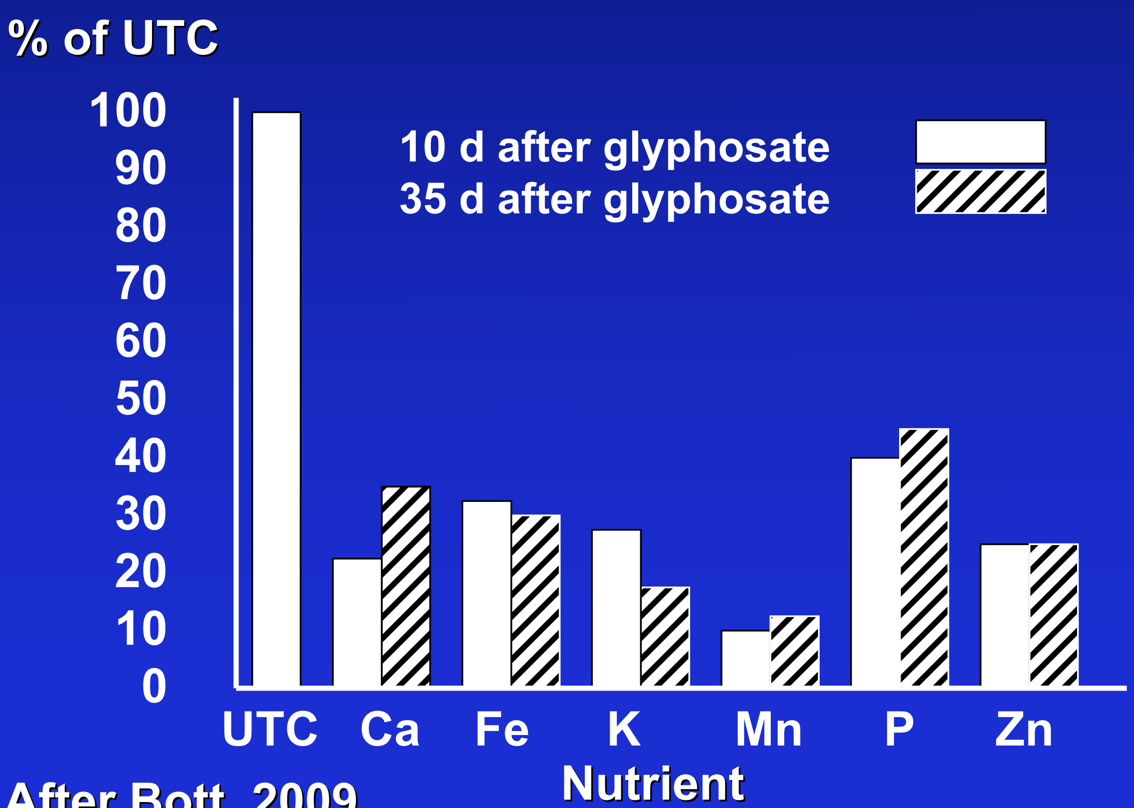
(After Farenhorst et al, 2009)

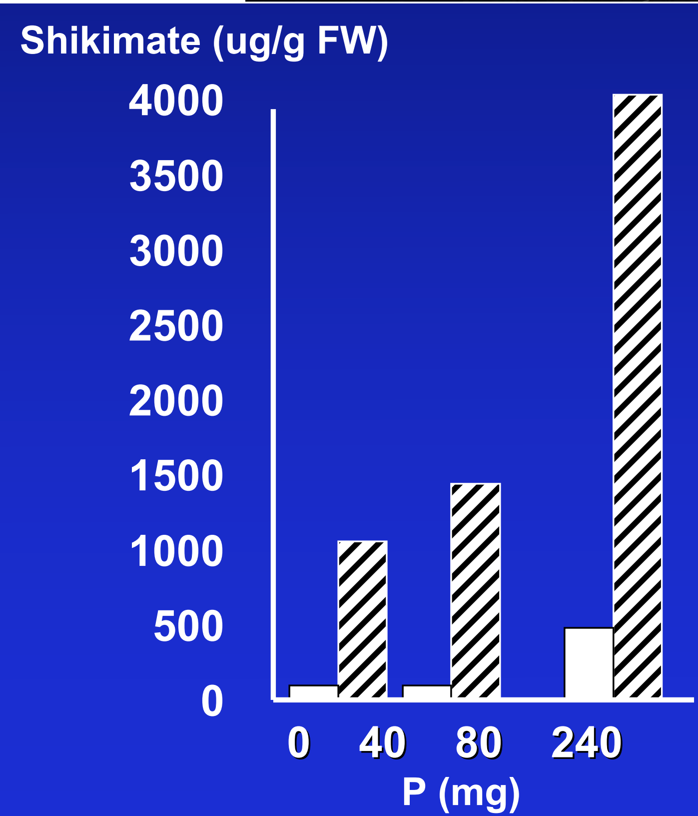


Glyphosate kd values = 19 - 547; 2,4-D kd values = 0.12 - 2.61

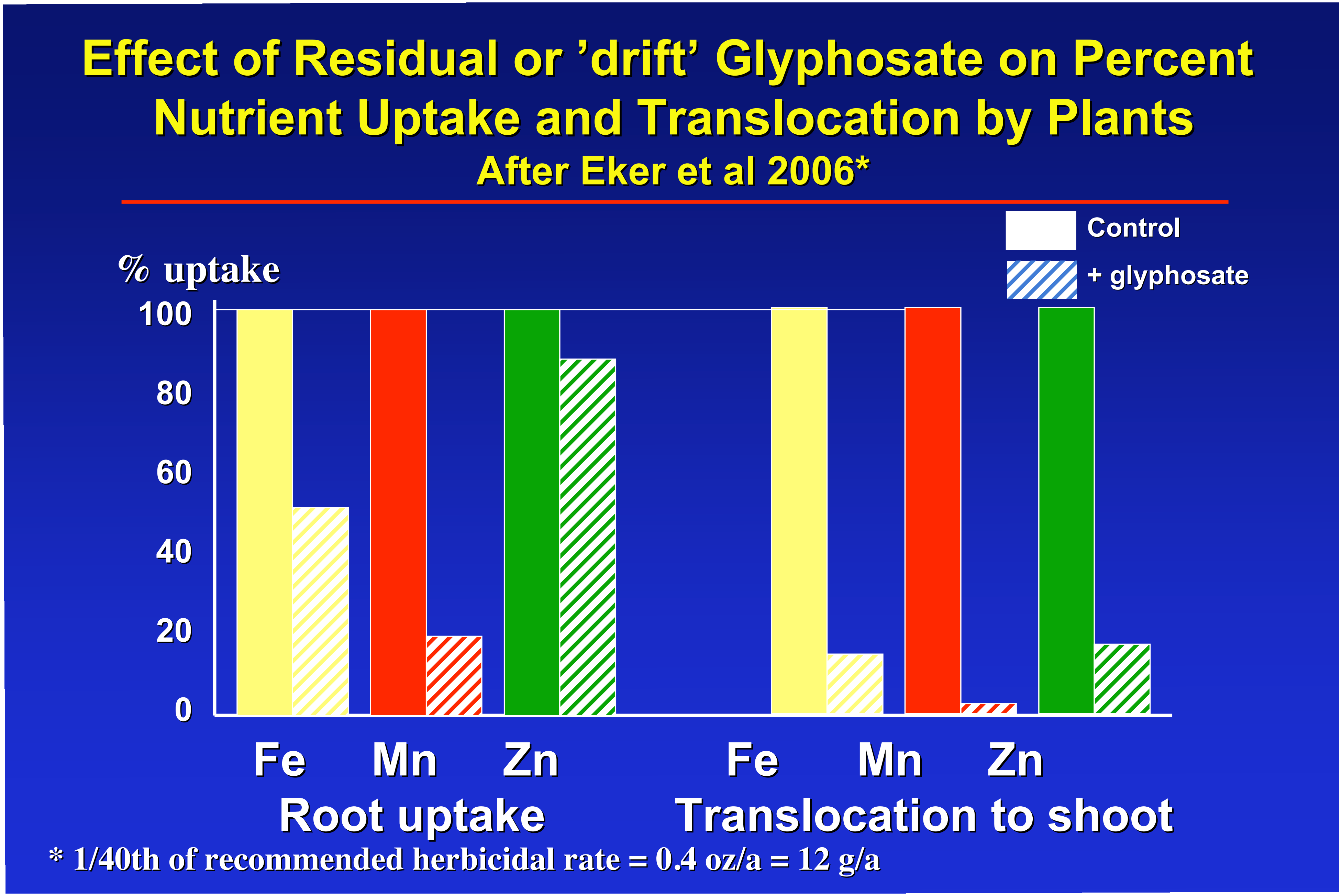
Effect of Phosphorus Desorption of Glyphosate in Soil on Soybean growth and Nutrient Content





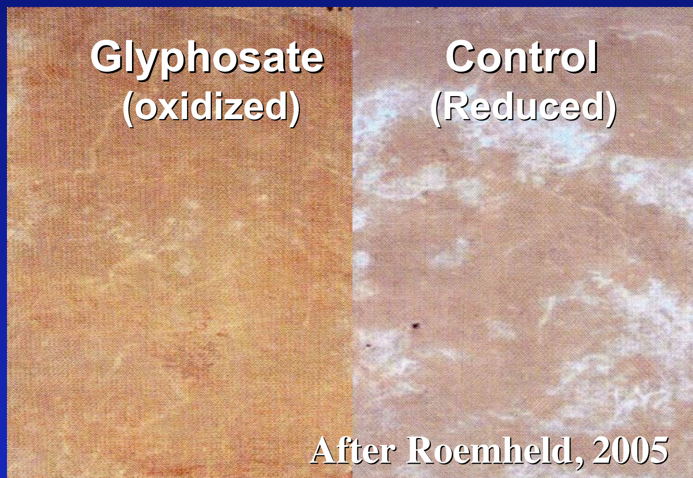


After Bott, 2009

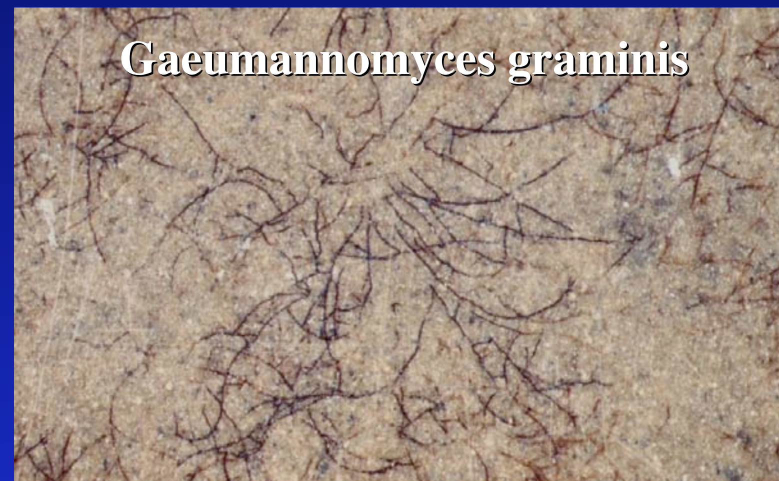


Effect of Residual or 'drift' Glyphosate on Percent Nutrient Uptake and Translocation by Plants
After Eker et al 2006*
Control
+ glyphosate
% uptake
100
80
60
40
20
0
Fe
Mn
Zn
Root uptake
Fe
Mn
Zn
Translocation to shoot
* 1/40th of recommended herbicidal rate = 0.4 oz/a = 12 g/a

Mn Oxidation/Reduction in Soybean Rhizosphere Soil



Fungal Mn oxidation in soil (increased virulence)



Manganese Oxidation in Soybean Rhizosphere

- In soybean rhizosphere soil (3 wks after glyphosate applied):

	Mn Reducing Organisms	Oxidizing Organisms
Control (no glyphosate)	7,250*	750
+ Glyphosate	740	13,250

*Colonies per gram of soil

Foliar application of glyphosate

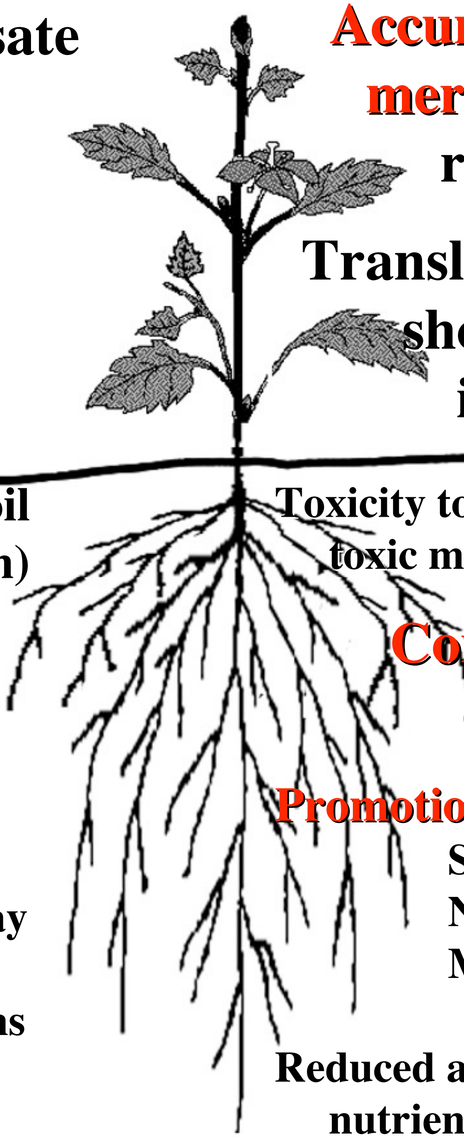
Systemic movement throughout the plant

Chelation of micronutrients

Intensifies stress

Accumulation of glyphosate in meristematic tissues (shoot, reproductive, and roots)

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



Accumulation of glyphosate in soil (fast sorption; slow degradation)

Desorbed by phosphorus

Residual soil and residue effects

Glyphosate toxicity to:

- N-fixing microbes
- Bacterial shikimate pathway
- Mycorrhizae
- Biological control organisms
- Earthworms
- PGPR organisms

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

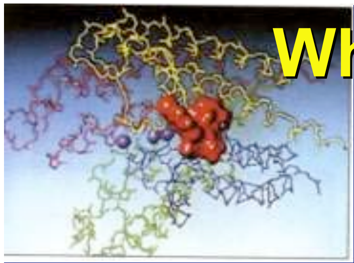
Compromise of plant defense mechanisms

Promotion of soil-borne organisms:

- Soilborne pathogens - DISEASE
- Nutrient oxidizers (Fe, Mn, N)
- Microbial nutrient sinks (K, Mg)

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

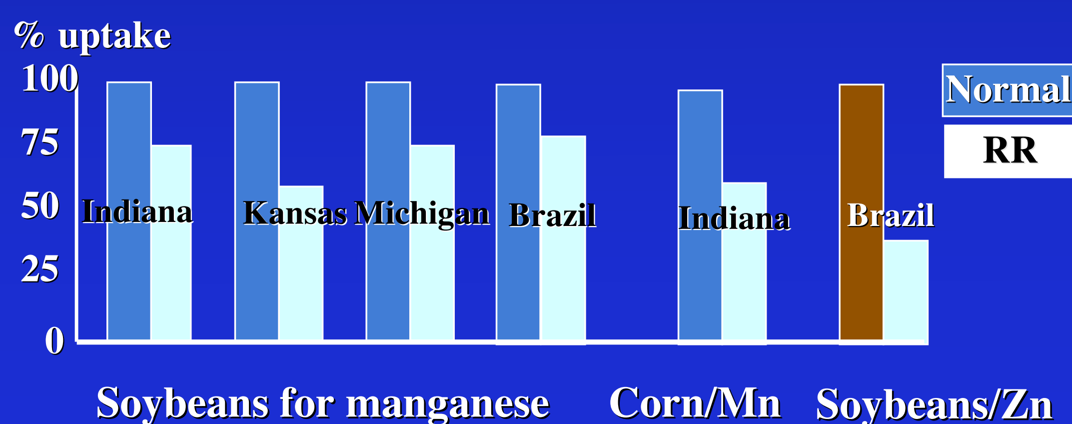
Schematic of glyphosate interactions in soil



What's Special About Glyphosate Tolerance? (Roundup Ready® Genes)

[Greatly expanded usage of glyphosate]

- <u>The technology inserts an alternative EPSPS enzyme that is not blocked by glyphosate in *mature* tissue</u>
- **There is nothing in the RR plant that operates on the glyphosate applied to the plant!**
  - Glyphosate chelation is not selective it immobilizes nutrients
    Ca, Co, Cu, Fe, K, Mg, Mn, Ni, Zn
  - Reduces nutrient uptake
- Can cause a "Yield Drag"
- It is there for the life of the plant



Evaluation of Roundup Ready® Yield Drag

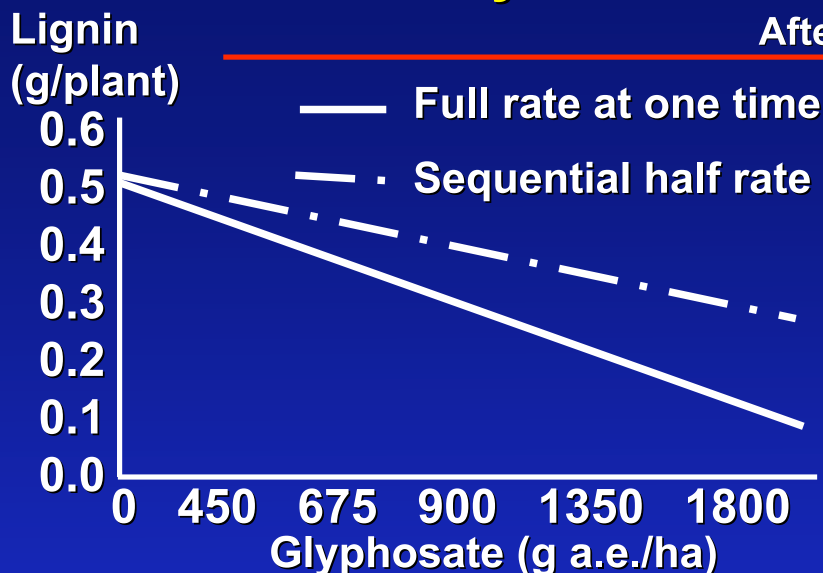
An Evaluation of 8,200 University-based Soybean Varietal Trials

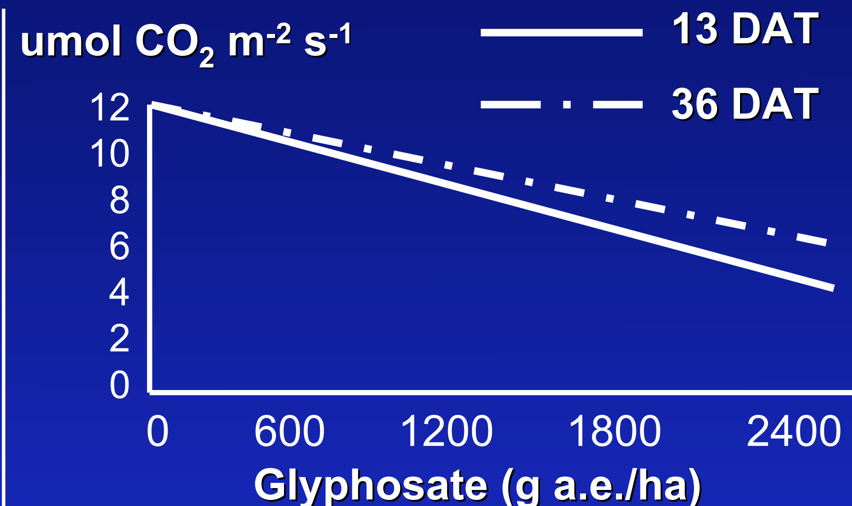
Source: Benbrook. Ag Biotech Info. Net. Tech. Paper No. 1

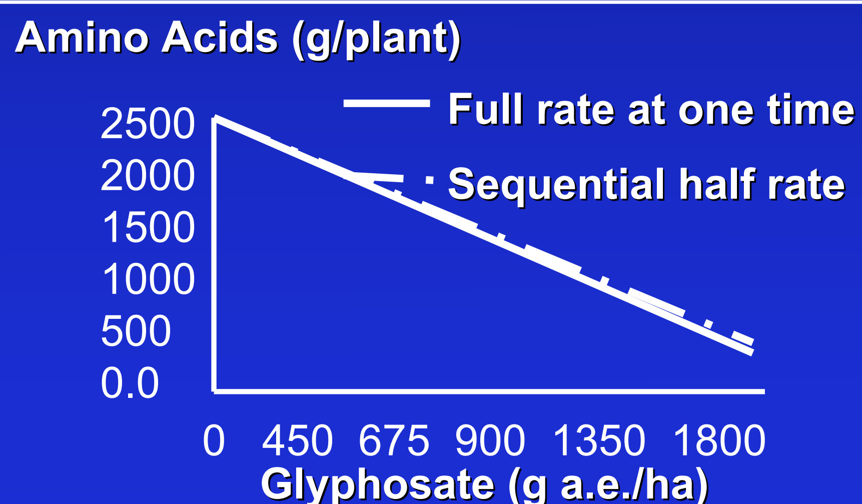
- 93 % showed lower yields for RR than non-GMO
  - 7 % no statistical difference
  - RR averaged 6.7 % lower than non-GMO
  - RR were 10 % lower than best Midwest varieties
- RR yield drag could result in a 2.0-2.5 % lower national yield
  - Potentially the most significant decline in a major crop ever associated with a single genetic modification
- RR uses 2 - 5 times more herbicide than conventional
  - 10 times more than multitactic
- RR yield drag and Tech fee impose an indirect tax
  - as much as 12 % of gross income per acre

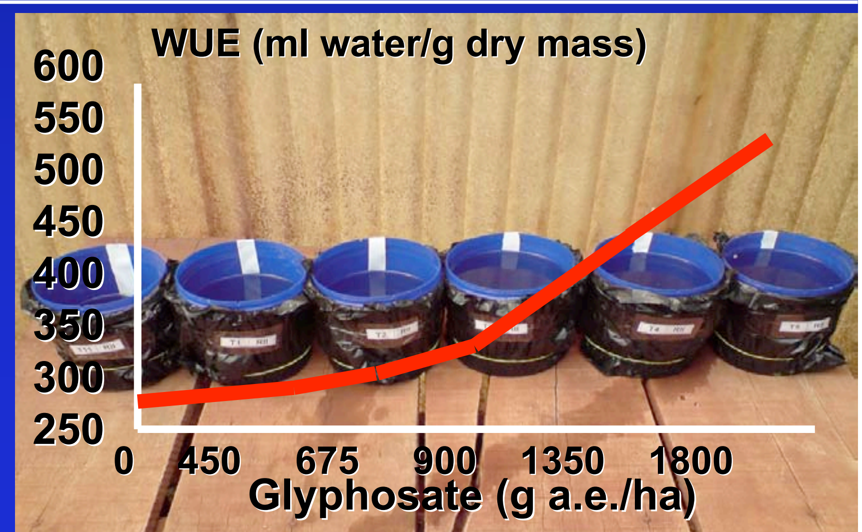
Effect of Glyphosate on Lignin, AA, Water Use Efficiency, and Photosynthesis of Glyphosate-Resistant Soybeans

After Zobiole, 2009



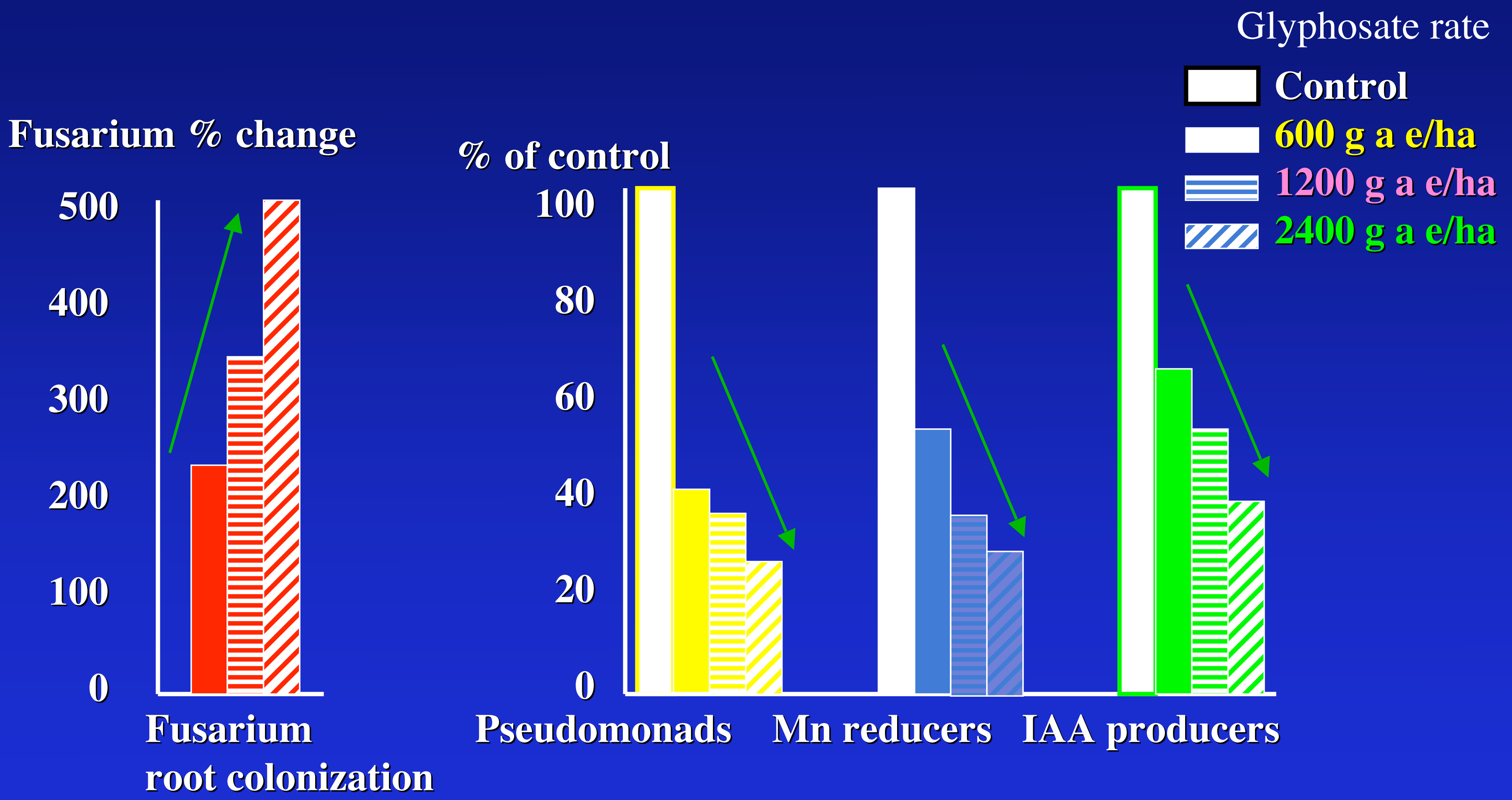






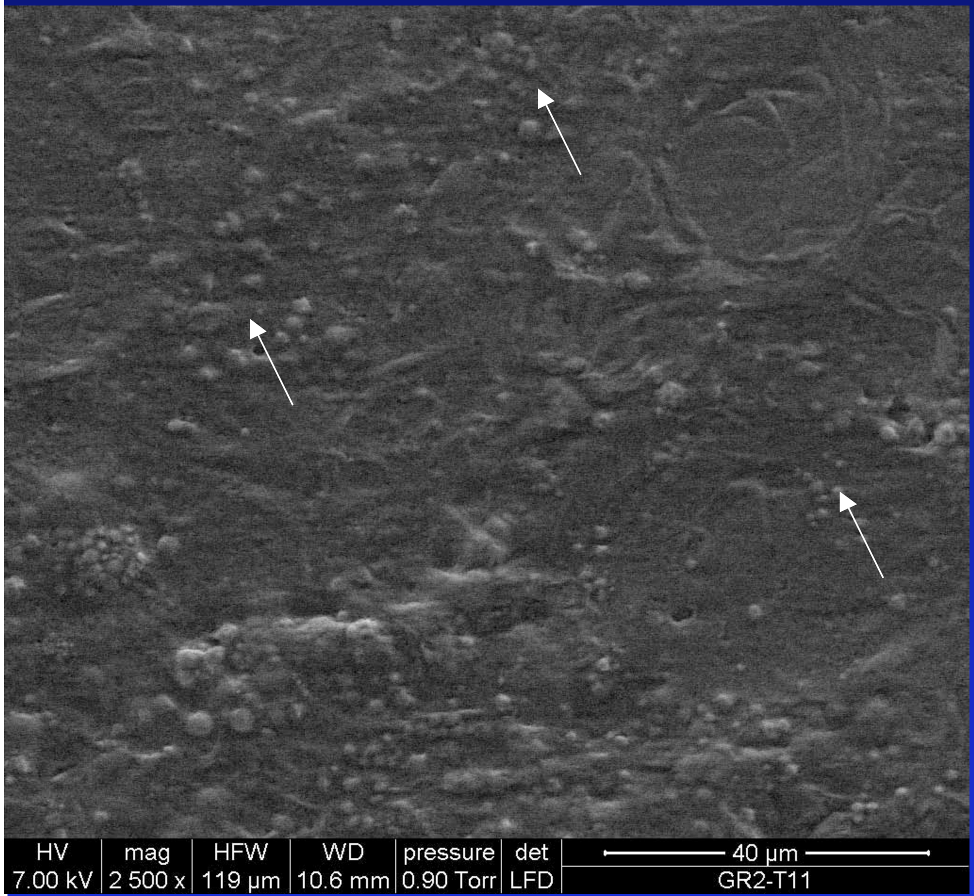
Effect of a 50 mph Wind on Corn in Iowa

Microbiocidal Activity of Glyphosate

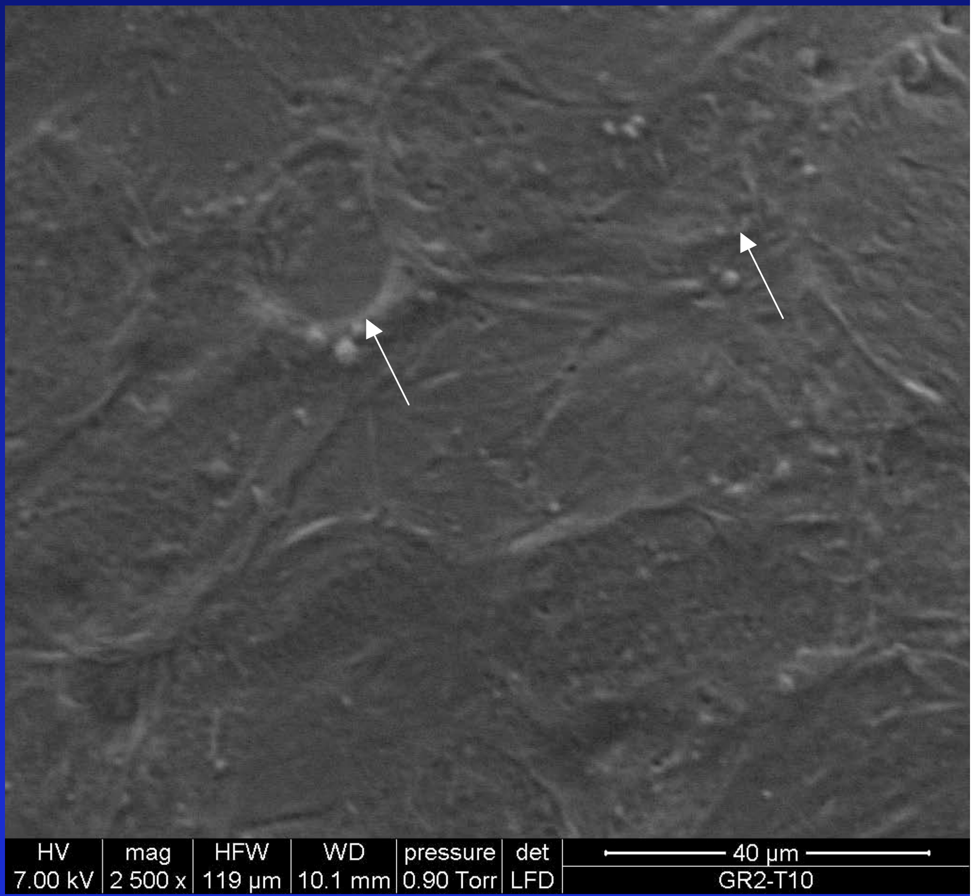


After Zobiole et al., 2010

Effect of Glyphosate on Nodule *Bradyrhizobium* on Roundup Ready® Soybeans



Normal nodule with many bacteria



Nodule after foliar glyphosate

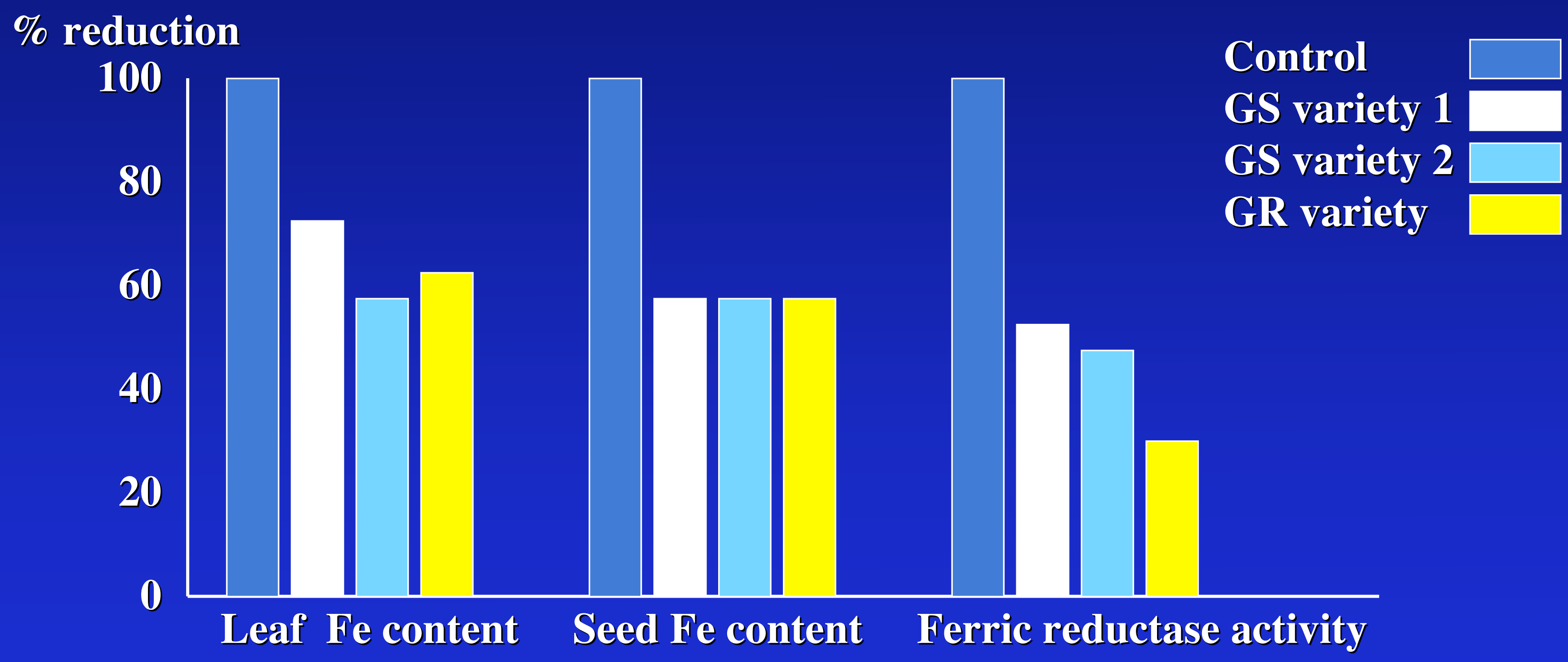
After Zobiole et al., 2010

Reduced Nutrient Efficiency of Isogenic RR Soybeans (After Zobiole et al, 2008, 2009)

Isoline	Tissue: 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!

Effect of Glyphosate Drift* on Soybean Leaf and Seed Iron and Ferric Reductase Activity



*Drift rate = 12.5 % of herbicide rate = 56 g/a

After Bellaloui et al, 2009

% Mineral Reduction in Tissue of 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		

Reduced:

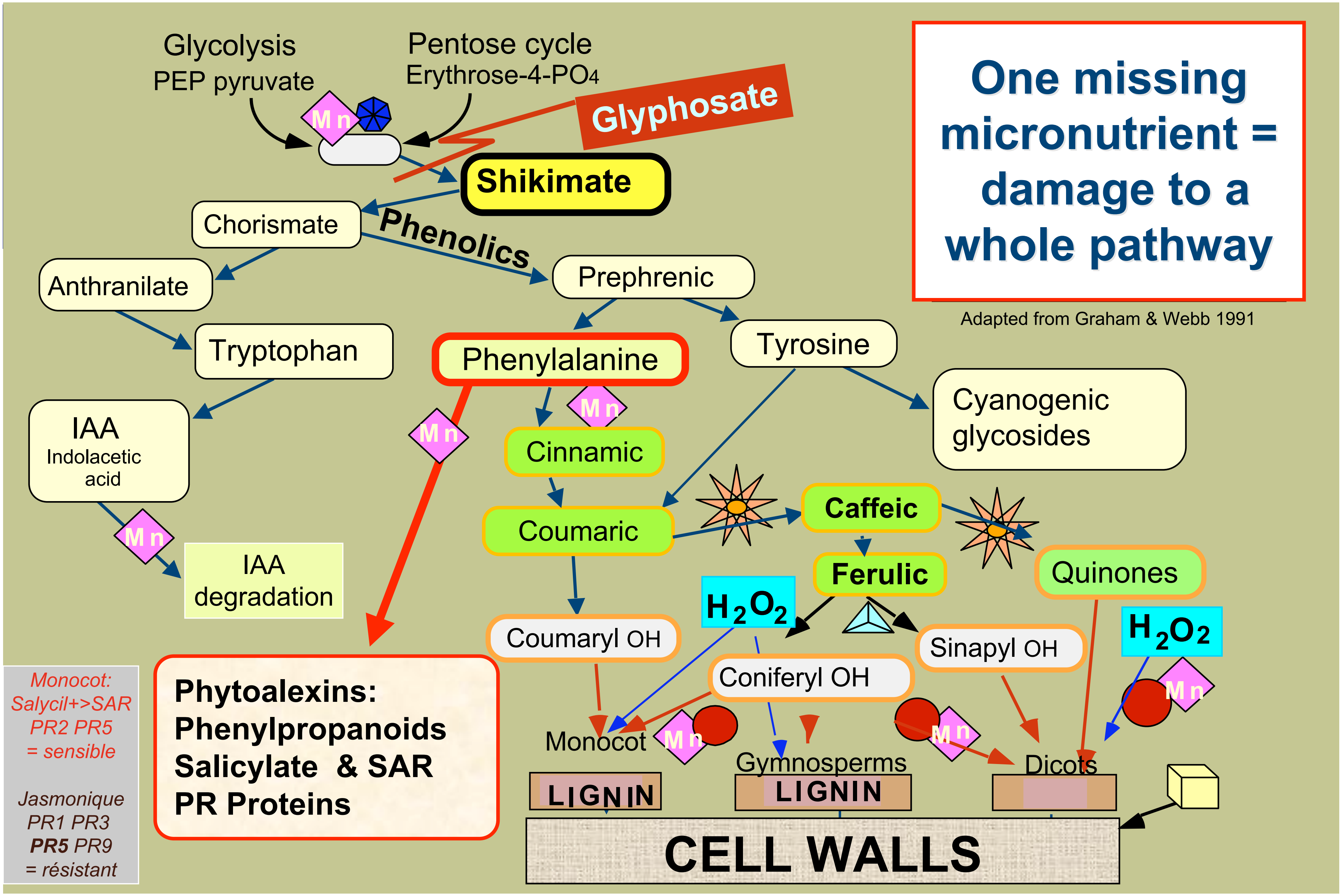
Yield 26%

Biomass 24%

After Cakmak et al, 2009

Benefit of High Nutrient Seed

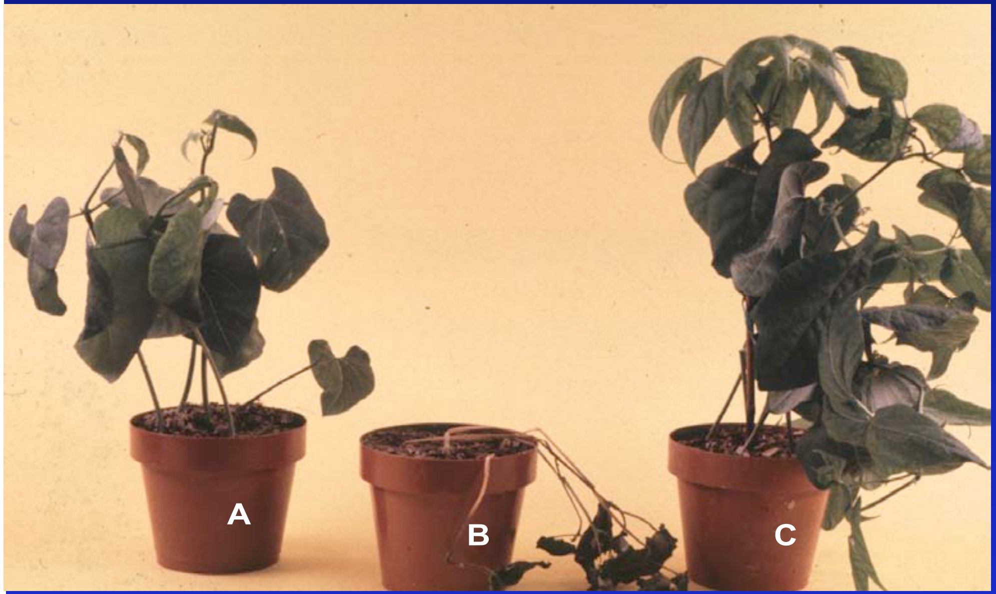
After Andre Comeau, 2008



Glycolysis
PEP pyruvate
Pentose cycle
Erythrose-4-PO4
Mn
Glyphosate
Shikimate
Chorismate
Phenolics
Anthranilate
Prephrenic
Tryptophan
Phenylalanine
Tyrosine
IAA
Indolacetic acid
Mn
Cinnamic
Cyanogenic glycosides
Coumaric
Caffeic
Ferulic
Quinones
IAA degradation
H_2O_2
Coumaryl OH
Sinapyl OH
Coniferyl OH
Monocot
Gymnosperms
Dicots
LIGNIN
LIGNIN
CELL WALLS
Phytoalexins:
Phenylpropanoids
Salicylate & SAR
PR Proteins
Monocot:
Salycil+>SAR
PR2 PR5
= sensible
Jasmonique
PR1 PR3
PR5 PR9
= résistant
One missing micronutrient = damage to a whole pathway
Adapted from Graham & Webb 1991

Herbicide action is by soil-borne fungal pathogens

Glyphosate Increases Disease Susceptibility



Glyphosate Sterile soil | Glyphosate Field soil | No glyphosate Control

Effect of glyphosate on susceptibility to anthracnose. A) hypersensitive response; B) non-limited response after glyphosate is applied.

After Rahe and Johal, 1988; 1990; See also Johal and Huber, 1999; Schafer et al, 2009.

Role of Soil Pathogens in Response to Glyphosate

- *Fusarium* and *Pythium* readily colonized susceptible giant ragweed roots when treated with glyphosate
- Resistant Giant Ragweed in unsterile soil were killed by a 4x rate of glyphosate, yet susceptible biotypes were not killed with the same rate in sterile soil.
- Dry weight of susceptible biotypes treated with Ridomil Gold was not changed by glyphosate
- Resistant giant ragweed biotypes were resistant to *Pythium*
- Glyphosate increased susceptibility to *Pythium*

Glyphosate susceptible biotype 4 DAT

Pythium Control | Pythium + glyphoste | Glyphosate control

Glyphosate treated
Susc. biotype | Resistant biotype

Ridomil Fungicide | Ck | Ridomil | Ck

Schafer et al, 2010

Some Plant Pathogens Affected by Glyphosate

Pathogen **Pathogen**

Increased:

Botryospheara dothidea
Corynespora cassicola
Fusarium spp.
Fusarium avenaceum
F. graminearum
F. oxysporum f. sp cubense
F. oxysporum f.sp (canola)
F. oxysporum f.sp. glycines
F. oxysporum f.sp. vasinfectum
F. solani f.sp. glycines
F. solani f.sp. phaseoli
F. solani f.sp. Pisi
Gaeumannomyces graminis
Magnaporthe grisea
***Cercospora* spp.**
Marasmius spp.
Monosporascus cannonbalus
Myrothecium verucaria
Phaeomoniella chlamydospora
Phytophthora spp.
Pythium spp.
Rhizoctonia solani
Septoria nodorum
Thielaviopsis bassicola
Xylella fastidiosa
Clavibacter nebraskensis
Xanthomonas sterwartii

Decreased (obligate pathogens):

Phykopsora pakyrhiza
Puccinia graminis

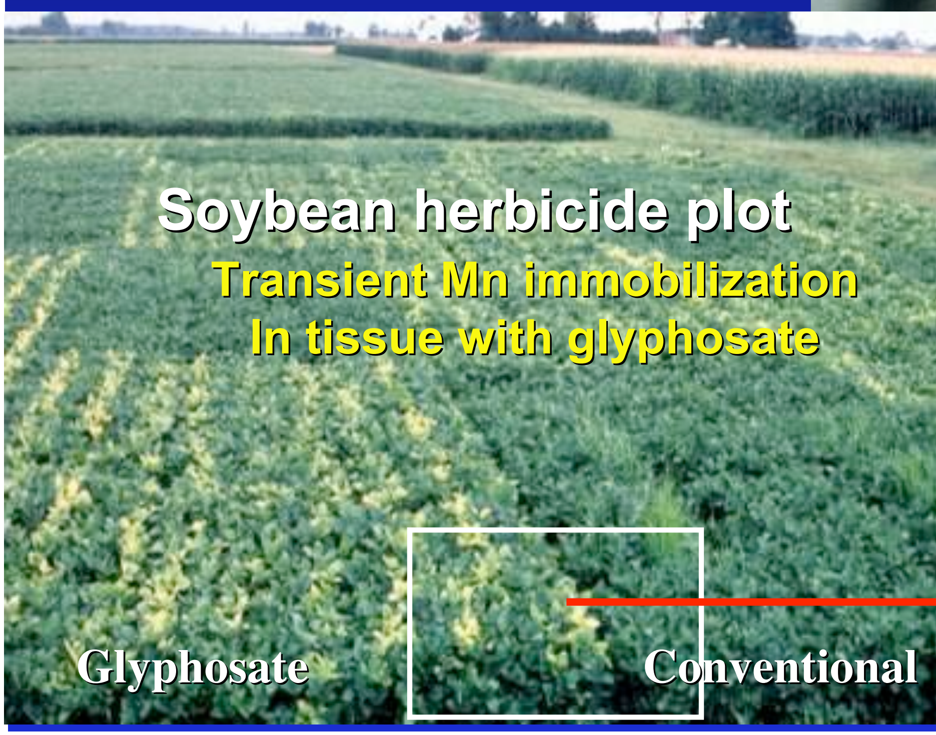
("Emerging" and "reemerging diseases")

Abiotic: Nutrient deficiency diseases; bark cracking, mouse ear, 'witches brooms'

Some Diseases Increased by Glyphosate

Host plant	Disease	Pathogen
Apple	Canker	*Botryosphaeria dothidea*
Banana	Panama	*Fusarium oxysporum* f.sp. *cubense*
Barley	Root rot	*Magnaporthe grisea*
Beans	Root rot	*Fusarium solani* f.sp. *phaseoli*
Bean	Damping off	*Pythium* spp.
Bean	Root rot	*Thielaviopsis bassicola*
Canola	Crown rot	*Fusarium* spp.
Canola	Wilt	*Fusarium oxysporum*
Citrus	CVC	*Xylella fastidiosa*
Corn	Root and Ear rots	*Fusarium* spp.
Cotton	Damping off	*Pythium* spp.
Cotton	Bunchy top	Manganese deficiency
Cotton	Wilt	*F. oxysporum* f.sp. *vasinfectum*
Grape	Black goo	*Phaeomoniella chlamydospora*
Melon	Root rot	*Monosporascus cannonbalus*
Soybeans	Root rot, Target spot	*Corynespora cassicola*
Soybeans	White mold	*Sclerotina sclerotiorium*
Soybeans	SDS	*Fusarium solani* f.sp. *glycines*
Sugar beet	Rots, Damping off	*Rhizoctonia and* Fusarium
Sugarcane	Decline	*Marasmius* spp.
Tomato	Wilt (New)	*Fusarium oxysporum* f.sp. *pisi*
Various	Canker	*Phytophthora* spp.
Weeds	Biocontrol	*Myrothecium verucaria*
Wheat	Bare patch	*Rhizoctonia solani*
Wheat	Glume blotch	*Septoria* spp.
Wheat	Root rot	*Fusarium* spp.
Wheat	Head scab	*Fusarium graminearum*
Wheat	Take-all	*Gaeumannomyces graminis*

Impact of Glyphosate on Take-all



Impact of Glyphosate on Take-all

Factors Predisposing to Fusarium Head Scab

(*Fusarium* spp.; *Gibberella zeae*)

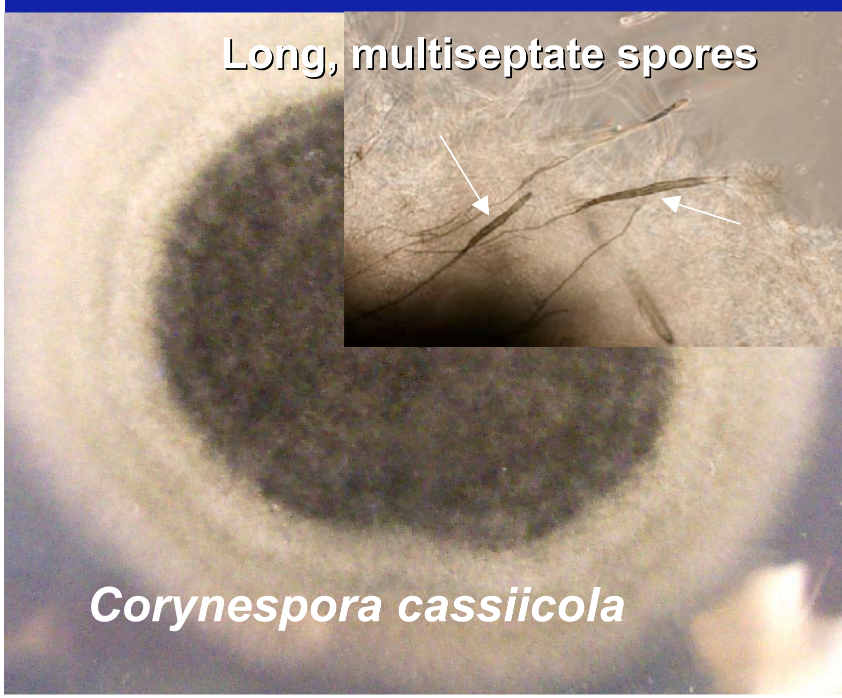
- ✓ *Environment* was the most important factor in FHB development in eastern Saskatchewan, from 1999 to 2002
- ✓ *Application of glyphosate formulations* was <u>the most important agronomic factor</u> associated with higher FHB levels in spring wheat
- ✓ Positive association of glyphosate with FHB was *not affected by environmental conditions* as much as that of other agronomic factors…

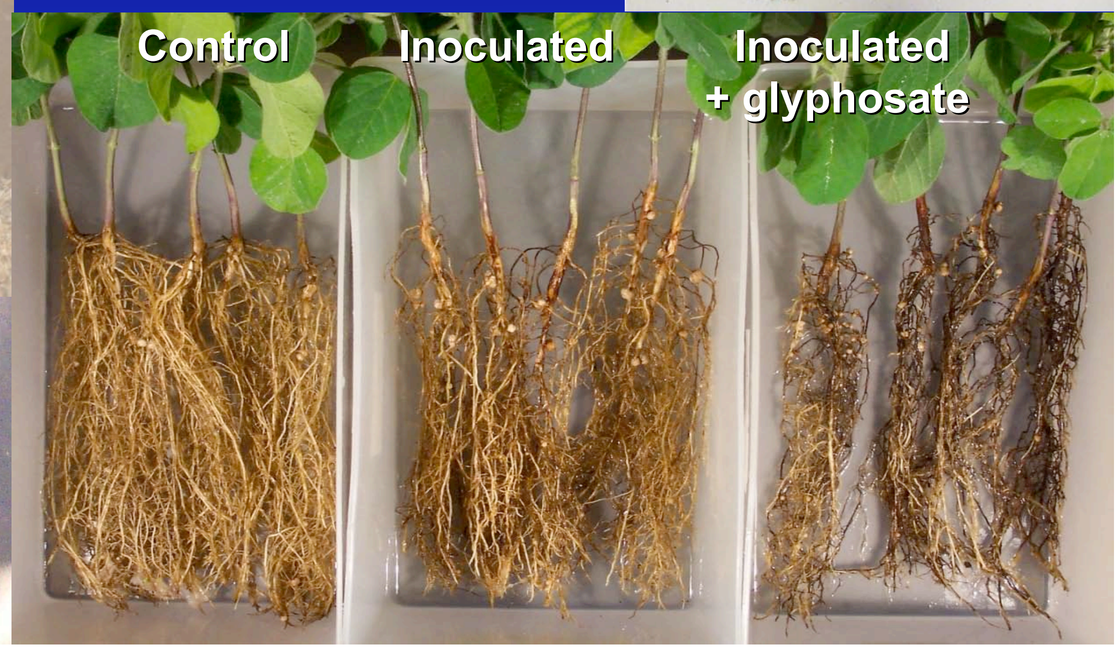
(Fernandez et al. 2005, *Crop Sci. 45: 1908-1916*)
(Fernandez et al., 2007, Crop Sci. 47:1574-1584)

Number of glyphosate applications the <u>previous three years</u>	% Increase in head scab
None	00
1 to 2	152 ***
3 to 6	295 ***

Corynespora Root Rot

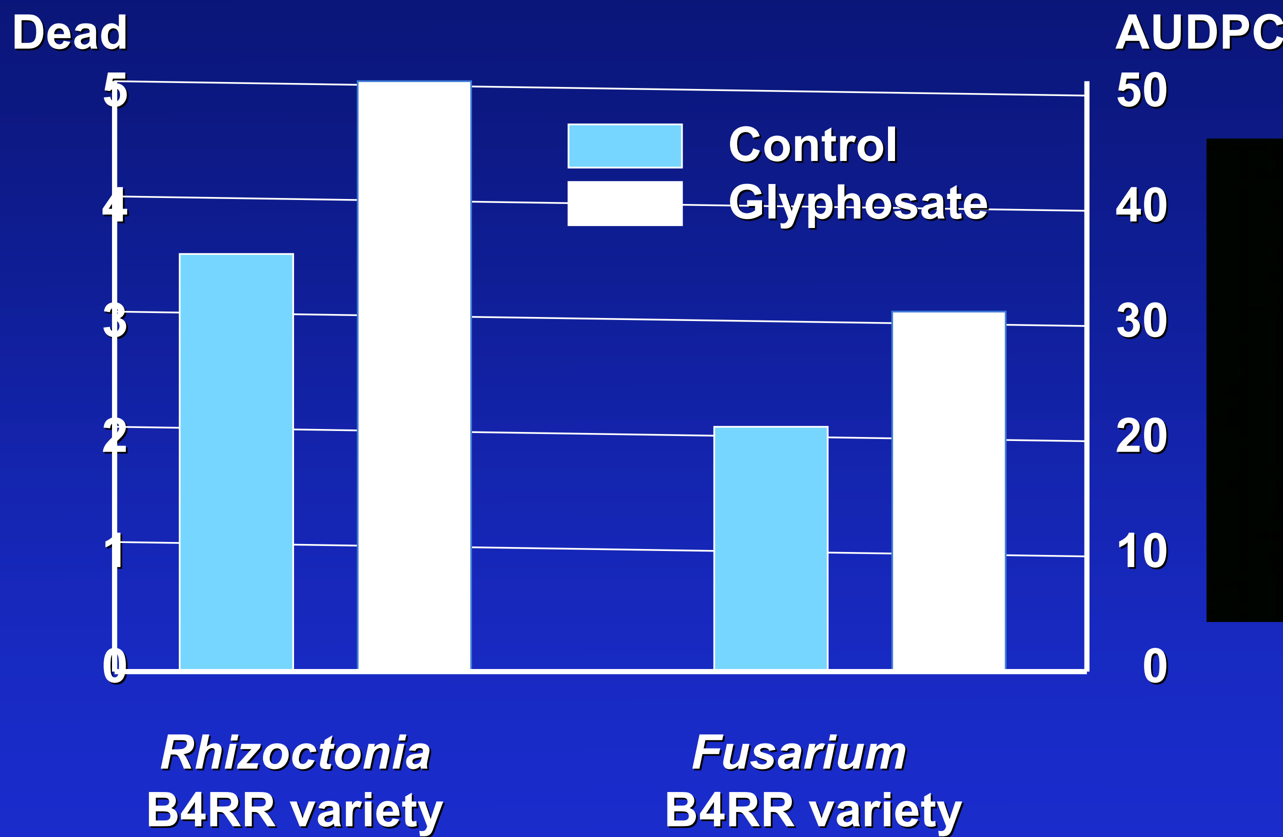
- An extensive dark brown to black rotting of small lateral roots
- Generally considered a root “nibbler”
- Severe with glyphosate and especially near weeds killed by glyphosate





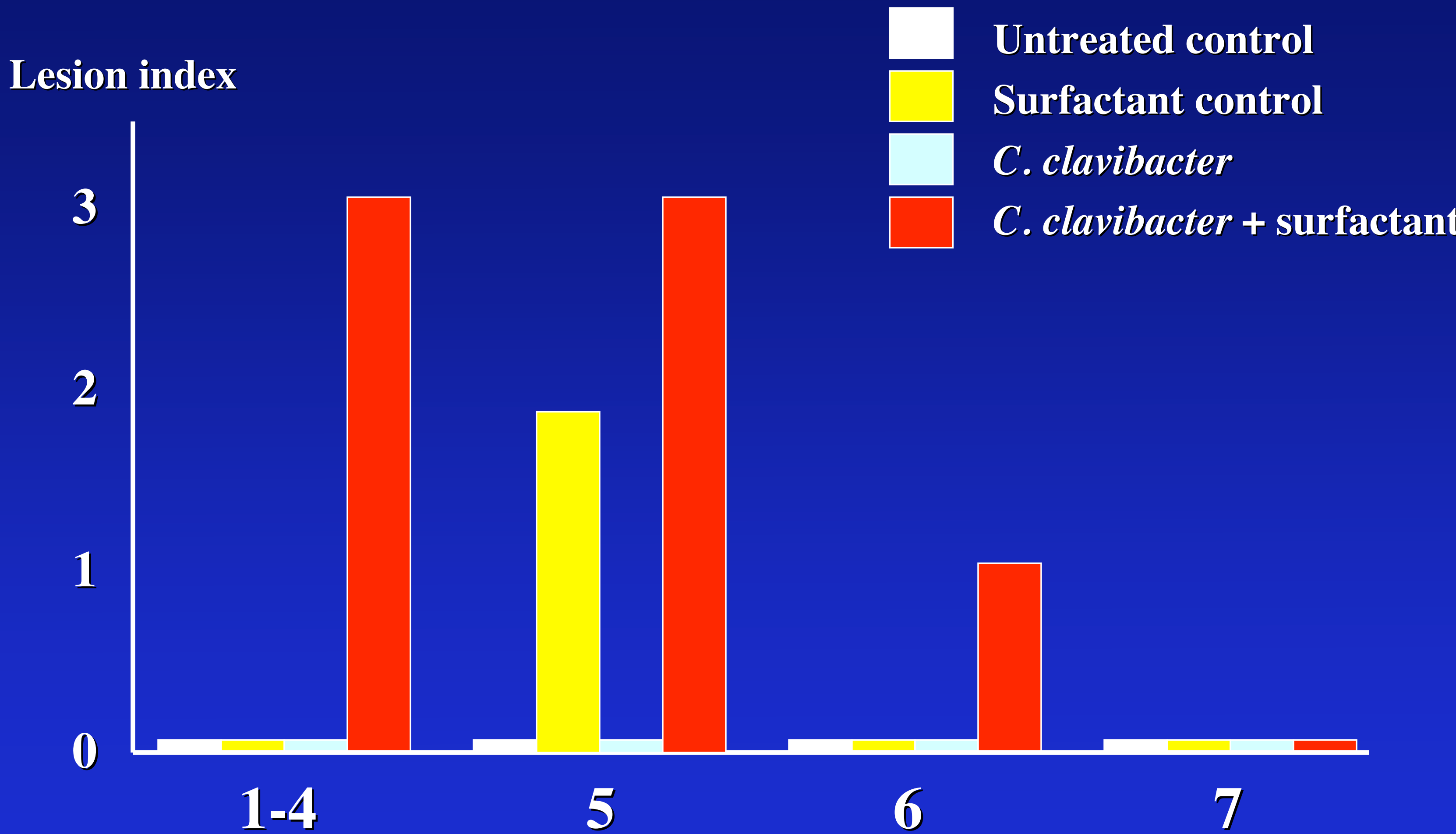
Glyphosate Predisposition to SDS, IA, 2010

Impact of Glyphosate on Sugar Beet



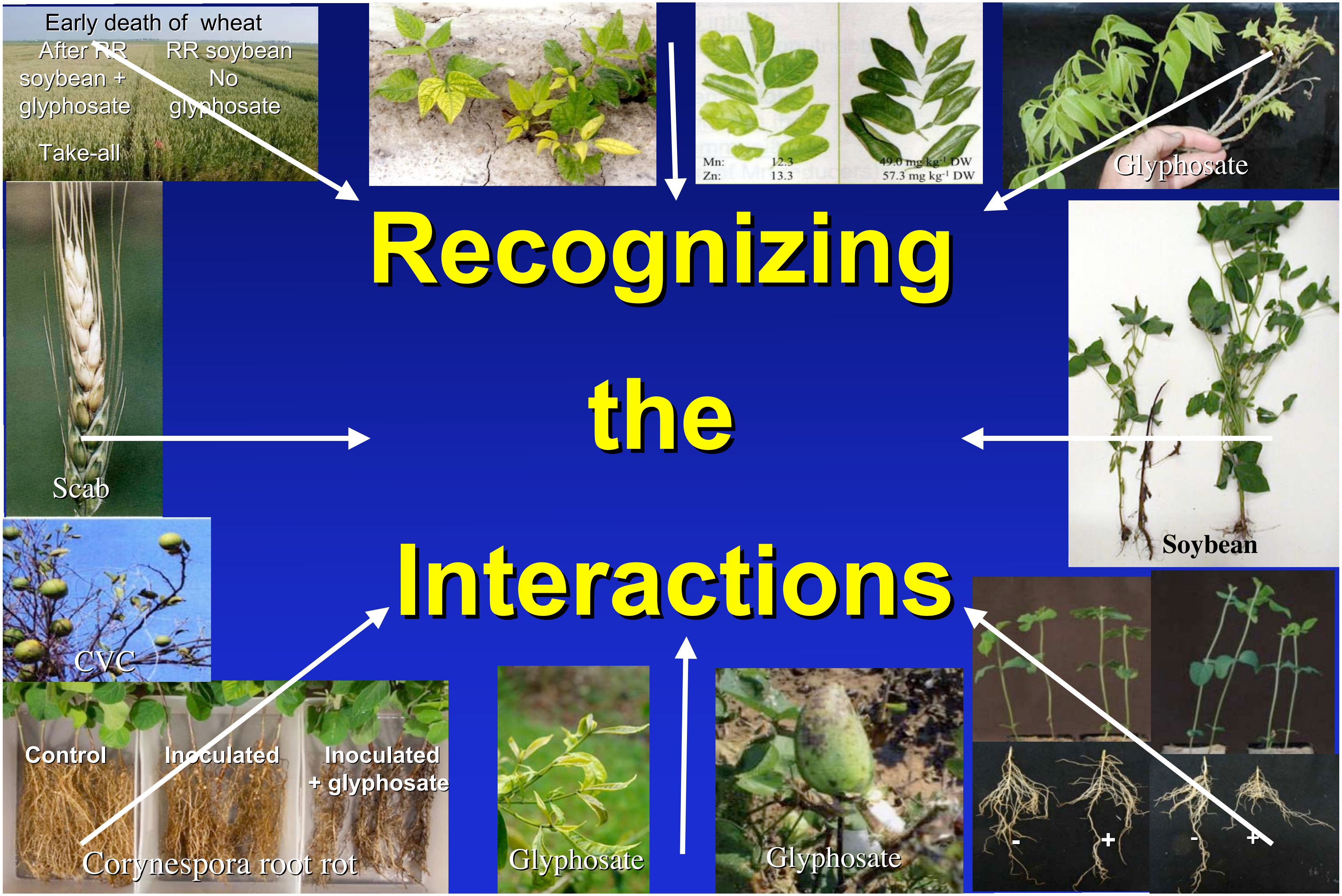
"Precautions need to be taken when certain soil-borne diseases are present if weed management for sugar beet is to include post-emergence glyphosate treatments." Larson et al., 2006

Effect of Surfactants on Goss' Wilt Infection



Goss' wilt resistant corn hybrid

Phys-Resistance   Phyto-susceptible   Phys-Resistant   Phys/physiol-Res

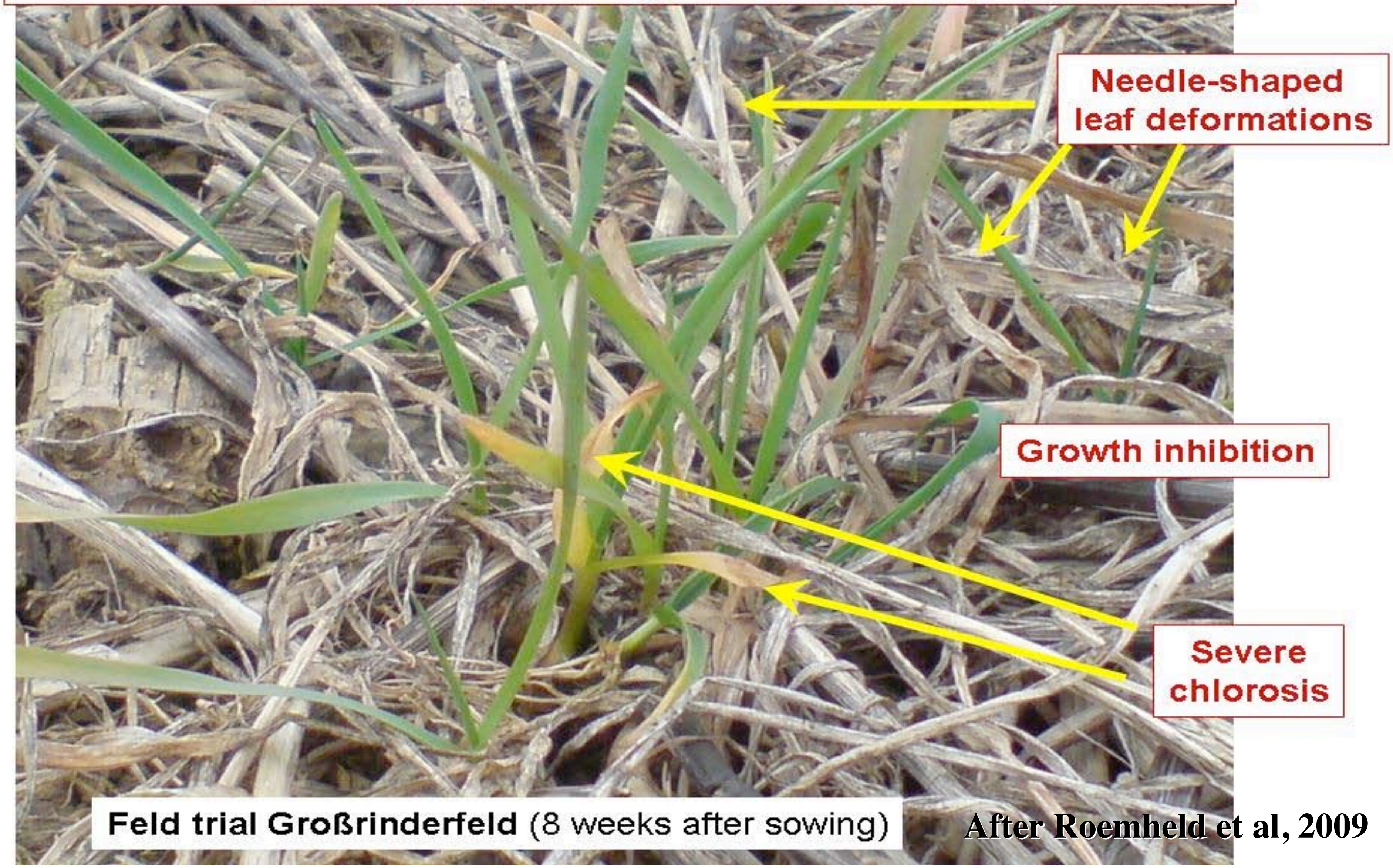

Early death of wheat
After RR soybean + glyphosate
RR soybean No glyphosate
Take-all
Mn: 12.3 49.0 mg kg-1 DW
Zn: 13.3 57.3 mg kg-1 DW
Glyphosate
Recognizing the Interactions
Scab
Soybean
CVC
Control
Inoculated
Inoculated + glyphosate
Corynespora root rot
Glyphosate
Glyphosate
- + - +

Some SYMPTOMS of Glyphosate Damage

(Sub-herbicidal depending on rate and length of exposure)

- ✓ Low vigor, stunting, slow growth
- ✓ Leaf chlorosis (yellowing) - complete or between the veins
- ✓ Leaf mottling - sometimes with necrotic flecks or spots
- ✓ Leaf distortion - small, curling, strap, wrinkling, 'mouse ear'
- ✓ Abnormal stem proliferation ('witches broom')
- ✓ Bud, fruit abortion
- ✓ Retarded regrowth after cutting (alfalfa, perennial plants)
- ✓ Lower yields, lower mineral value
- ✓ Predisposition to infectious diseases - NUMEROUS!
- ✓ Predisposition to insect damage
- ✓ Induced abiotic diseases - drought, winter kill, sun scald
- ✓ Root stunting, poor growth, inefficient N-fixation and uptake
- ✓ Bark cracking *after Univ. of Hawaii; Univ. of Connecticut, Ohio State University*

Close up of field symptoms of plant damage in treatments with short waiting times (1 d) after Glyphosate pre-crop application



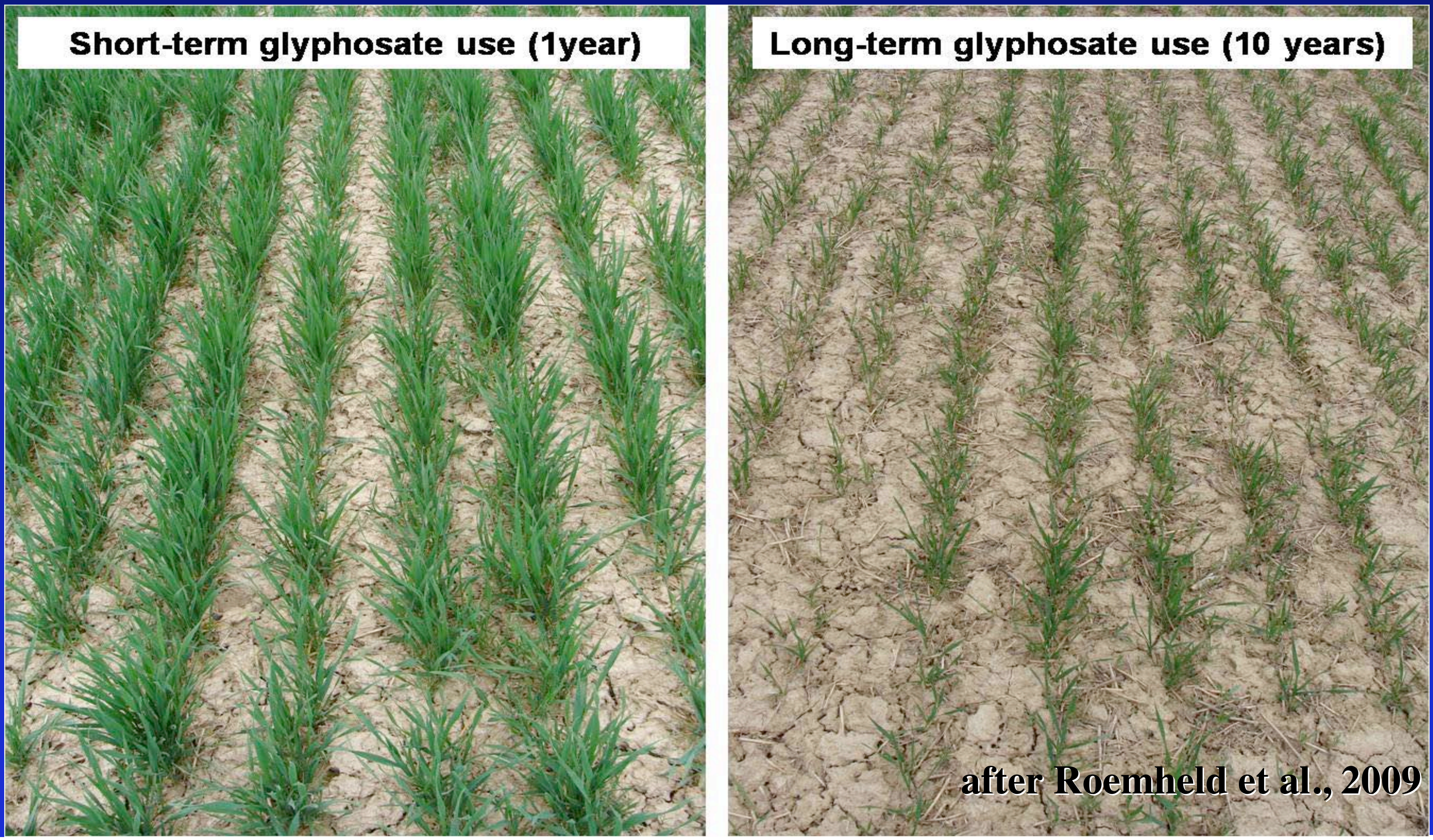
After Roemheld et al, 2009

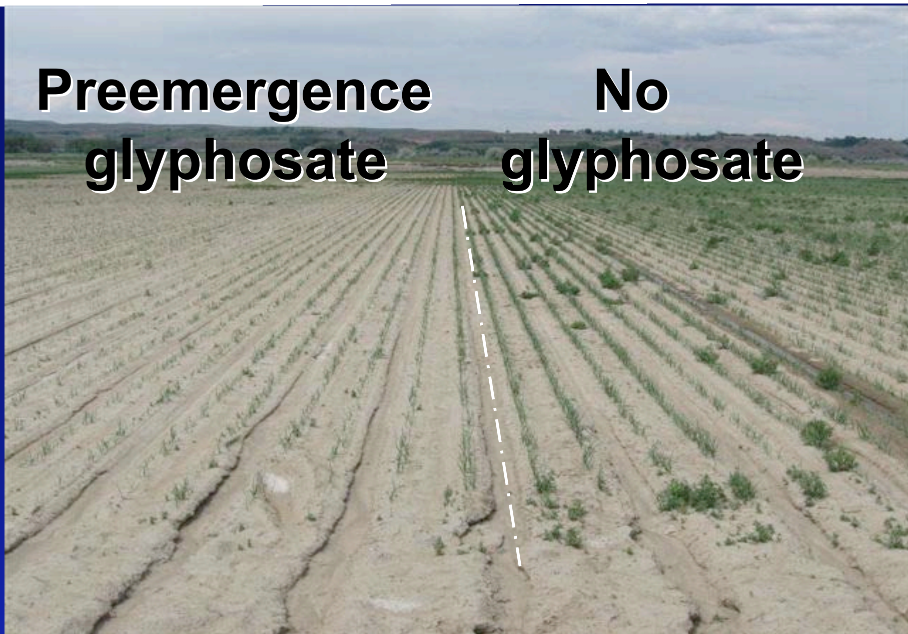
Effect of Planting Delay after Glyphosate (Residual Glyphosate in Soil)

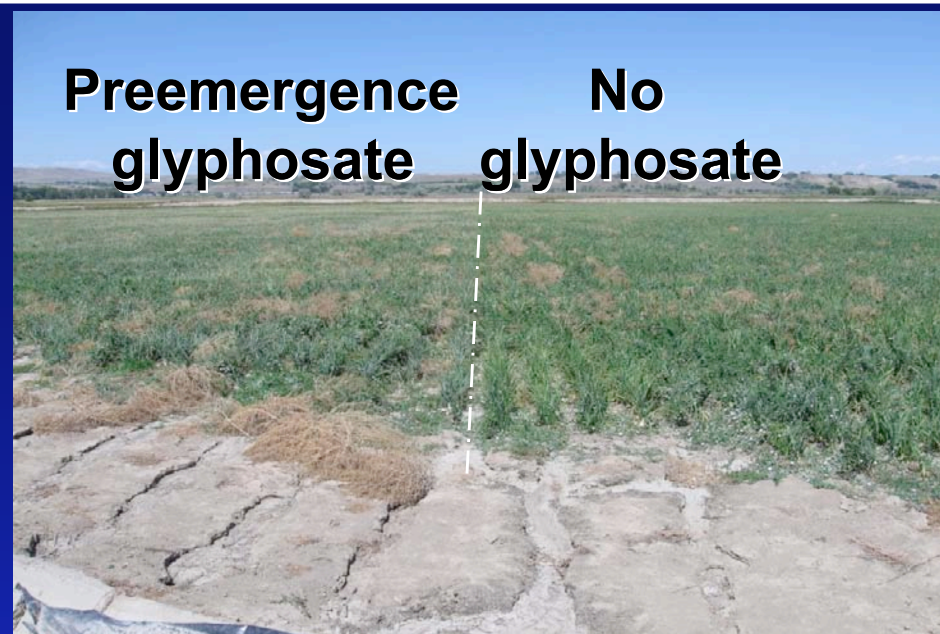
Winter Wheat

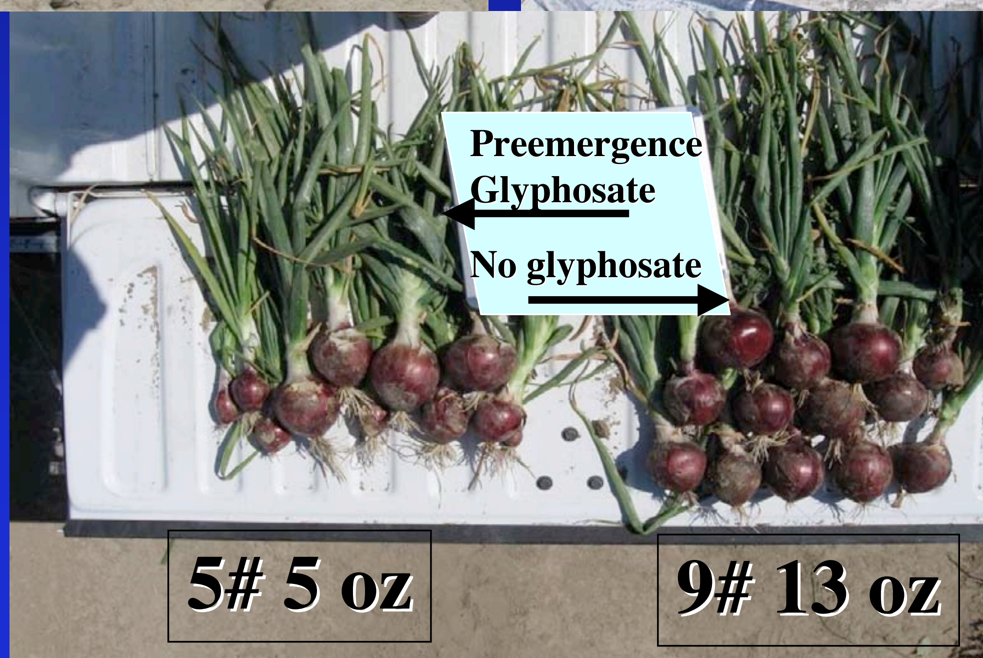
Long-term Effect of Glyphosate

Field observations in winter wheat production systems in 2008 & 2009 point to potential negative side-effects of long-term glyphosate use.



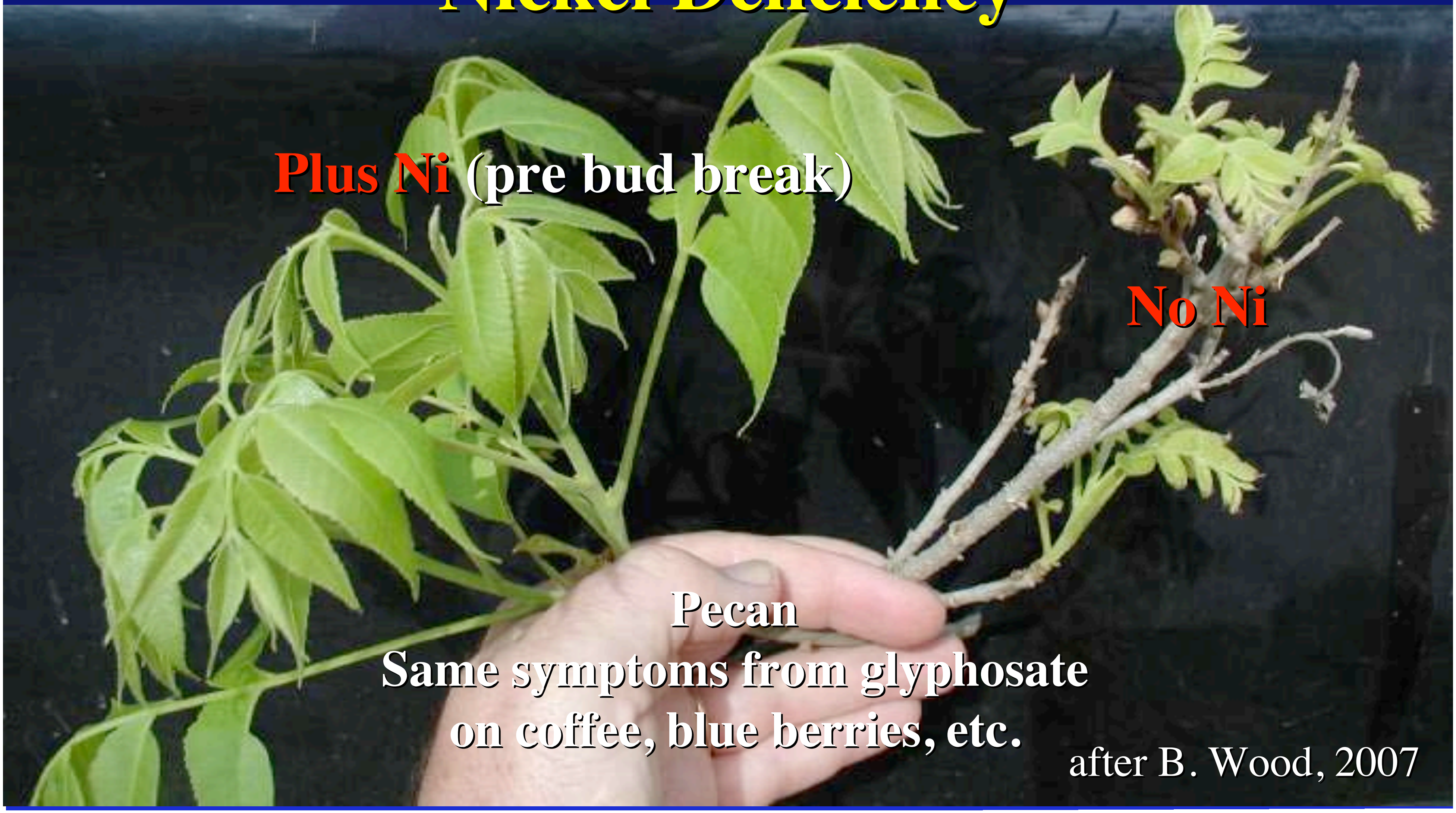

Preemergence glyphosate
No glyphosate


Preemergence glyphosate
No glyphosate


Preemergence Glyphosate
No glyphosate
5# 5 oz
9# 13 oz

Poor Boll Retention, Sterile Locules in Cotton. WHY?

Poor Bud Break, Small Leaves, Stem Epinasty
Nickel Deficiency



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. Increasing plant resistance to diseases and toxins

Nutrient-related pathways (Shikimate, AA, CHO, etc.)

5. Judicious use of glyphosate

Yield Response of Roundup Ready® Soybeans to Micronutrients

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

Glyphosate-induced Fe-deficiency chlorosis

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

Treatment	Visual chlorosis score [1 = green; 5 = yellow] - Fe	Visual chlorosis score [1 = green; 5 = yellow] + Fe	Grain yield (bu/a) - Fe	Grain yield (bu/a) + Fe
Control (no herbicide)	3.1	2.8	33	56
Glyphosate	3.7	3.3	8	19

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

Effect of Glyphosate on Roundup Ready© Corn

Colorado State University, 2007

Mike Bartolo, Sr. Res. Scientist

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

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

Glyphosate & Manganese Effects on Cotton

Untreated Check (conventional herbicide)

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

Glyphosate @ 22 oz/ac plus AMS + Manganese

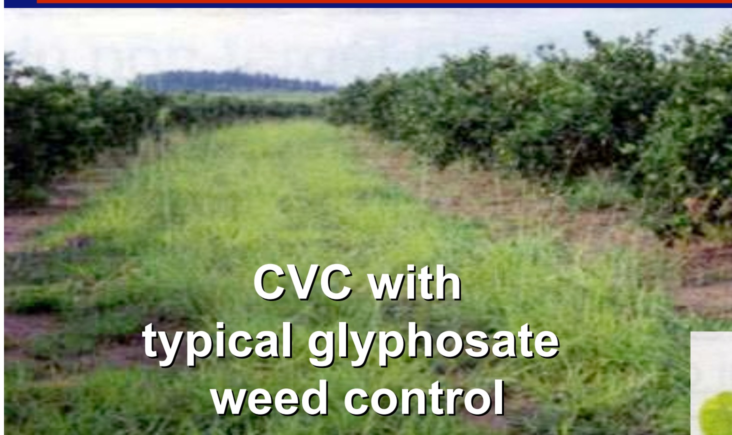
Effect of glyphosate and Manganese on Cotton Yield (Texas)

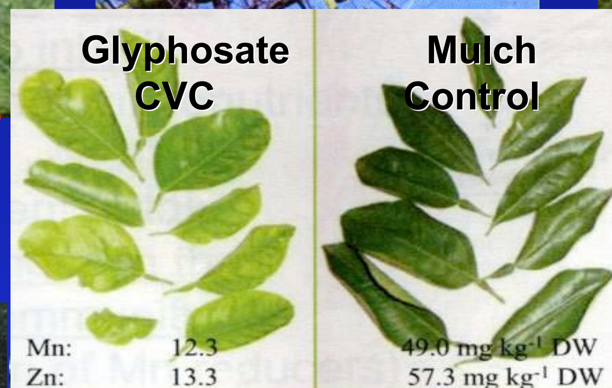
Treatment	% chlorotic plants	# seed cotton
Conventional herbicide	5	4885
Glyphosate	97	2237
Glyphosate + Mn, Zn	2	4693

after Ronnie Phillips, 2009

Citrus Variegated Chlorosis

Predisposition to CVC (*Xylella fastidiosa*) by glyphosate





Effect of Tillage on Glyphosate Injury & Yield

Field History: 8 years Cons. Res. Program

2 qt blyphosate burndown 2008

1 qt glyphosate on RR corn 2009

1 qt glyphosate burndown 2010

No-till **Fall chisel**

Photos: Nesters Farm Services

Glyphosate Resistant Weeds

It starts this way >>>>> and >>>>> Develops into this

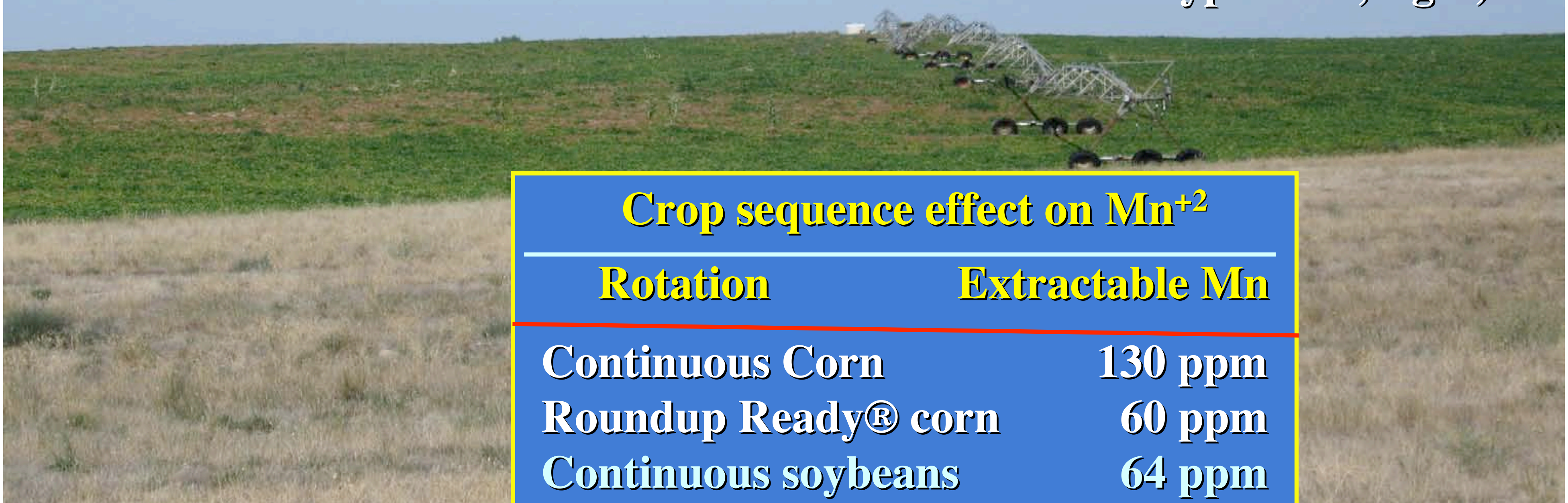
Increased Disease on Crops in the Rotation

- Beans (*P. vulgaris*) after RR sugar beets
  - Fusarium root rot
  - Rhizoctonia hypocotyl rot
- Alfalfa after RR corn or RR soybeans
  - Fusarium root and crown rot
  - Phytophthora root and crown rot
  - Aphanomyces root rot
- Wheat after RR canola
  - Fusarium root and crown rot
  - Fusarium head scab
- Potatoes after RR corn (RR sugar beets?)
  - Verticillium wilt
  - Fusarium dry rot
  - Rhizoctonia stolon canker
  - Common scab

Residual Soil & Crop Sequence Effects of 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, <u>corn</u>	91 ppm
Wheat, corn, <u>soybean</u>	79 ppm

Food and Feed Safety Concerns

- Increased levels of mycotoxins
  - Fusarium toxins (DON, NIV, ZEA)
  - Aflatoxins
- Nutrient deficiency
  - Cu, Fe, Mg, <u>Mn</u>, Zn
- Gene flow
  - Weeds
  - Soil microbes
  - Intestinal microbes
- Direct toxicity of residual glyphosate
  - Infertility - endocrine system
  - Cell death - Disease resistance
- Allergenic reactions to foreign proteins

Carmen, et al., 2010
Fernandez, et al., 2009
Gasnier, et al., 2009
Heiman, 2010
Seralini et al., 2010
Smith, 2010
Walsh, et al., 2000
Watts, 2009

Mycotoxins in Straw and Grain

- ✓ *Fusarium* spp. act synergistically to cause death of glyphosate-treated plants
- ✓ Glyphosate-induced root colonization by *Fusarium* spp.
- ✓ Toxins (DON, ZEA) produced in crown and translocated to stem and grain - Well above 'clinically significant' levels!
- ✓ Toxin concentrations not always correlated with *Fusarium* damaged grain (FDG) - [Strobilurin fungicides increase mycotoxins]
- ✓ Head must be protected for 18 days (10 days after anthesis)

Deoxynivalenol and Zaeralenone Concentrations in plant parts

Toxin (ppm)	Grain	Chaff	Straw
Deoxynivalenol	4.7	16.9	3.5
Zaeralenone	4.4	42.9	55.5

Proc. Natl. FHB Forum 2009, Orlando, FL

% Reduction in Alfalfa Nutrients by Glyphosate*

Nutrient	% reduction compared with Non-RR
Nitrogen	13 %
Phosphorus	15 %
Potassium	46 %
Calcium	17 %
Magnesium	26 %
Sulfur	52 %
Boron	18 %
Copper	20 %
Iron	49 %
Manganese	31 %
Zinc	18 %

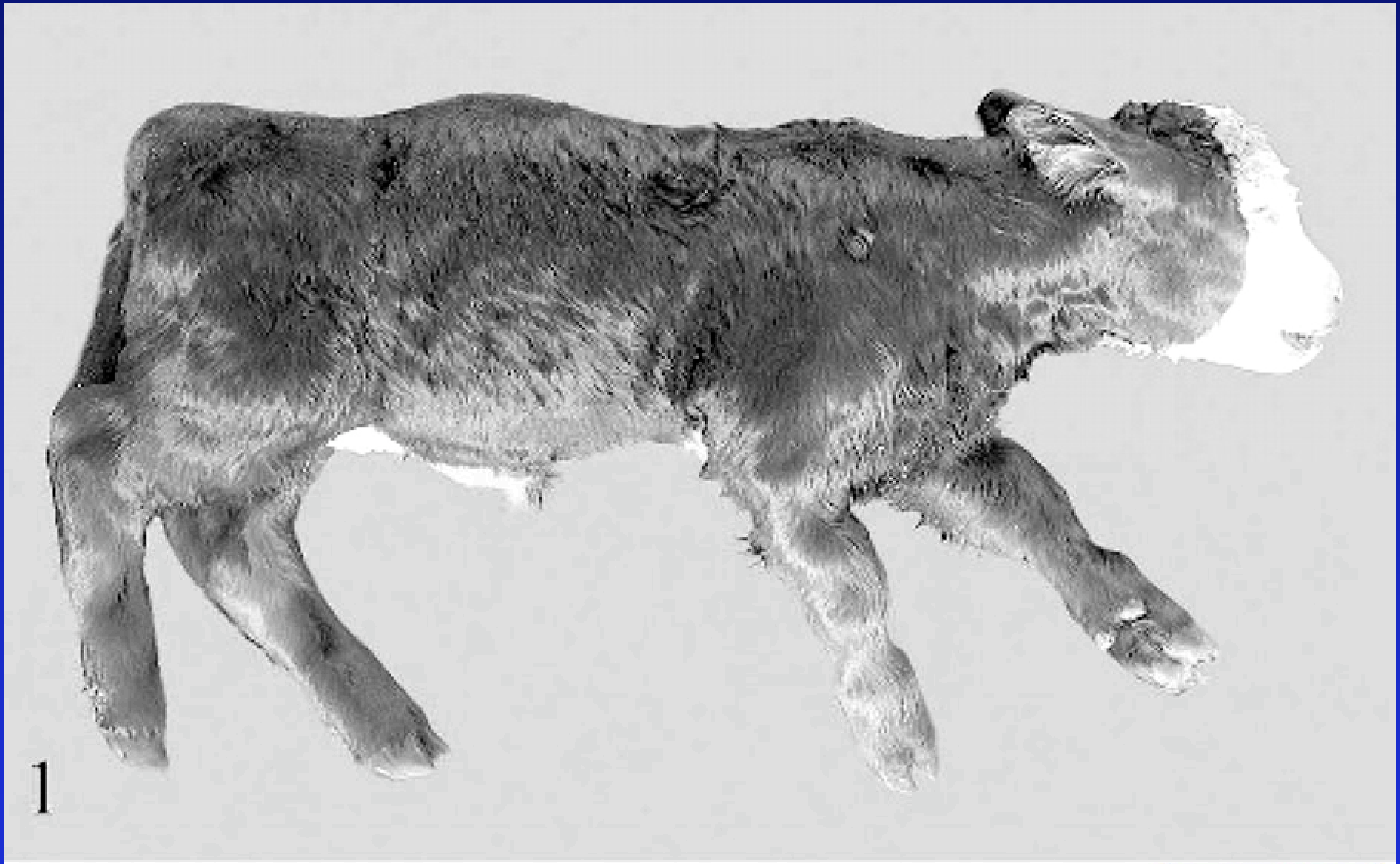
*Third year, second cutting analysis; Glyphosate applied one time in the previous year

Percent Decrease in Mineral Nutrients in Corn Silage - 2000 to 2010, Dairy One*

Mineral nutrient	Percent decrease
Calcium	22.0 % lower
Phosphorus	3.8 % lower
Magnesium	11.4 % lower
Potassium	16.1 % lower
Iron	5.2 % lower
Copper	9.6 % lower

*Based on 1629 samples

Stillborne Calf from Manganese Deficiency



McLaren P J et al. Vet Pathol 2007;44:342-354

Veterinary Pathology

Effect of the GM "Gene" Proteins in Corn/Soybeans on Pig Stomachs

After Carman et al., 2010

Non-GMO Feed

Normal color

GMO Feed

Inflamed, irritated

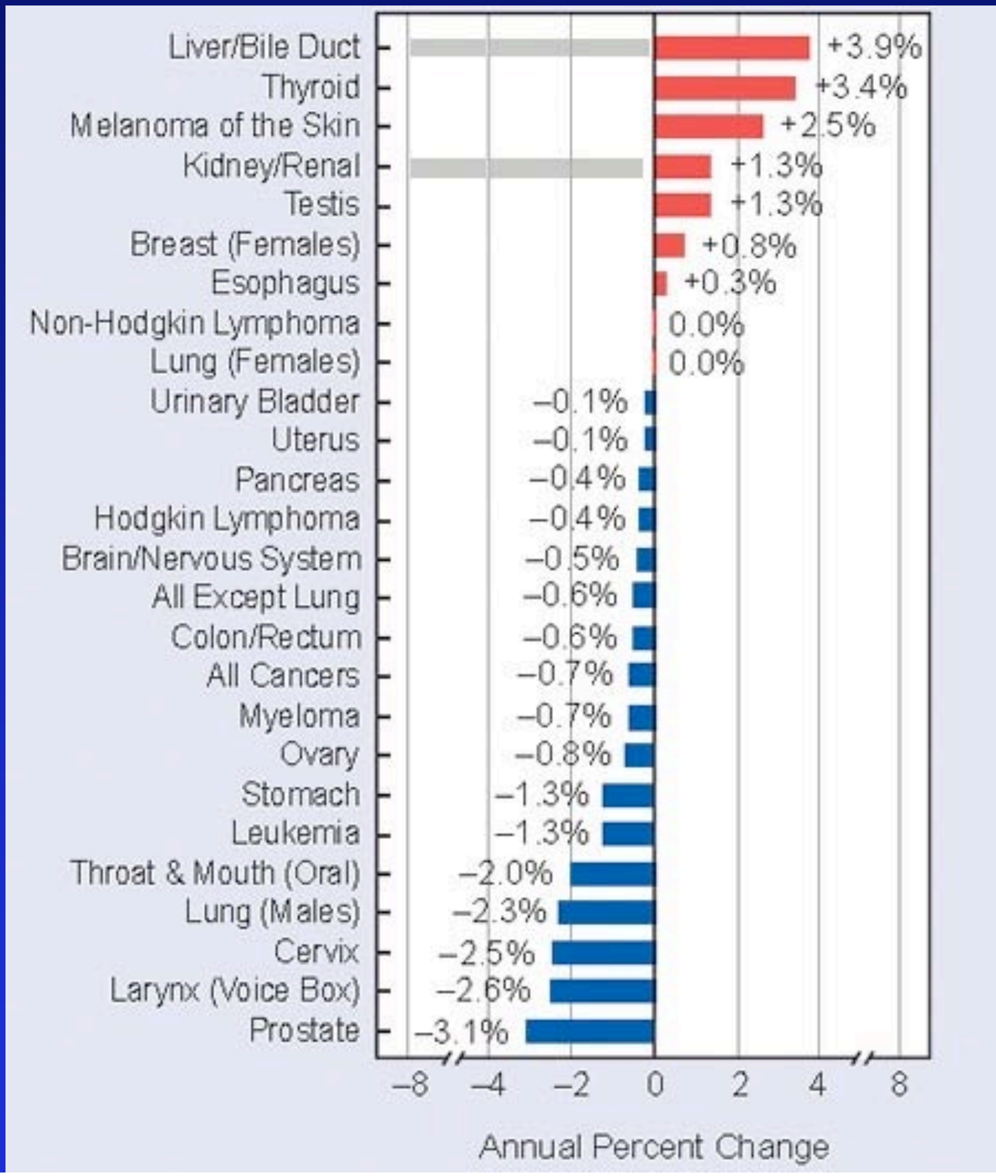
And the Mice Prefer……

GMO Corn

Non-GMO Corn

Photos: Gilbert Hostetler

Annual % Change in Cancers



<u>Target Tissues for glyphosate;</u>

Liver

Kidney

Testicle

Hormone system

Bone (Ca, Mn chelation?)

Thyroid (Mn chelation?)

Hello, my name is ____________. I am a veterinarian in Michigan.

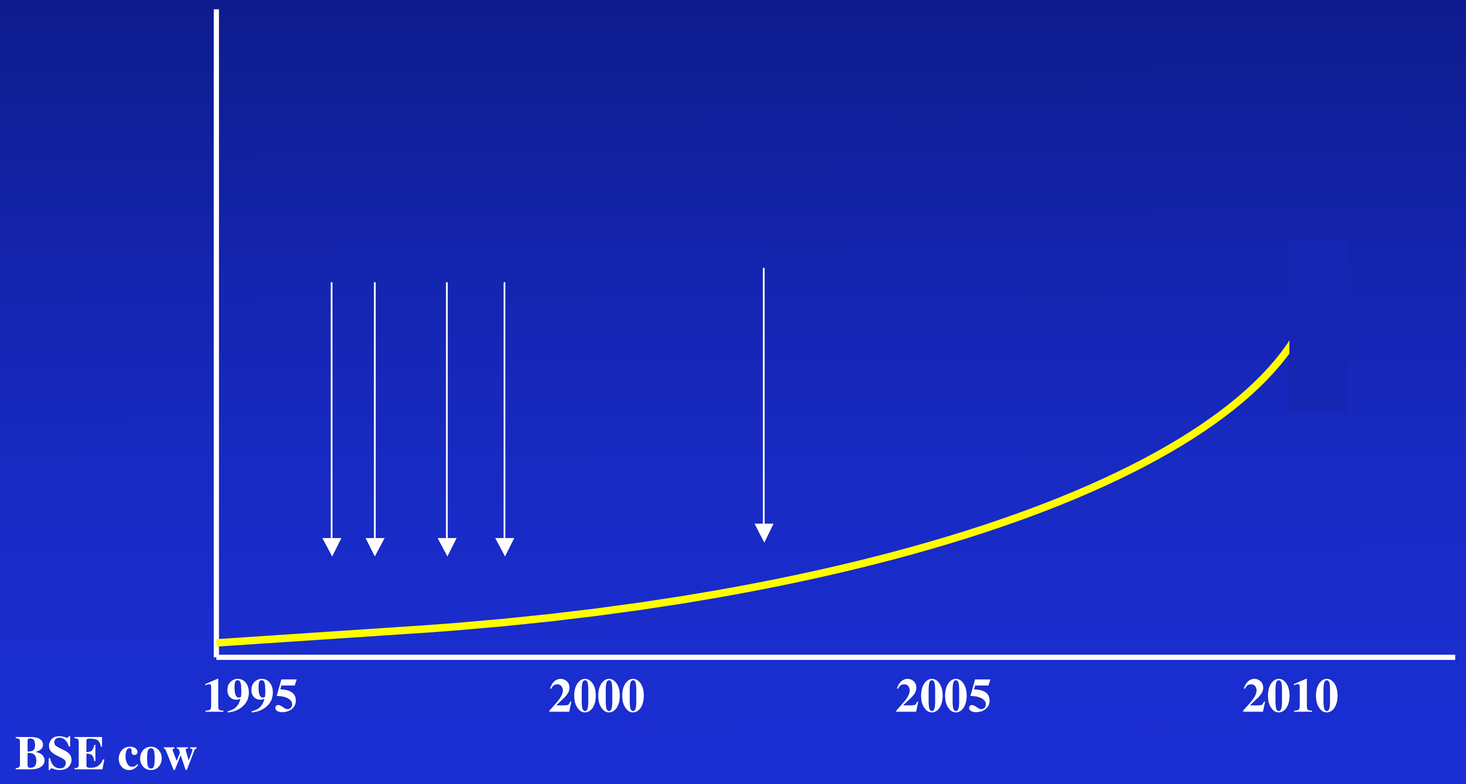
I am working with a sow herd that has had elevated death loss for over two years and very poor reproductive performance for the last 6-8 months. I have done extensive diagnostics (primarily at Iowa State) and can find nothing infectious that is routinely found to explain the problem.

I suspect there is a toxin involved; I have done extensive testing on liver, feed, and water but can find no evidence of those compounds either. We have had a few individuals mention that the use of GMO crops could be contributing to these problems.

The producer recently saw your article to the secretary of agriculture and forwarded it to me. We are very intrigued by the organism you mention. Could you tell me if any laboratory is looking for this agent? How do we go about finding it? We are at the end of our rope and cannot figure this out. Any help you can give us would be greatly appreciated.

Late term Spontaneous abortion

Generalized Graph of Incidence



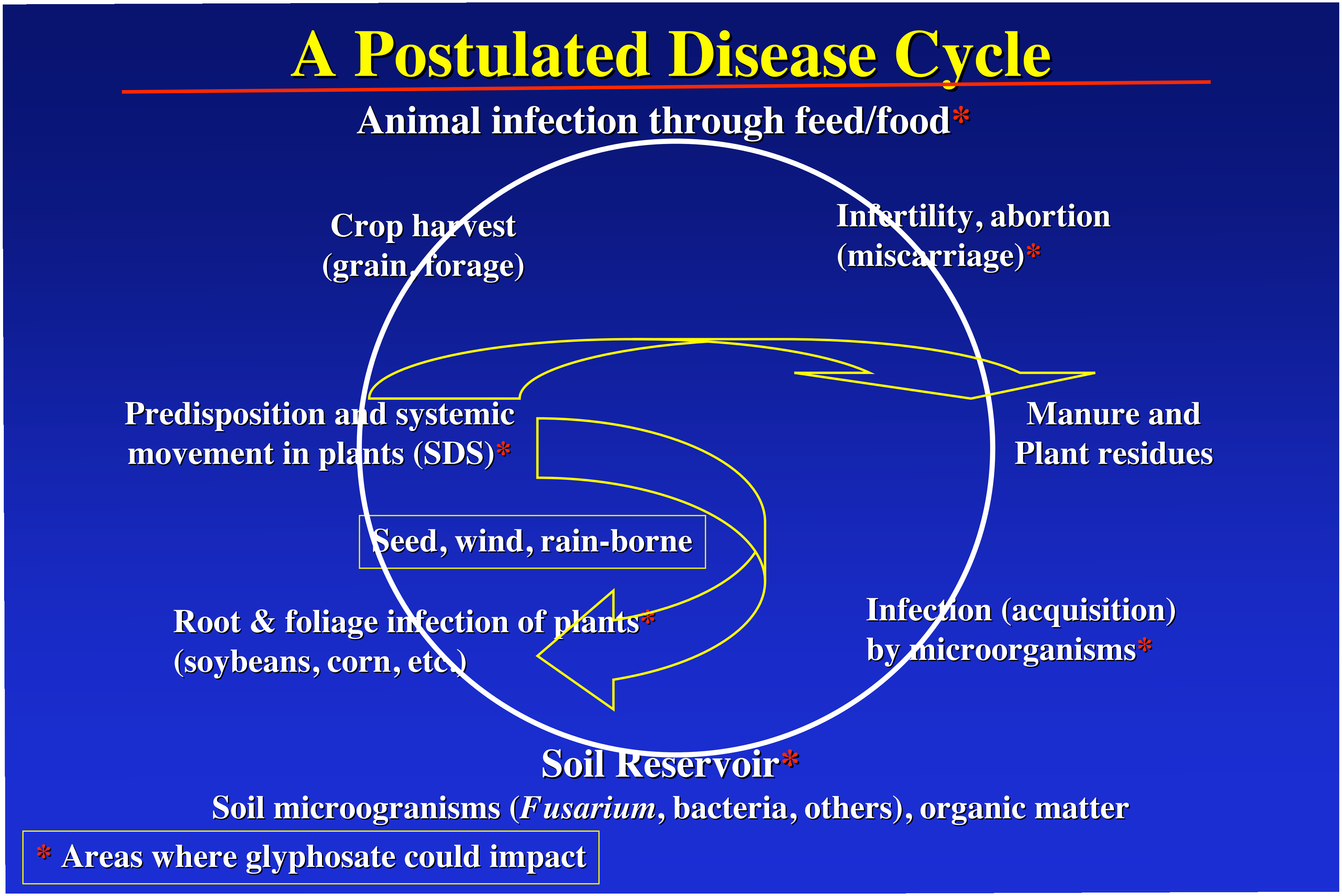
What is Known About the Organism

- **Characteristics**
  - Very small (EM visible at 38,000 X) - (size of a virus)
  - Filterable - passes through a bacterial filter
  - Culturable - self replicating
  - Common in nature (ubiquitous? - in soil) - IA, IL, KY, MI, NE, ND, WI
  - Unknown taxonomic position (genetic sequencing in progress)
  - Synergist with bacteria (gram+, e.g. alfa-Streptococcus) and other microbes
- **Infectious nature** - infects animals, plants, fungi (systemic)
- **Affect in animals** (horses, cattle, pigs, poultry)
  - Causes infertility
  - Causes spontaneous abortions (miscarriage-man)
  - Death of chicken embryos
  - In milk from cows fed high infected feed
- **Affect in plants**
  - High population in ‘scorch’ type diseases
  - ‘Extends’ symptoms of Goss’ wilt (corn) and SDS (soybean)
  - Seed-borne (?) - in soybean seed and feed/food products

Occurrence

- Verified in IA, IL, KY, NE, ND, SD, WI
- Sources:

<u>'Environmental'</u>	<u>Animal tissue</u>
Soybean meal	Placental tissue
Wheatlage, haylage, silage	Amniotic fluid
Corn leaves and silage	Semen
SDS Soybean plants	Stomach contents
Oak 'scorch' leaves	Eggs
Manure	Milk
Soil	
Fusarium solani fsp *glycines* mycelium	


A Postulated Disease Cycle
Animal infection through feed/food*
Crop harvest
(grain, forage)
Infertility, abortion
(miscarriage)*
Predisposition and systemic
movement in plants (SDS)*
Manure and
Plant residues
Seed, wind, rain-borne
Root & foliage infection of plants*
(soybeans, corn, etc.)
Infection (acquisition)
by microorganisms*
Soil Reservoir*
Soil microogranisms (Fusarium, bacteria, others), organic matter
* Areas where glyphosate could impact

Potential Interactions of 'new organism' with Glyphosate

- **Glyphosate affects plants (predisposes):**
  - Inhibits plant defenses
  - Reduces nutrient content and efficiency [chemical and RR gene(s)]
  - Increases root colonization
  - Increases membrane permeability
  - Surfactant affect for penetration of natural openings and wounds
- **Glyphosate affects animals (predisposes):**
  - Inhibits aramatose system – endocrine hormone system
  - Toxic to liver, placental, testicular, and kidney cells
  - Reduced defense - liver function [from lower Mn, etc. in feed]
- **Glyphosate affects pathogens:**
  - Stimulates growth and virulence (direct/indirect)
  - Favors synergism, infection (as a carrier)
  - Increases movement into plant tissues (water film for plant infection)
- **Glyphosate affects the environment:**
  - Toxic to soil microbes that constrain plant pathogens
  - Micronutrient availability reduced

What has Changed?

Change:

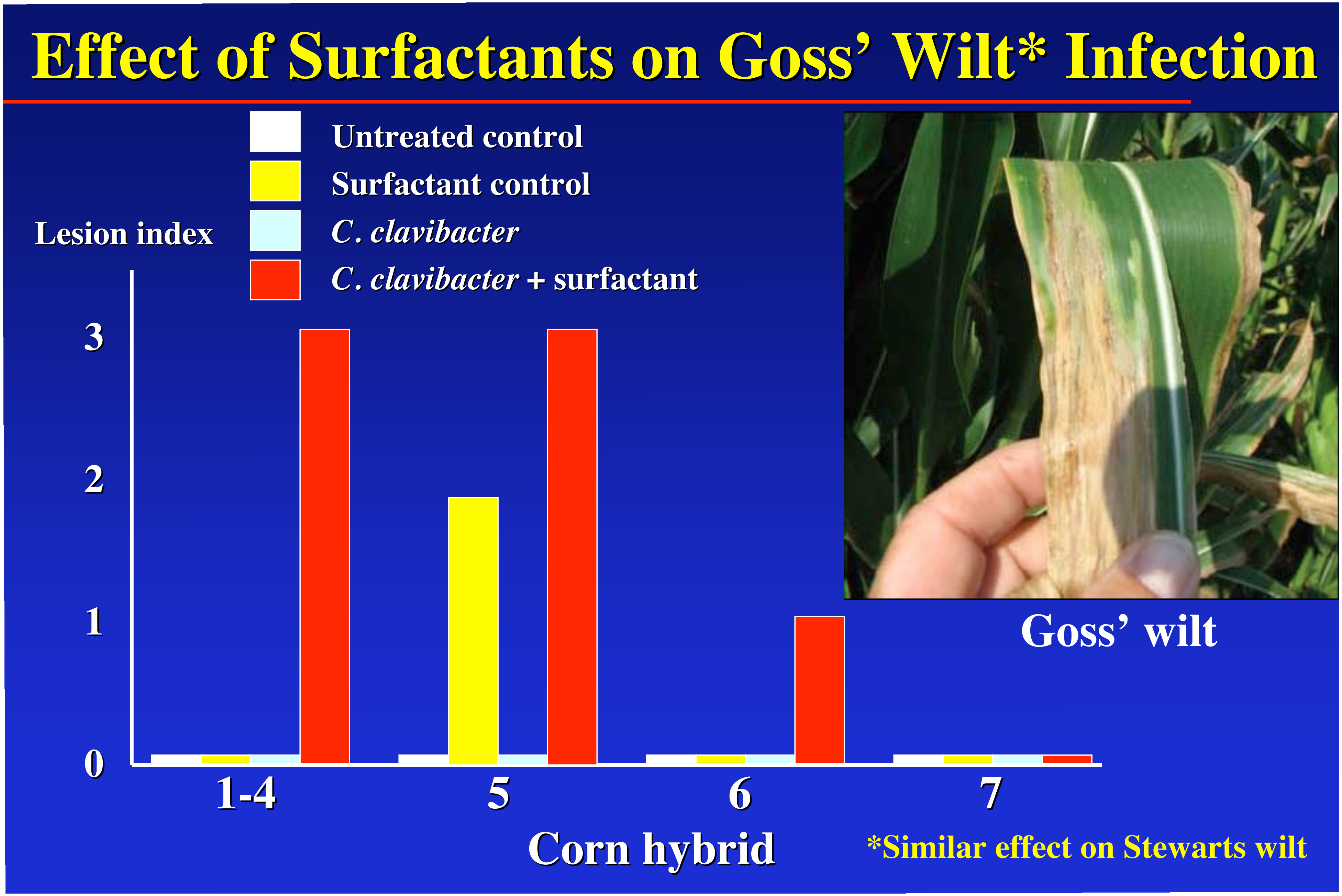
Increased disease
New diseases
Low mineral nutrition
Resistant weeds

Precedent:

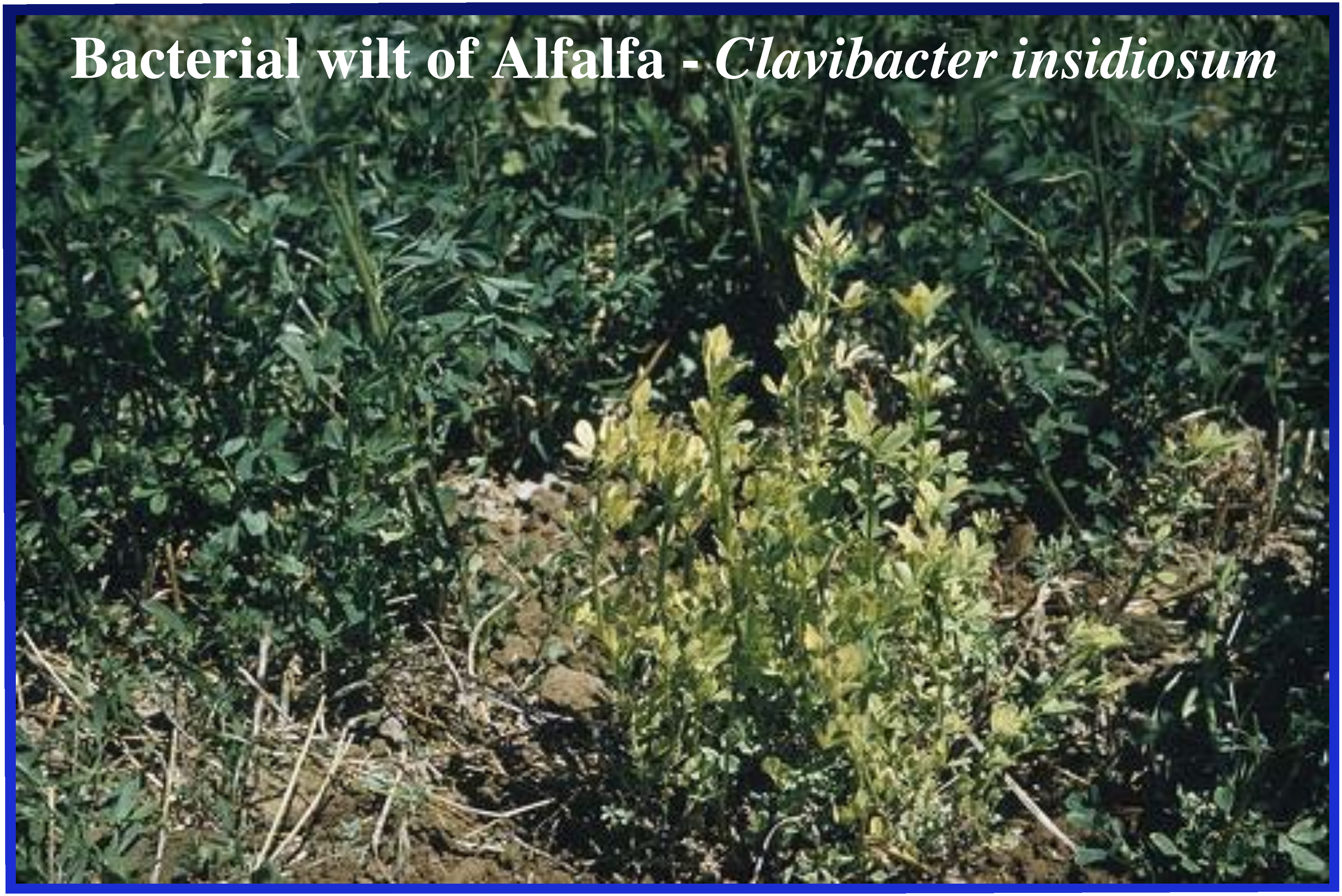
Victoria blight (oats)
H. carbonum disease (toxin)
Texas male-sterile gene (corn leaf blight epidemic)
Glyphosate-resistance gene?????

Why (vulnerability)?

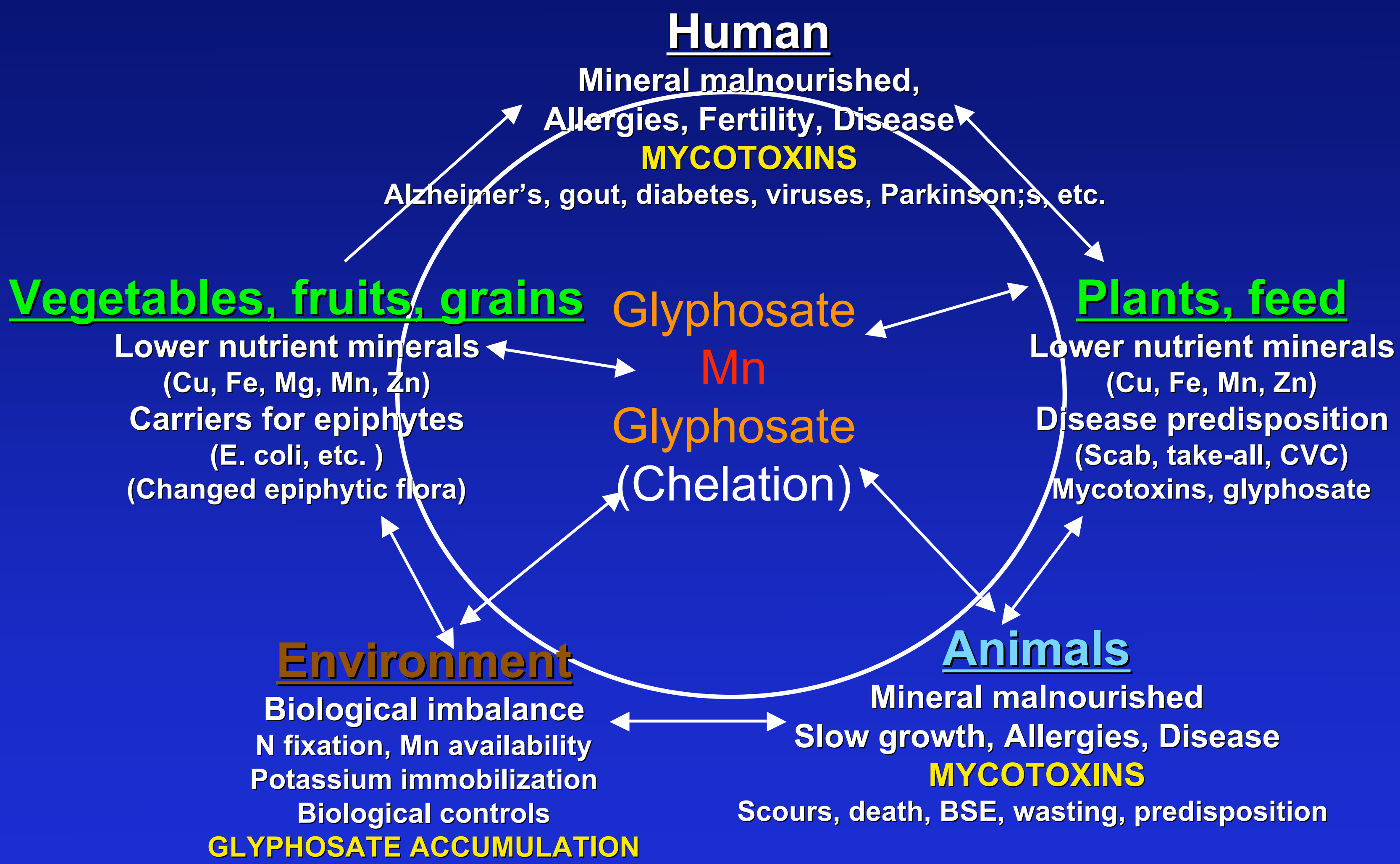
Predisposition
Direct toxicity
Gene flow
No relief - single source approach


Effect of Surfactants on Goss' Wilt* Infection
Untreated control
Surfactant control
C. clavibacter
C. clavibacter + surfactant
Lesion index
3
2
1
0
1-4
5
6
7
Corn hybrid
Goss' wilt
*Similar effect on Stewarts wilt

Bacterial wilt of Alfalfa - *Clavibacter insidiosum*



Potential Far-Reaching Impact of Glyphosate



Make Sure You Provide the Food!