Glyphosate Effects on Crops, Soils, Animals, and Consumers

Europe
October 2011

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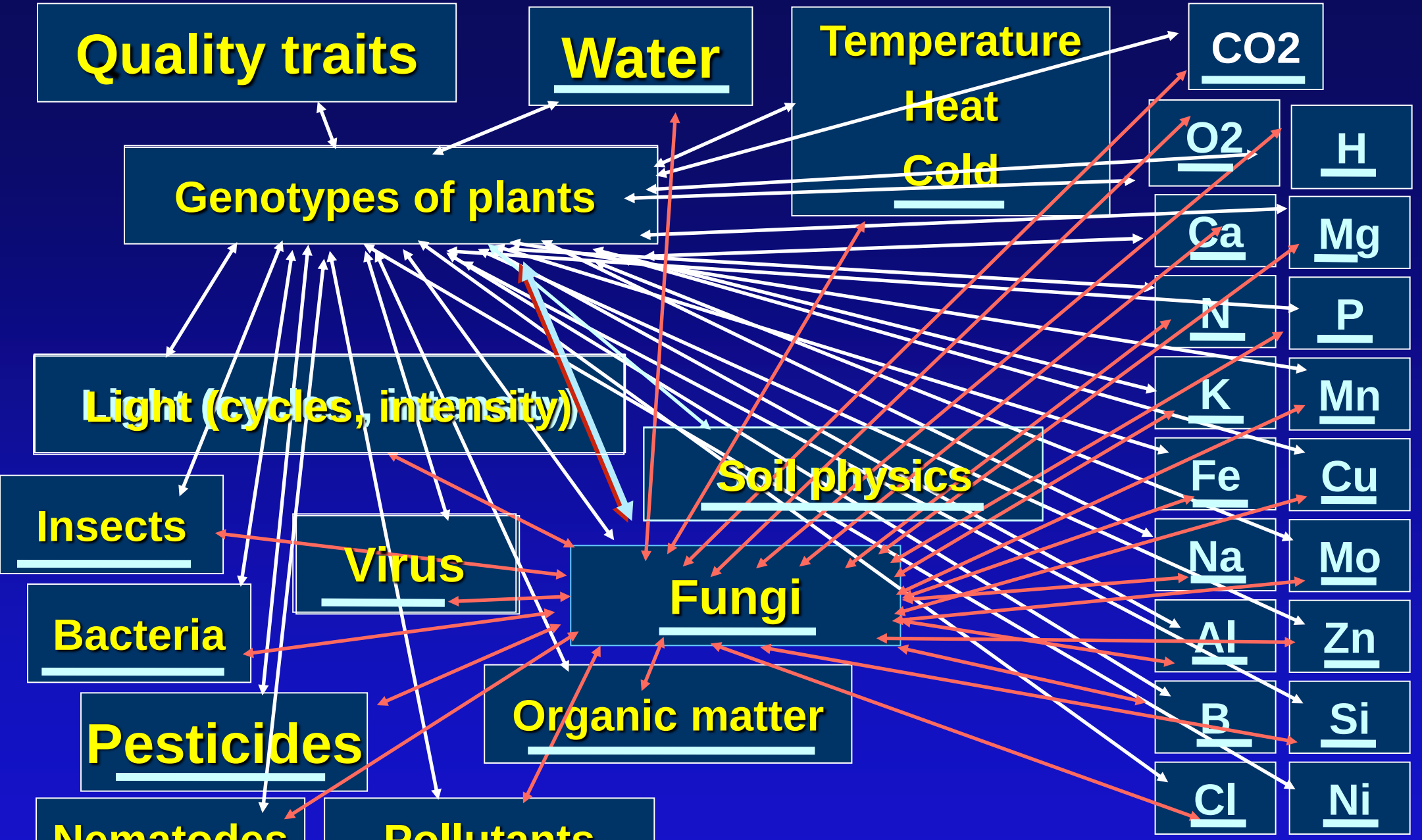
The Importance of Reducing Stresses

Potential - Stresses = Yield

There is no free lunch!



are a large number of interconnected plant properties and responses to physical and biological environmental

Nutrients are:

Components of plant parts as well as

Activators,

Inhibitors,

and Regulators

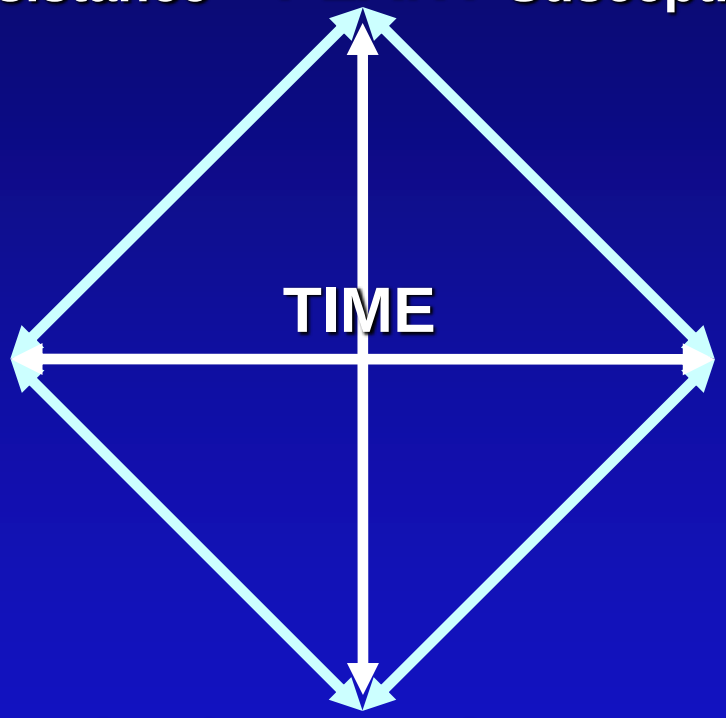
of Physiological Processes

Many herbicides and pesticides are chelators

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

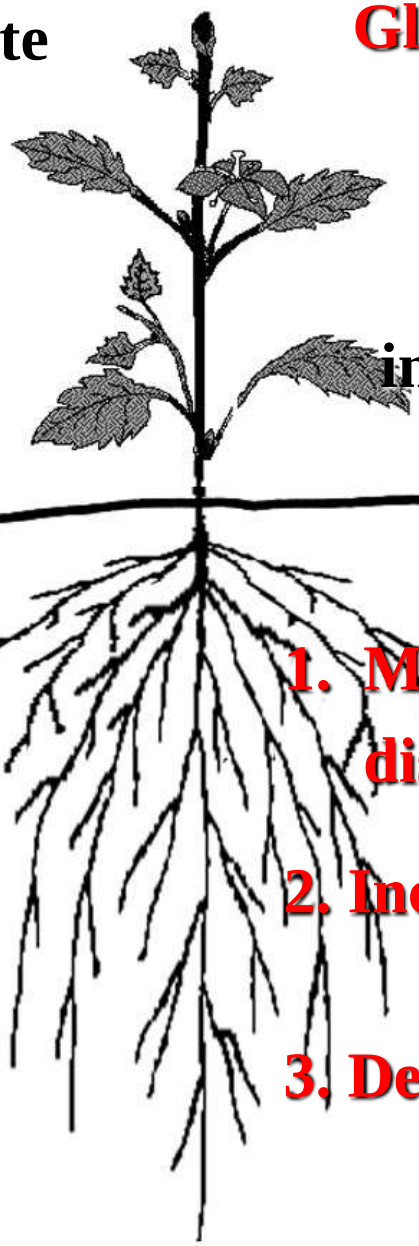
BIOTIC ENVIRONMENT

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

Foliar application of glyphosate

Moves throughout the plant

Intensifies stress



Glyphosate accumulates in Plant tissues (shoot, reproductive, and roots)

Glyphosate moves into roots and is released into soil

Glyphosate accumulates in soil (fast sorption; slow degradation)

Desorbed by phosphorus

Glyphosate is toxic to:

(Beneficial soil organisms)

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

1. **Makes the plant susceptible to diseases**
2. **Increases soil-borne diseases**
3. **Decreases Nutrient availability**

Schematic of glyphosate interactions in soil

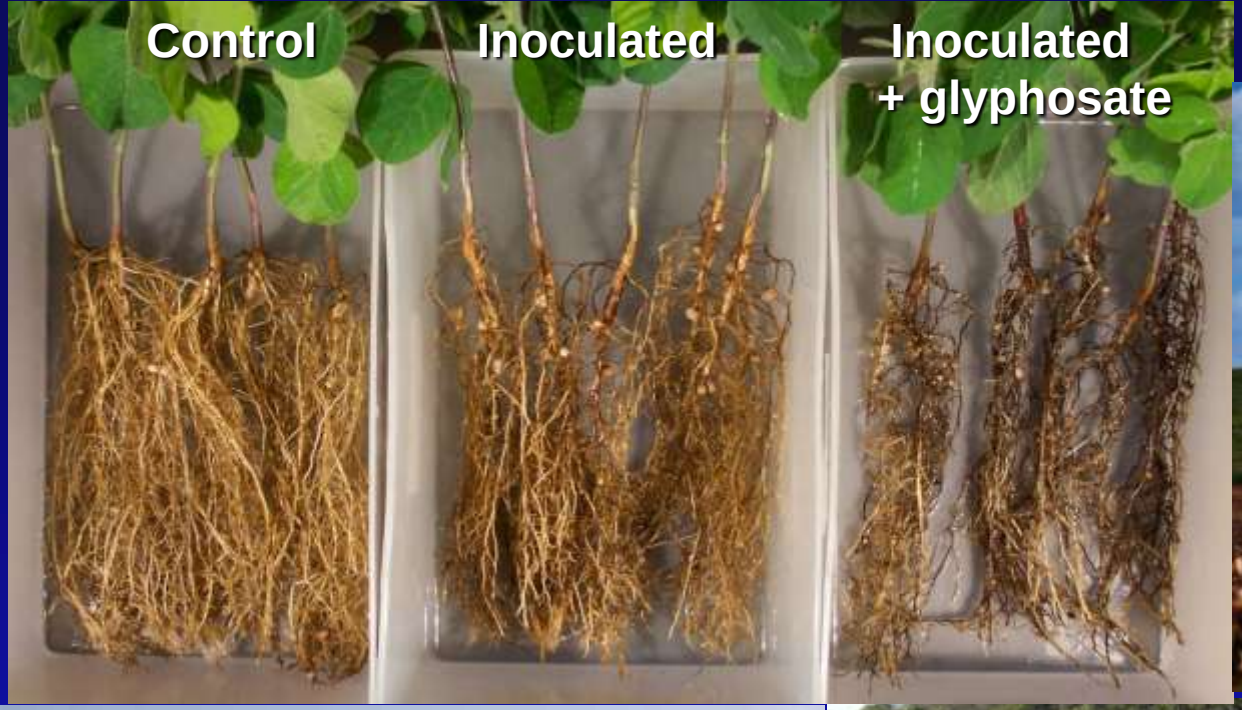
Herbicide action is by soil-borne fungal pathogens

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.


Control
Inoculated
Inoculated
+ glyphosate


Non-glyphosate
Non-GMO
GMO+glyphosate


Glyphosate
No glyphosate


Non-glyphosate
Glyphosate

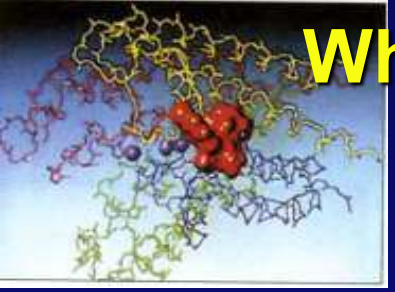
Factors Predisposing to Fusarium Head Scab

(*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 the most important agronomic factor 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 previous three years	% Increase in head scab
None	00
1 to 2	152 ***
3 to 6	295 ***



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

[Greatly expanded usage of glyphosate]

- **The technology inserts an alternative EPSPS enzyme that is not blocked by glyphosate in *mature* tissue**

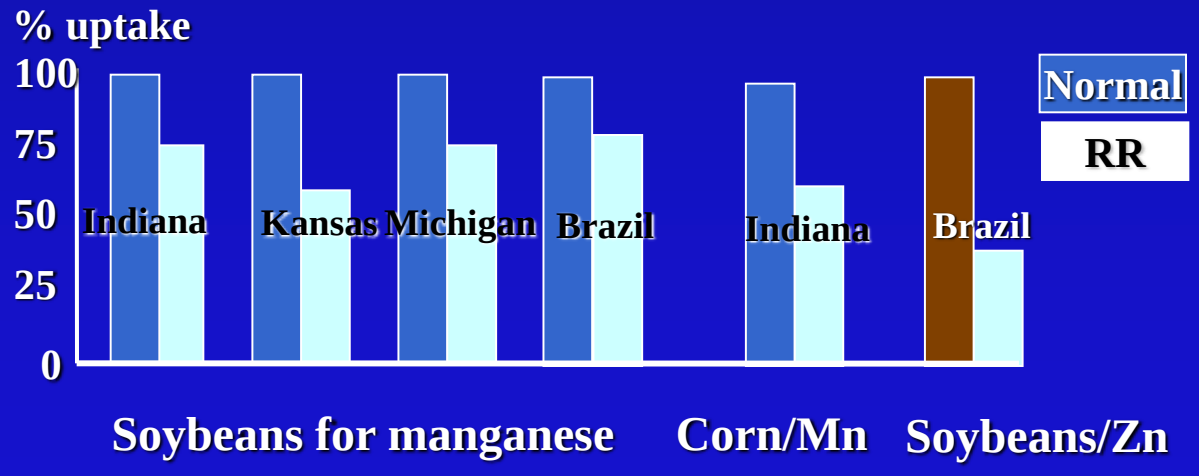
- **There is nothing in the RR plant that operates on the glyphosate applied to the plant!**

  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



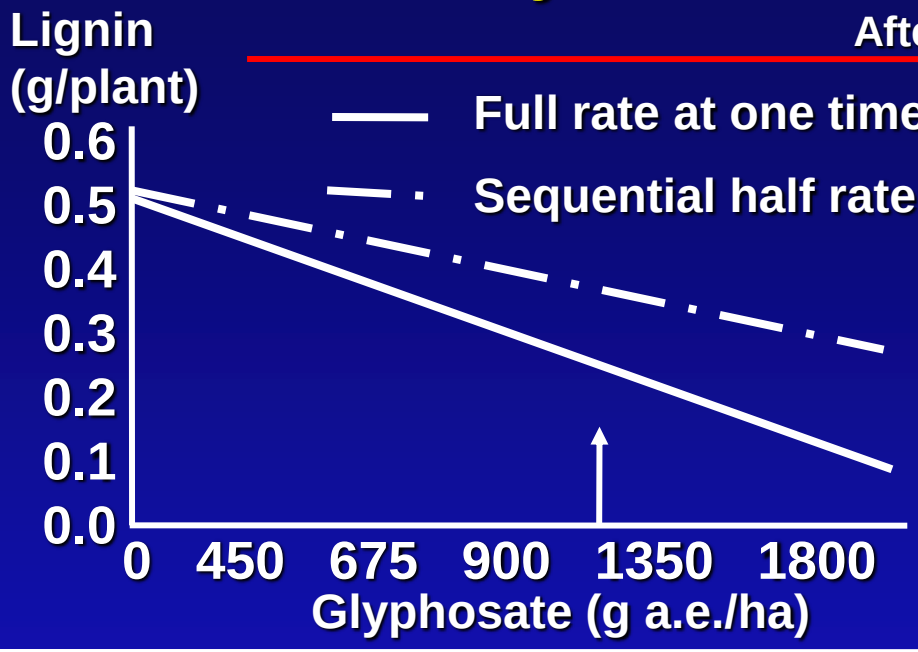
Reduced Nutrient Efficiency of Isogenic RR Soybeans (After Zobiole et al, 2008, 2009)

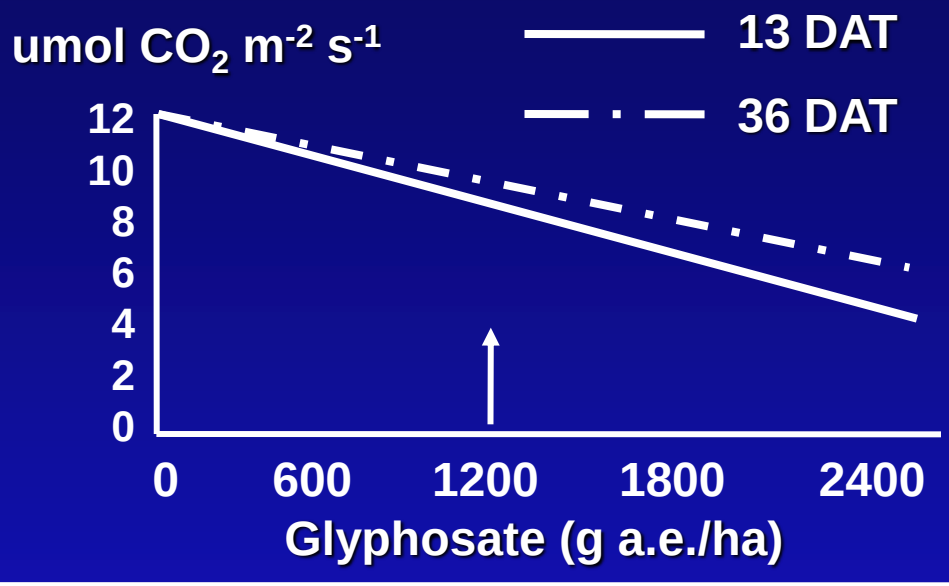
Tissue:	Mn	Zn
Isoline	%	%
Normal	100	100
Roundup Ready©	83	53
RR + glyphosate	76	45

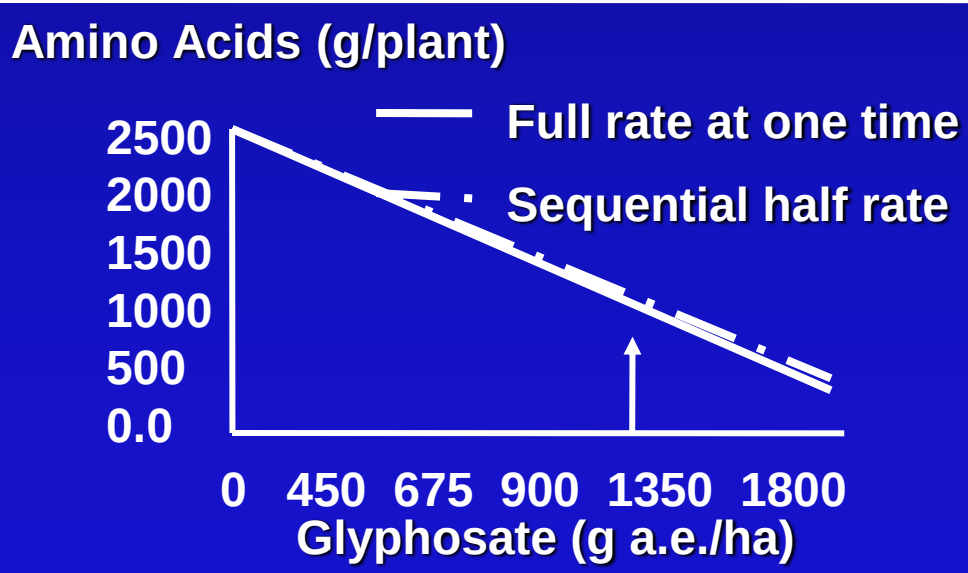
Copper, iron, and other essential nutrients Were also lower in the RR isoline and reduced further by glyphosate!

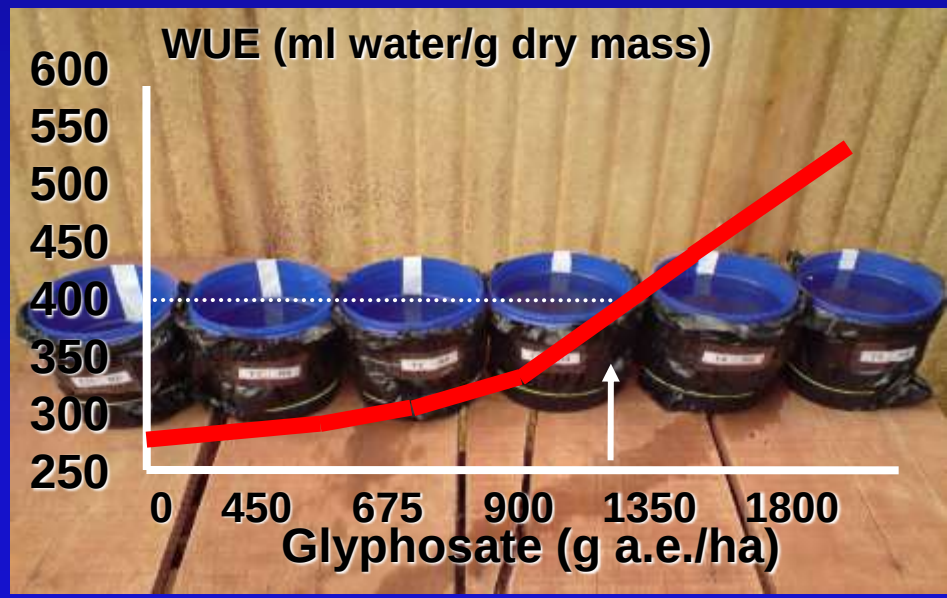
Effect of Glyphosate on Lignin, AA, Water Use Efficiency, and Photosynthesis of 'Glyphosate-Resistant' Soybeans

After Zobiole, 2009

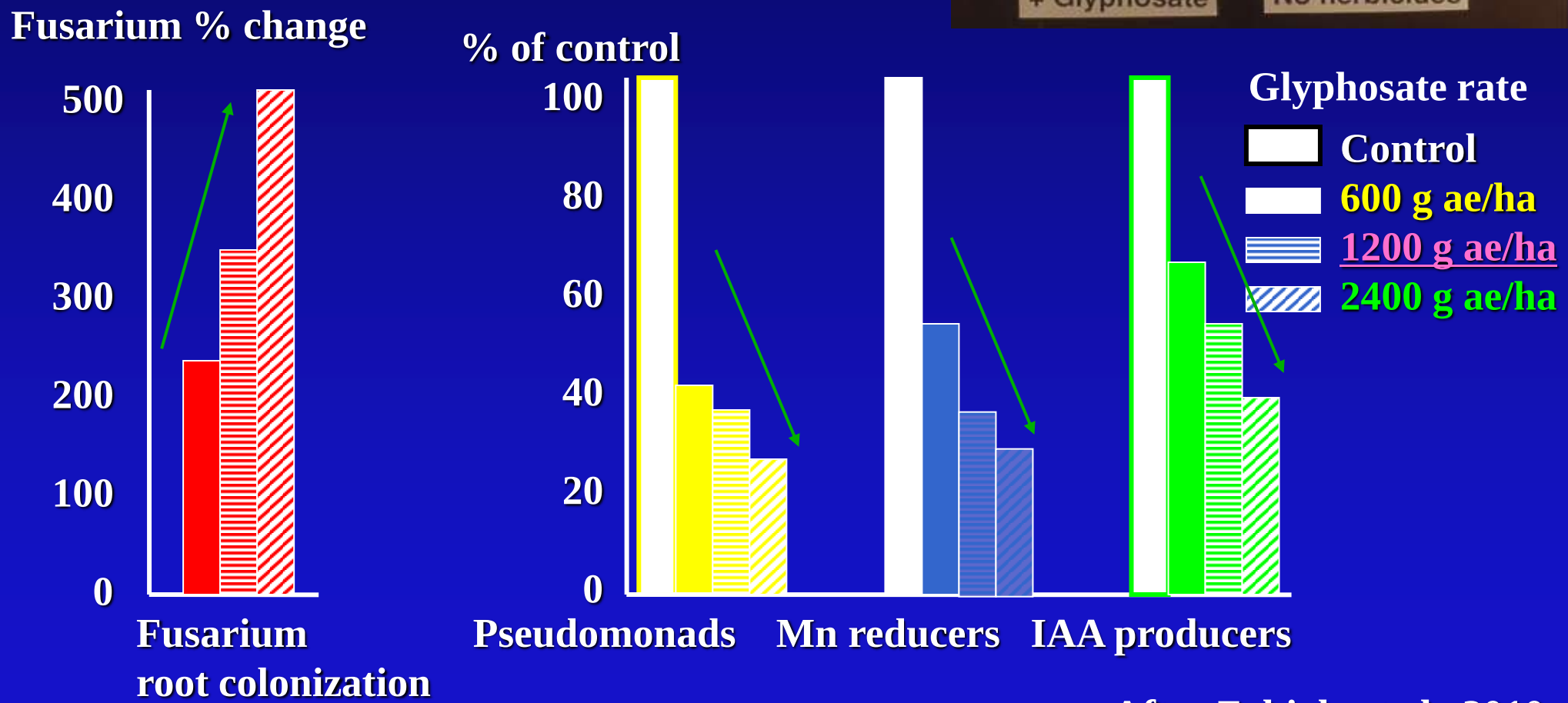








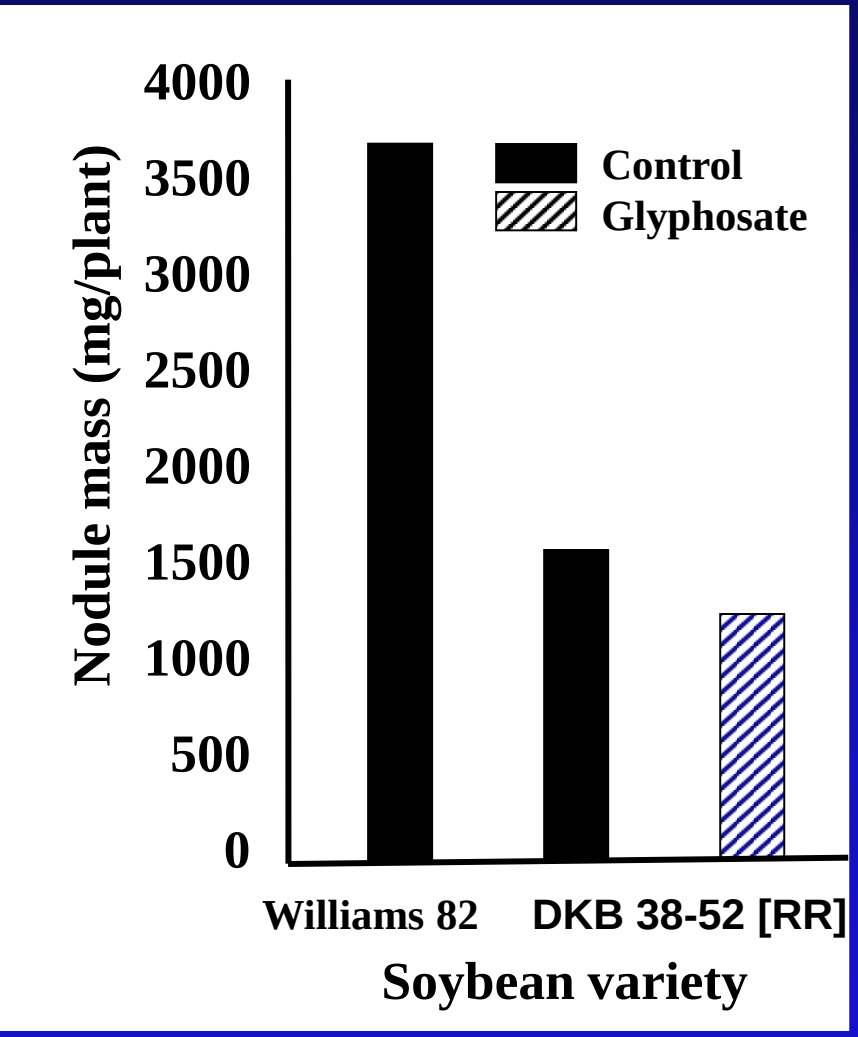
Microbiocidal Activity of Glyphosate



After Zobiole et al., 2010
Kremer, 2010

Effect of the RR Gene & Herbicide on Root Nodule Mass

After Kremer & Means, 2009



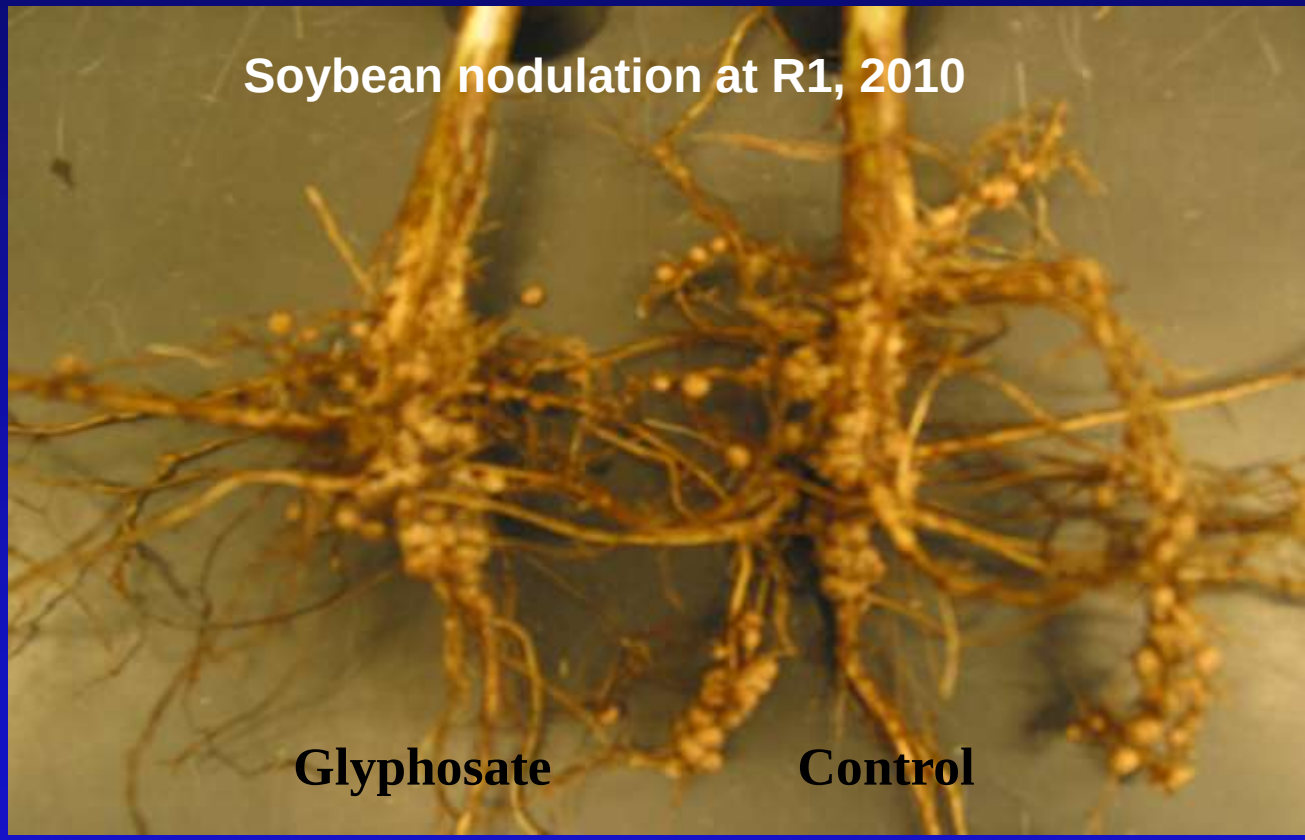
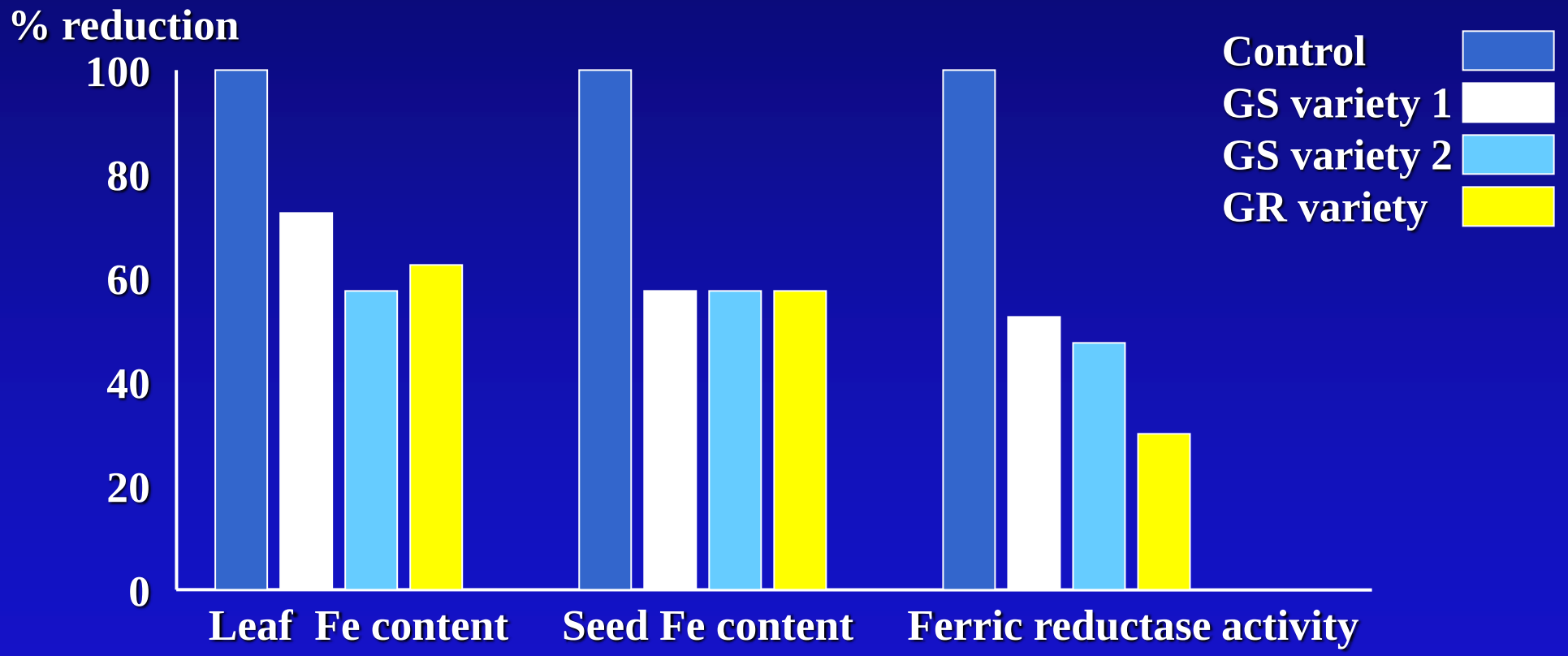


Photo by R. Kremer

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



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

After Bellaloui et al, 2009

% Mineral Reduction in Roundup Ready® Soybeans Treated with Glyphosate

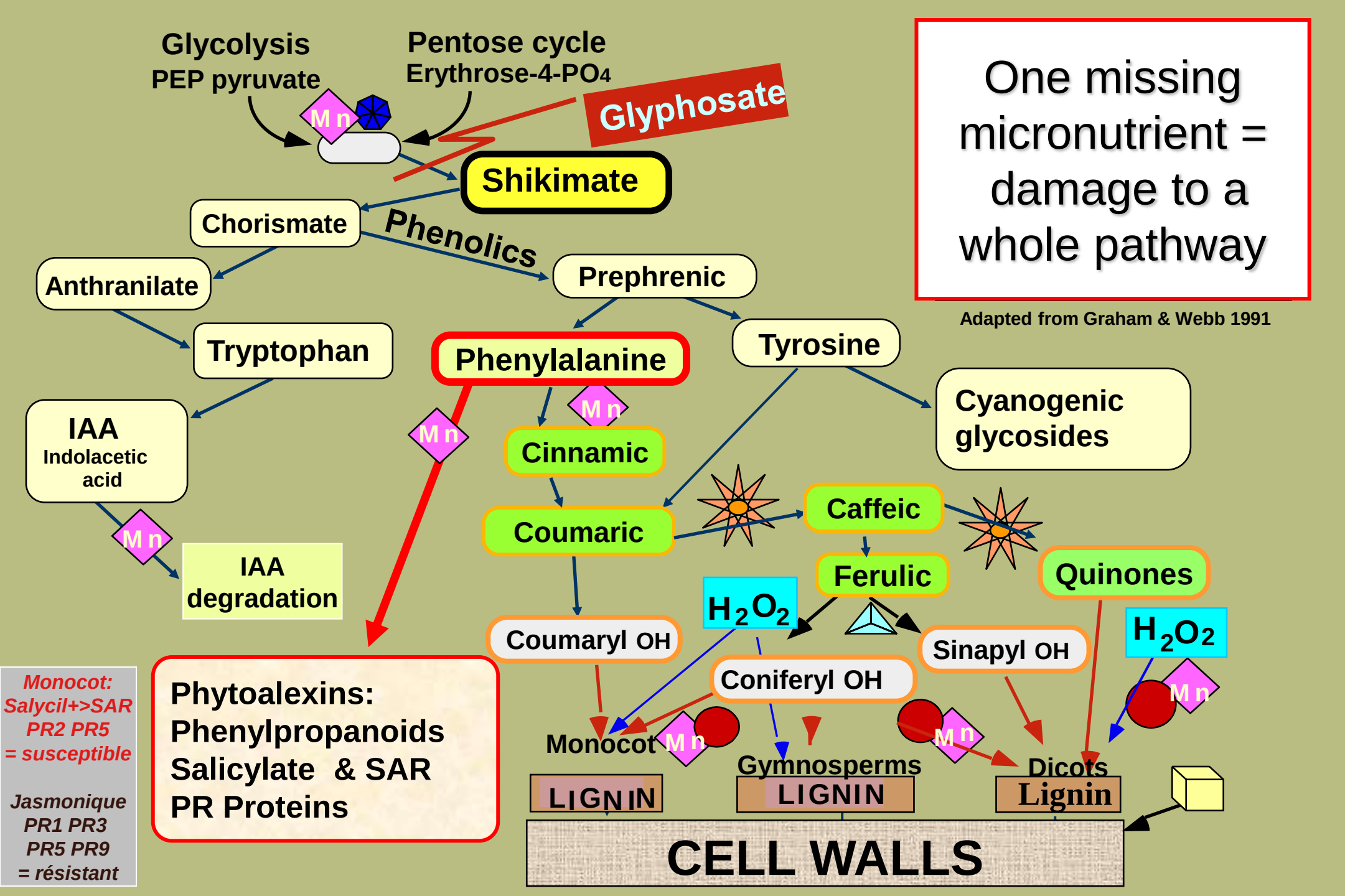
Plant tissue	Ca	Mg	Fe	Mn	Zn	Cu
Young leaves	40	28	7	29	NS	NS
Mature leaves	30	34	18	48	30	27
Mature grain	26	13	49	45		

Reduced:

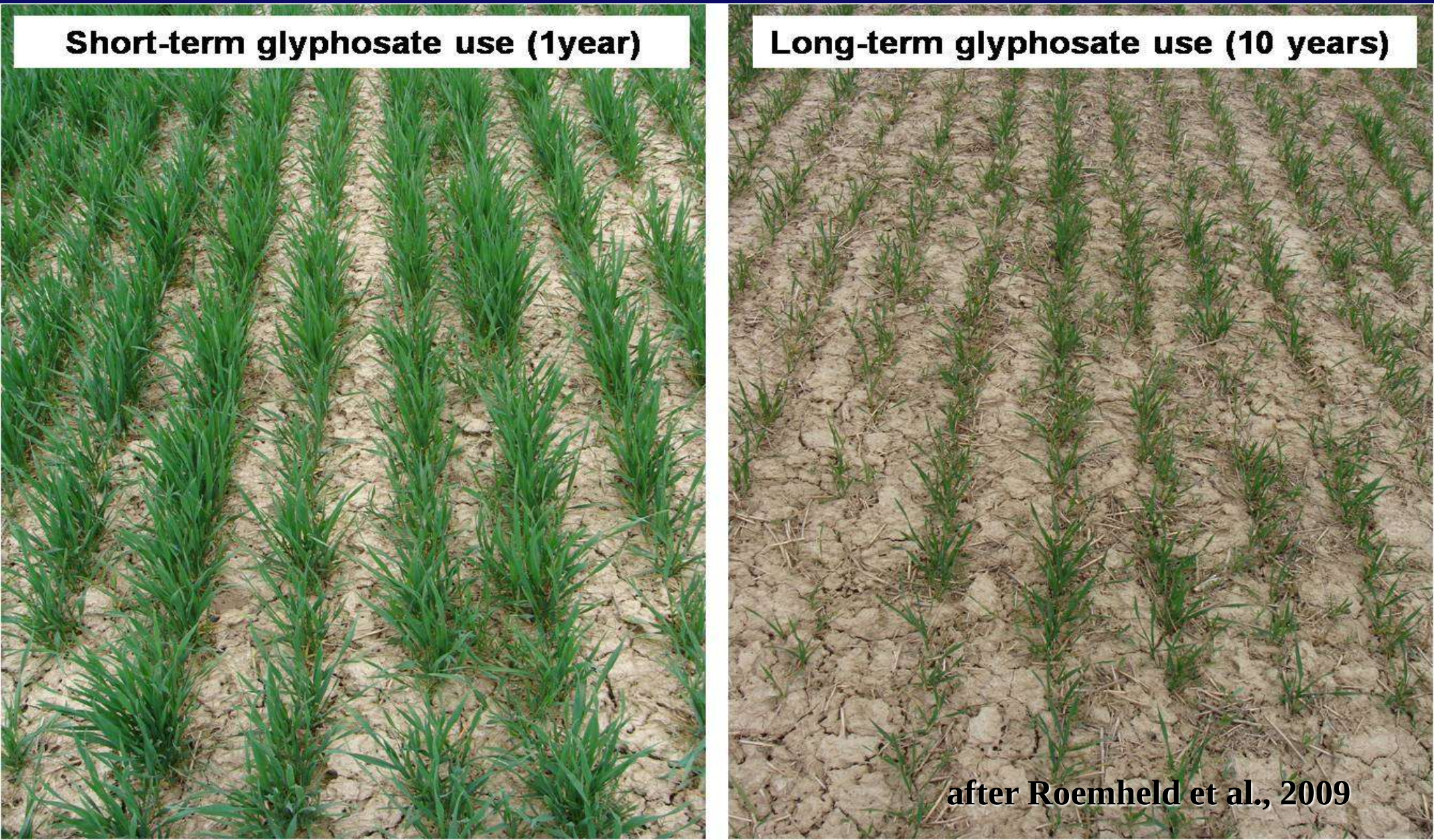
Yield 26%

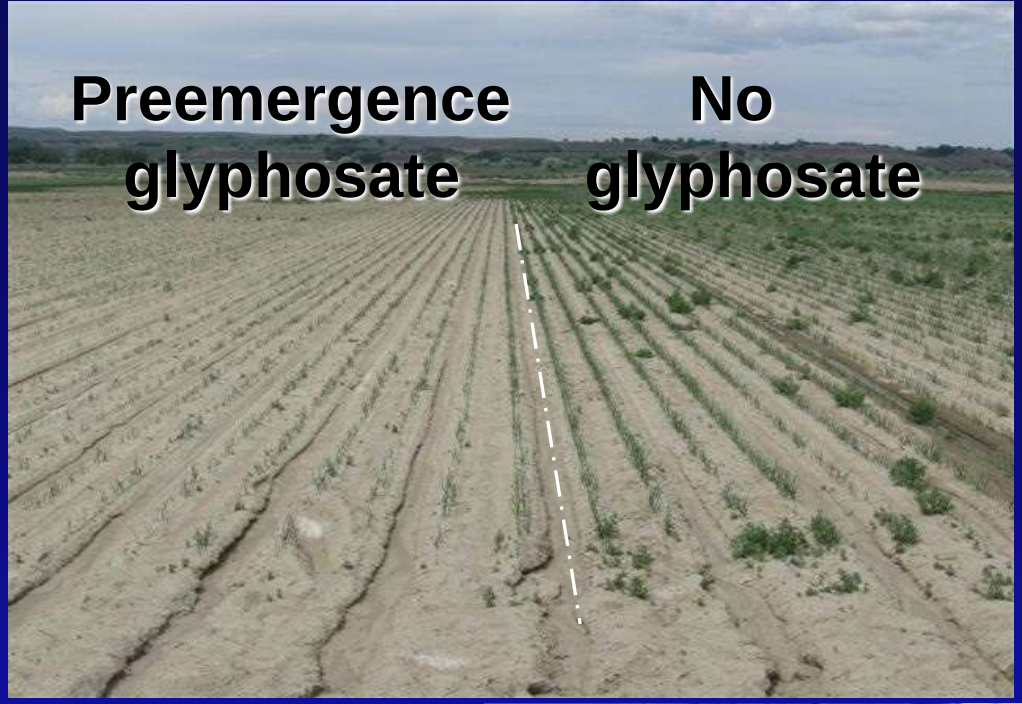
Biomass 24%

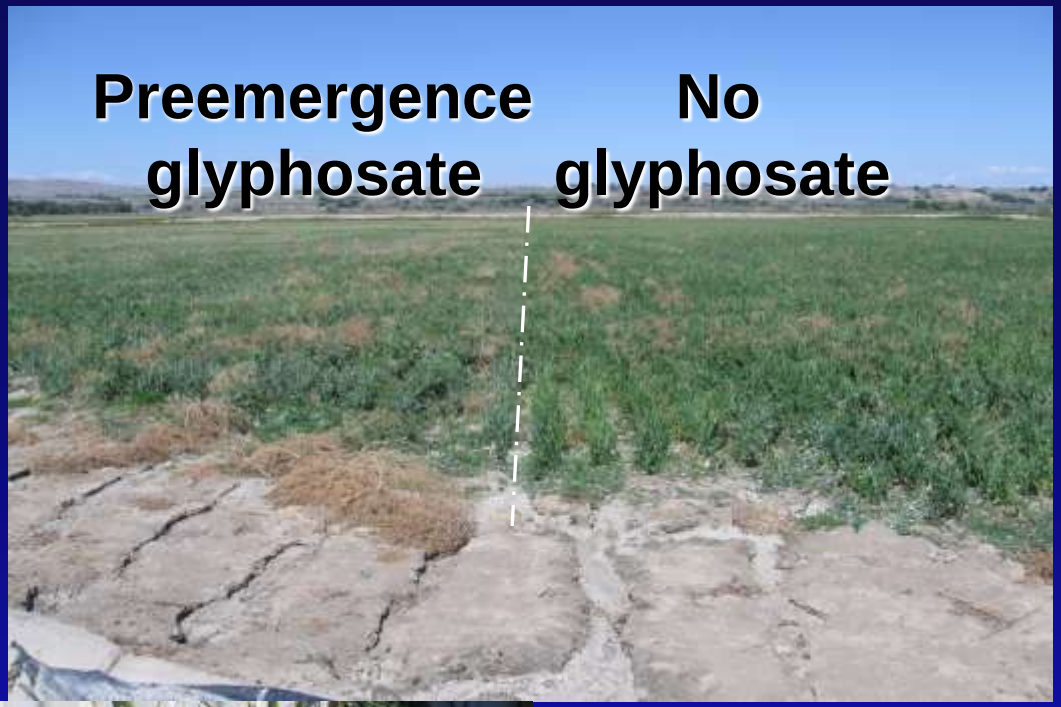
After Cakmak et al, 2009


Glycolysis
PEP pyruvate
Pentose cycle
Erythrose-4-PO4
Mn
Glyphosate
Shikimate
Chorismate
Phenolics
Anthranilate
Prephrenic
Tryptophan
Phenylalanine
Tyrosine
IAA
Indolacetic acid
Mn
Mn
Cinnamic
Cyanogenic glycosides
Coumaric
Caffeic
Ferulic
Quinones
IAA degradation
H2O2
H2O2
Coumaryl OH
Coniferyl OH
Sinapyl OH
Monocot
Gymnosperms
Dicots
LIGNIN
LIGNIN
Lignin
CELL WALLS
Phytoalexins:
Phenylpropanoids
Salicylate & SAR
PR Proteins
Monocot:
Salycil+>SAR
PR2 PR5
= susceptible
Jasmonique
PR1 PR3
PR5 PR9
= résistant
One missing micronutrient = damage to a whole pathway
Adapted from Graham & Webb 1991

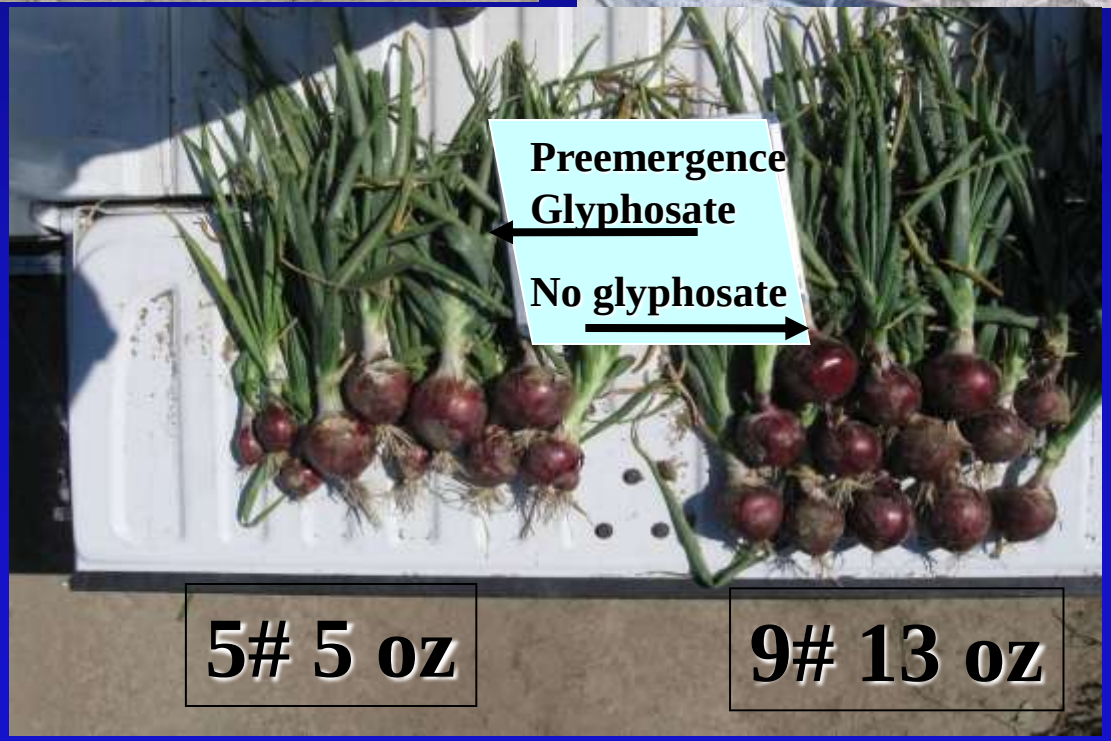
Long-term Effect of Glyphosate







Poor



Bulking

Failure to 'Bulk' of Russet Potatoes

Glyphosate frequency	How applied	No. growers	% Potatoes over 10 oz
None in the previous 2 yrs	None	5	35.3
1-2 in the previous 2 yrs	Burn down	17	20.2
Preceding year	RR crop	5	5.4

Parent plant with glyphosate drift

Daughter seed pieces

Food and Feed Safety Concerns

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

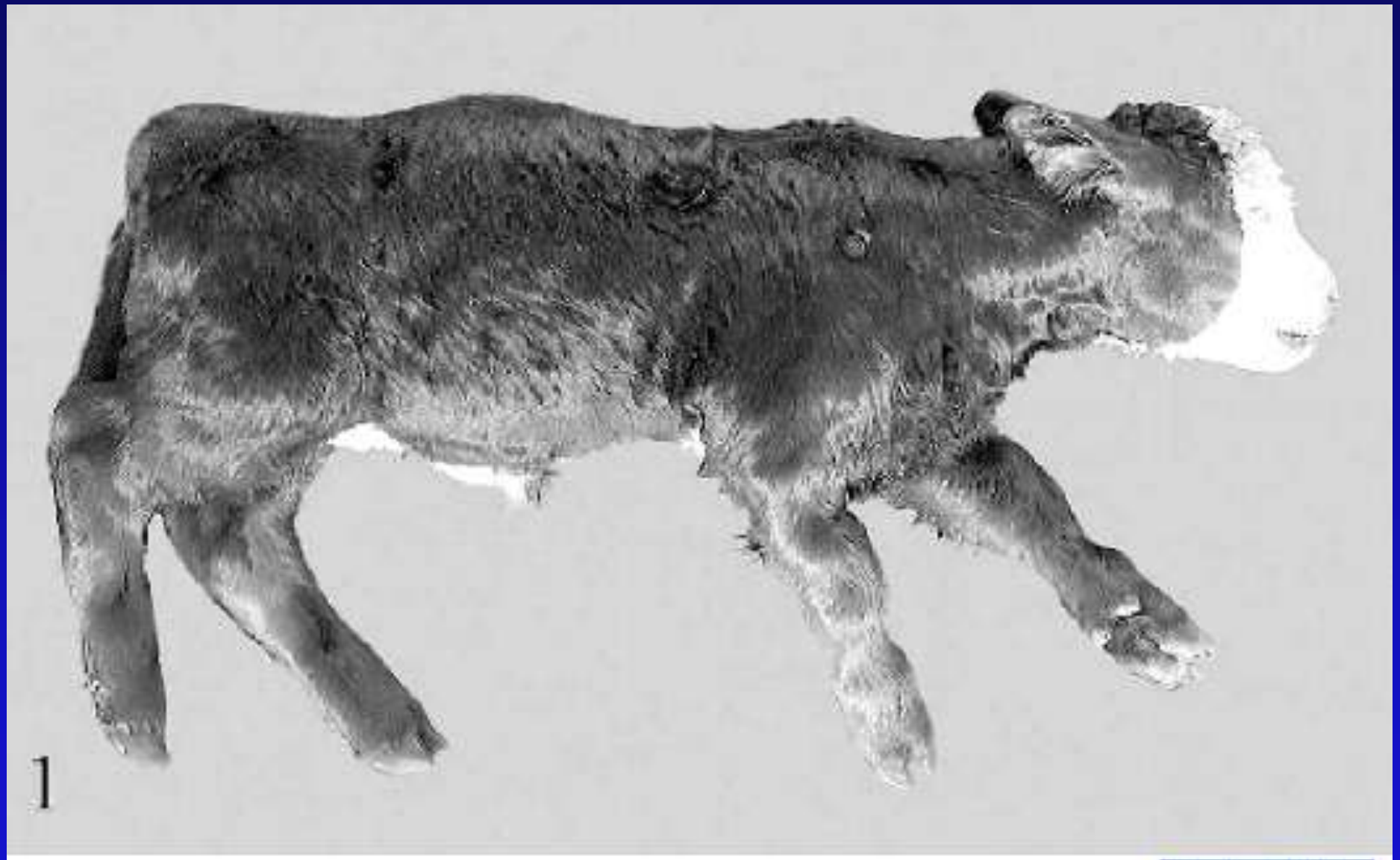
Aris & Leblanc, 2011
Benachour et al, 2007
Carmen, et al., 2011
Fernandez, et al., 2009
Gasnier, et al., 2009
Heiman, 2010
Matzk et al, 1996
Seralini et al., 2010, 2011
Smith, 2010
Walsh, et al., 2000
Watts, 2009

% 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

Stillborne Calf from Manganese Deficiency



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

Veterinary Pathology

U.S. Cattlemen's Association Statement to Congress

"Cattle ranchers are facing some puzzling - and, at times, economically devastating problems with pregnant cows and calves. At some facilities, high numbers of fetuses are aborting for no apparent reason. Other farmers successfully raise what look to be normal young cattle, only to learn when the animals are butchered that their carcasses appear old and, therefore, less valuable."

"The sporadic problem is so bad both in the United States and abroad that in some herds around 40-50 percent of pregnancies are being lost."

"Many pesticides and industrial pollutants also possess a hormonal alter ego."

"The viability of this important industry is threatened."

Source: Testimony of the Ranchers-Cattlemen Action Legal Fund, United Stockgrowers of America, to the Senate Agriculture Committee July 24, 2002.

Feed Source Effect on Stomach Liner Color, Carmen et al, 2010

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

2011

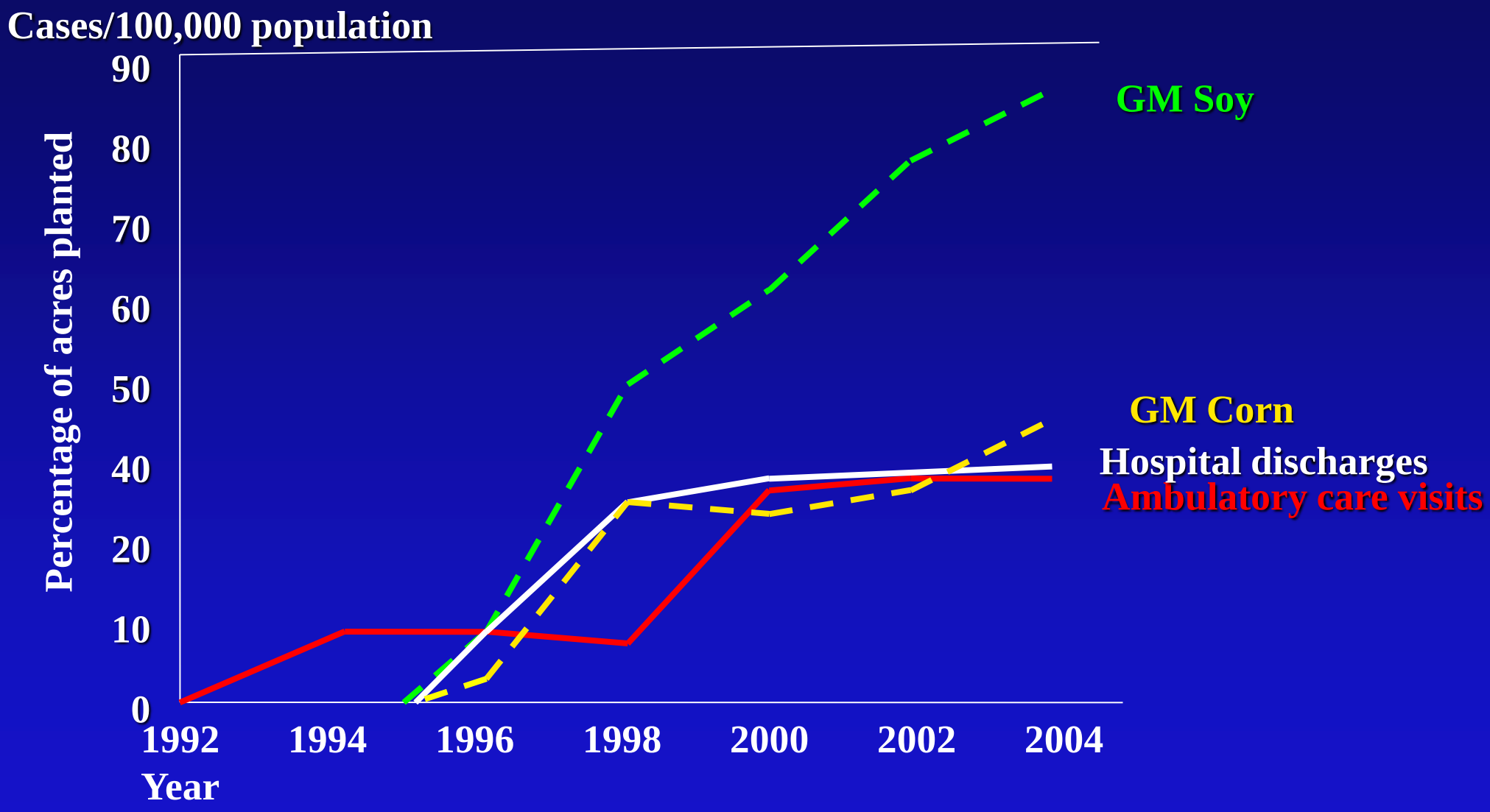
Non-GMO Feed

Normal color

GMO Feed

Inflamed, irritated

Inflammatory Bowel Disease, USA



And the Mice Prefer……

GMO Corn

Non-GMO Corn

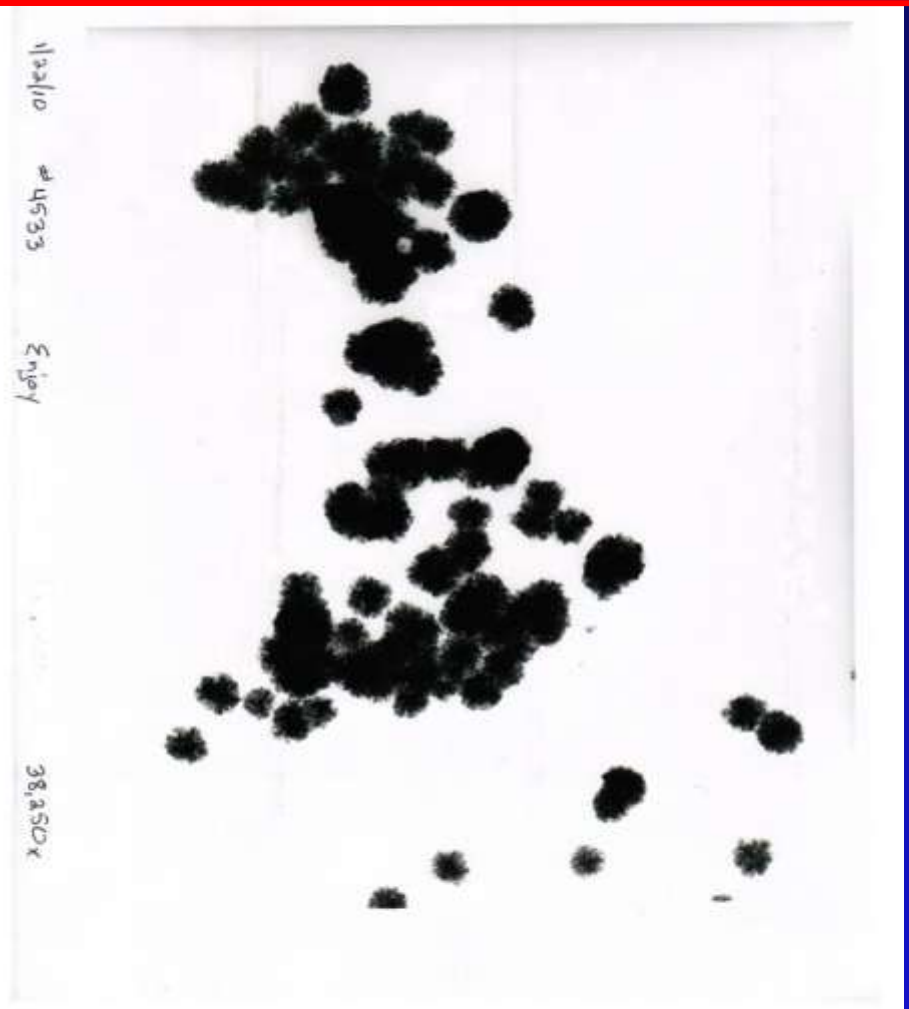
Photos: Gilbert Hostetler

Direct Toxicity of Glyphosate

Rate (ppm)	System affected	Reference
0.5	Human cell endocrine disruption	Toxicology 262:184-196, 2009
0.5	Anti-androgenic	Gasner et al, 2009
1.0	Disrupts aramatase enzymes	Gasnier et al, 2009
1-10	Inhibits LDH, AST, ALF enzymes	Malatesta et al, 2005
1-10	Damages liver, mitochondria, nuclei	Malatesta et al, 2005
2.0	Anti-Oestrogenic	Gasnier et al, 2009
5.0	DNA damage	Toxicology 262:184-196, 2009
5.0	Human placental, umbilical, embryo	Chem.Res.Toxicol. J. 22:2009
10	Cytotoxic	Toxicology 262:184-196, 2009
10	Multiple cell damage	Seralini et al, 2009
10	Total cell death	Chem.Res.Toxicol. J. 22:2009
All	Systemic throughout body	Andon et al, 2009
1-10	Suppress mitochondrial respiration	Peixoto et al, 2005
Parkinson’s		El Demerdash et al, 2001
POEA, AMPA even more toxic		Seralini et al, 2009

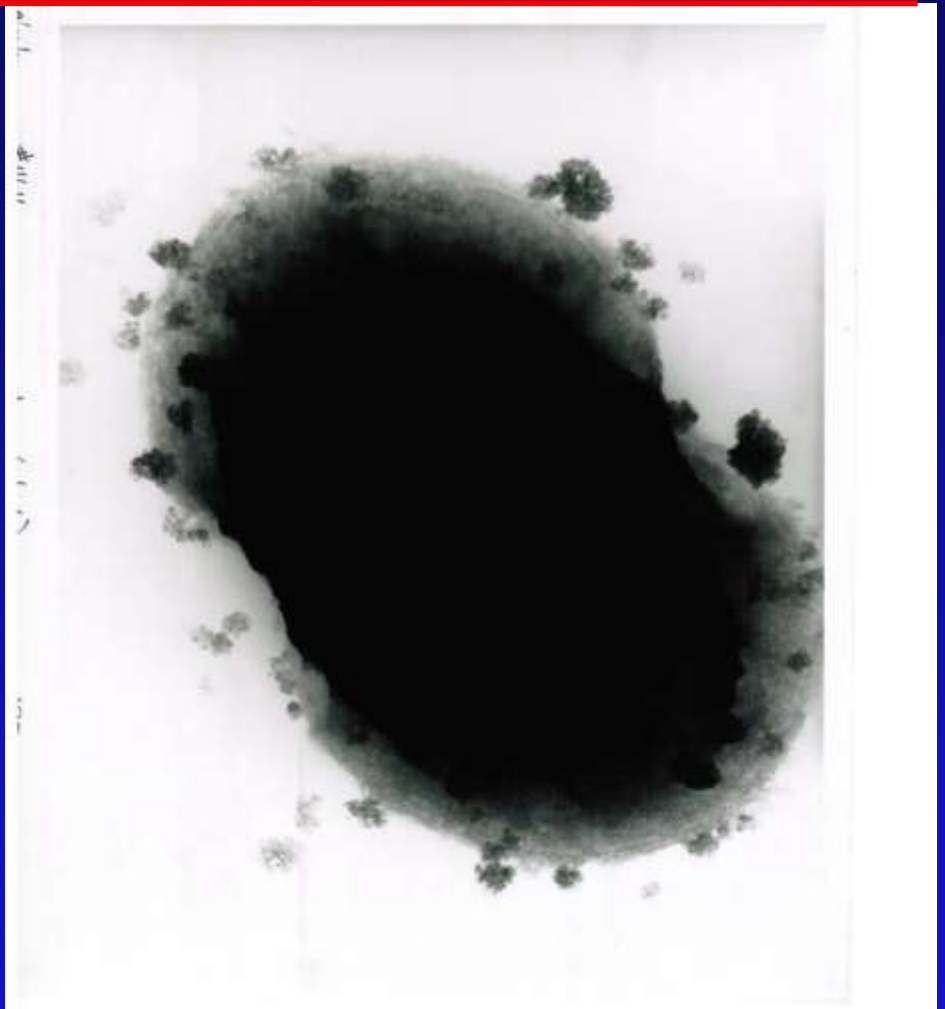
Late term 'Spontaneous Abortion' (Miscarriage)

‘Fungus-like’ Growth (transmission EM)



38,250 X magnification

Size of organism compared with alfa-*Streptococcus*



Size relative to gram^{+} bacterium

Occurrence

- **Verified in IA, IL, KY, MI, NE, ND, SD, WI**
- **Sources: ‘Environmental’**

Environmental	Animal tissue
Soybean meal	Placental tissue
Silage	Amniotic fluid
Corn grain and silage	Semen
SDS Soybean plants	Stomach contents
Manure	Eggs
Soil	Milk

***Fusarium solani* fsp *glycines* mycelium**

Potential Interactions of 'new entity' 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

Failure to Honor

* **Scientific Precautionary Principle**

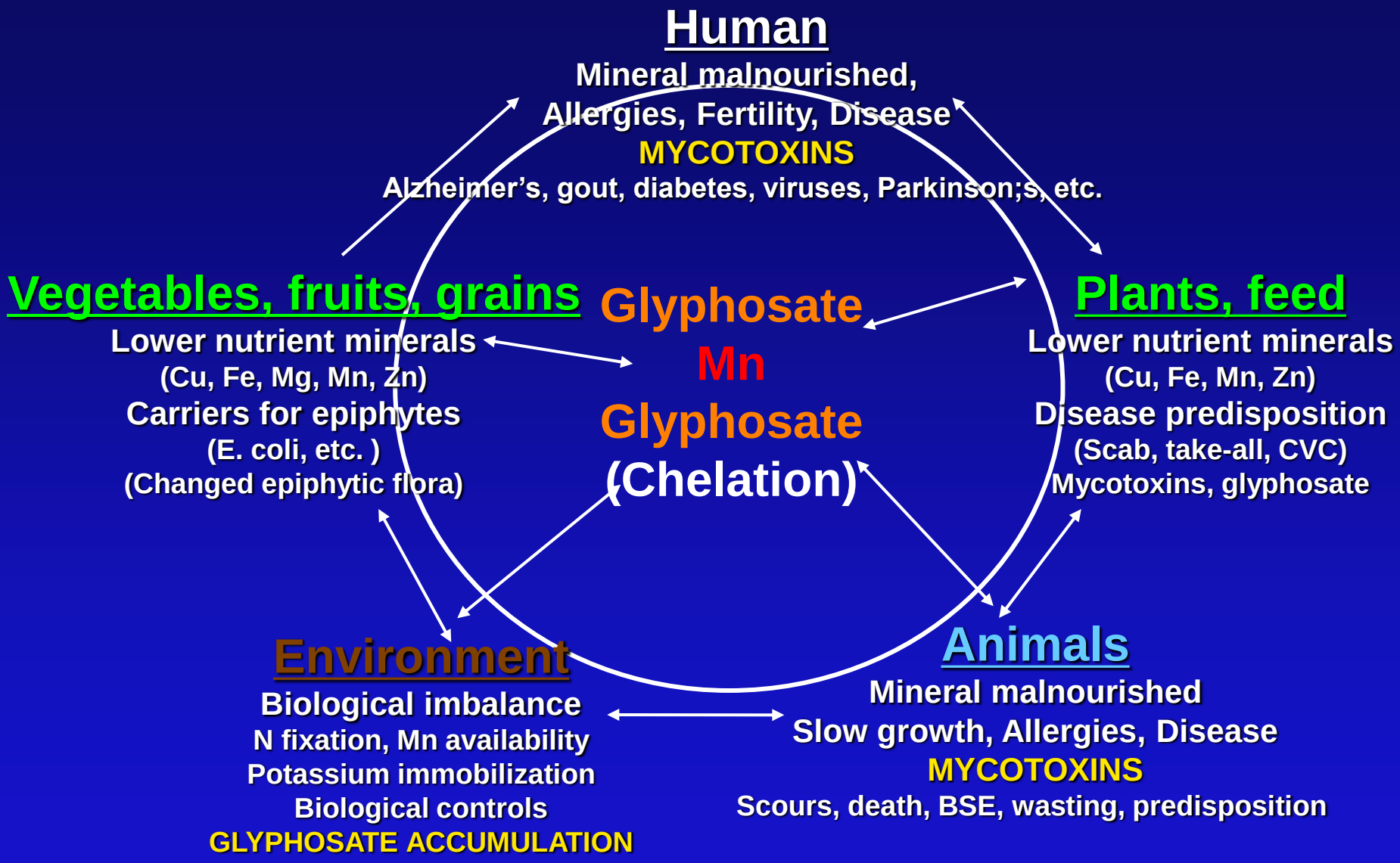
1. Margin of safety to prevent damage
2. Anticipation of unknowns
3. Initiate as a “pilot project”

* **Not “Substantially Equivalent”- Significant deviation in:**

1. Expression of ‘end products’ (new/tissues in)
2. More like virus infection than sexual transfer
3. Functional and regulatory controls absent
4. Greatly extended exposure
5. Production, quality, safety & toxicity differ

After Brown, 2000

Potential Far-Reaching Impact of Glyphosate



Failed Promises – 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

Make Sure You Provide the Food!