Detrimental Effects of Glyphosate on Nutritional Status of Plants with Micronutrients

I. Cakmak
Sabanci University Istanbul, Turkey
cakmak@sabanciuniv.edu

Glyphosate: extensively applied herbicide

- Increasing usage in minimum and no-tillage agricultural practices

- Extensive application on RR crops

.

In regions with extensive use of glyphosate there are increasing reports on:

- reductions in growth and yield,
- increases in disease problems,
- increased use of insecticides and fungicides,
- inhibition of N fixing bacteria
- **increased use of foliar micronutrient fertilizers**
- **micronutrient deficiencies**

Particular micronutrient deficiencies induced by Glyphosate: Manganese and Iron Deficiencies

Repeated use of glyphosate induces Fe and Mn deficiencies in soybeans in USA

(Photo: Prof. Don Huber)

(areas which are not treated with glyphosate)

Glyphosate-induced Fe-deficiency chlorosis

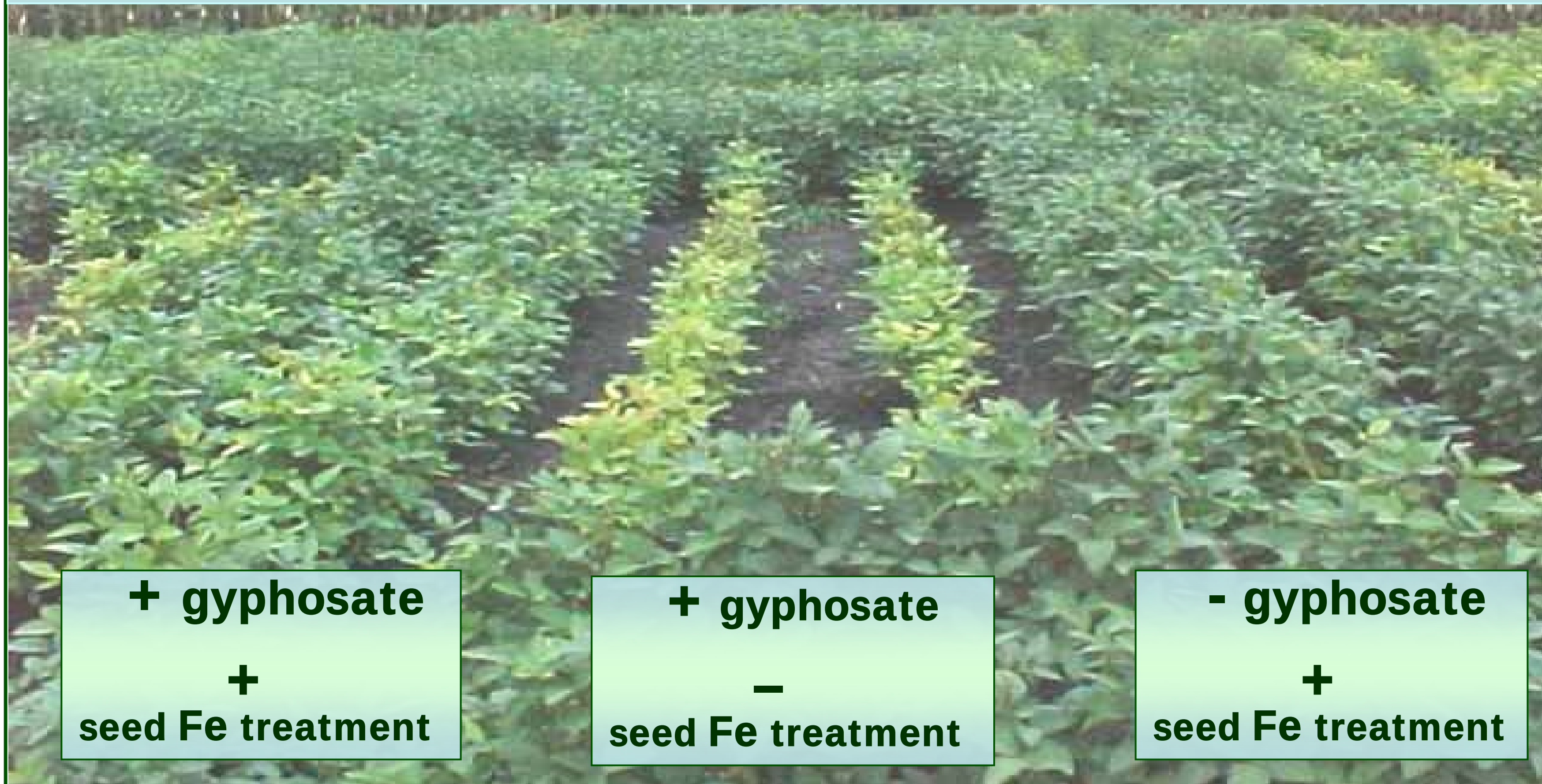


Photo: N.C. Hansen,
Fort Collins, USA

(Jolley et al., Soil Sci Plant Nutr. 50, 793-981, 2004)

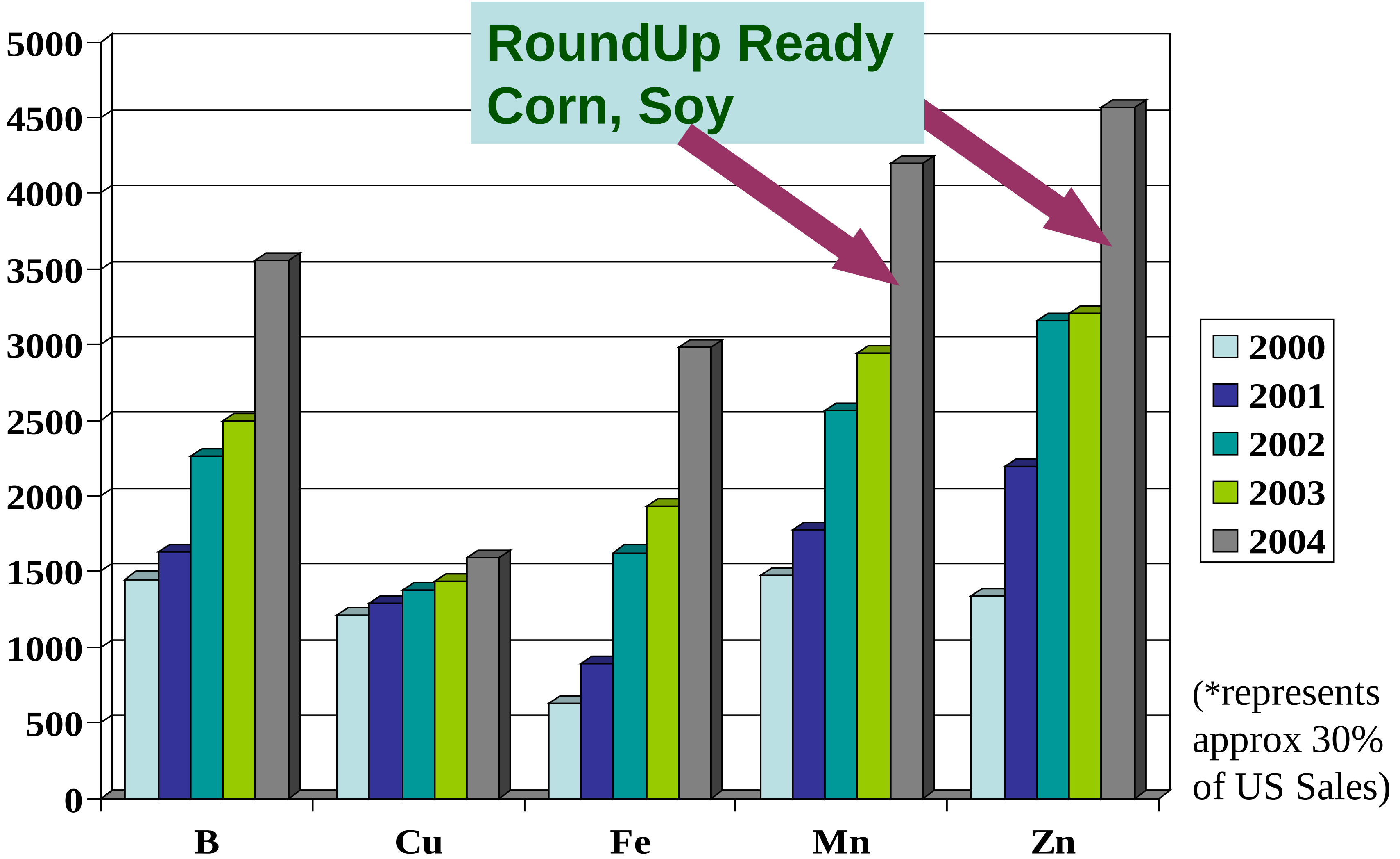
Interaction of seed applied Fe and glyphosate application on Fe deficiency chlorosis in soybeans; Minnesota, USA

Treatment	visual chlorosis scrore (1=green to 5 =severe)		grain yield (t/ha)	
	– Fe	+ Fe*	– Fe	+ Fe*
Control (no herbicide)	**3.1**	**2.8**	**1.01**	**1.70**
Glyphosate	**3.7**	**3.3**	**0.27**	**0.61**

* 50g Fe/ha as FeEDDHA applied to seeds

(Jolley et al., Soil Sci Plant Nutr. 50, 793-981, 2004)

Foliar and Soluble Micronutrient* Sales in USA



(Courtesy of Prof. P. Brown, UC Davis)

Glyphosate is toxic to plants whether from a drift or residues in soil

A significant amount of glyphosate applied to target plants reaches the soil as a result of direct contact, wash off from leaves and exudation from roots of the treated weeds.

Up to 10 % of the applied glyphosate move to non-target plants

entweb.clemson.edu.

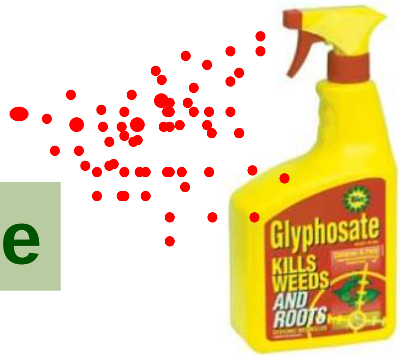
http://www.uky.edu/Ag/Tobacco/Pages/RoundupFloat.html

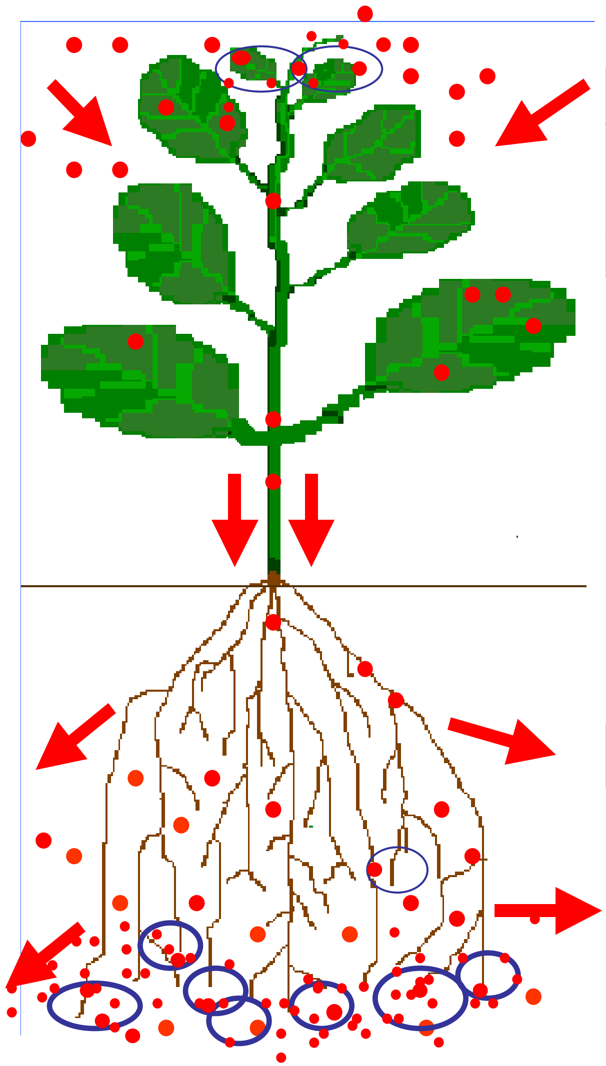
no
Glyphosate

with
Glyphosate

REMEMBER

Glyphosate is highly phloem mobile



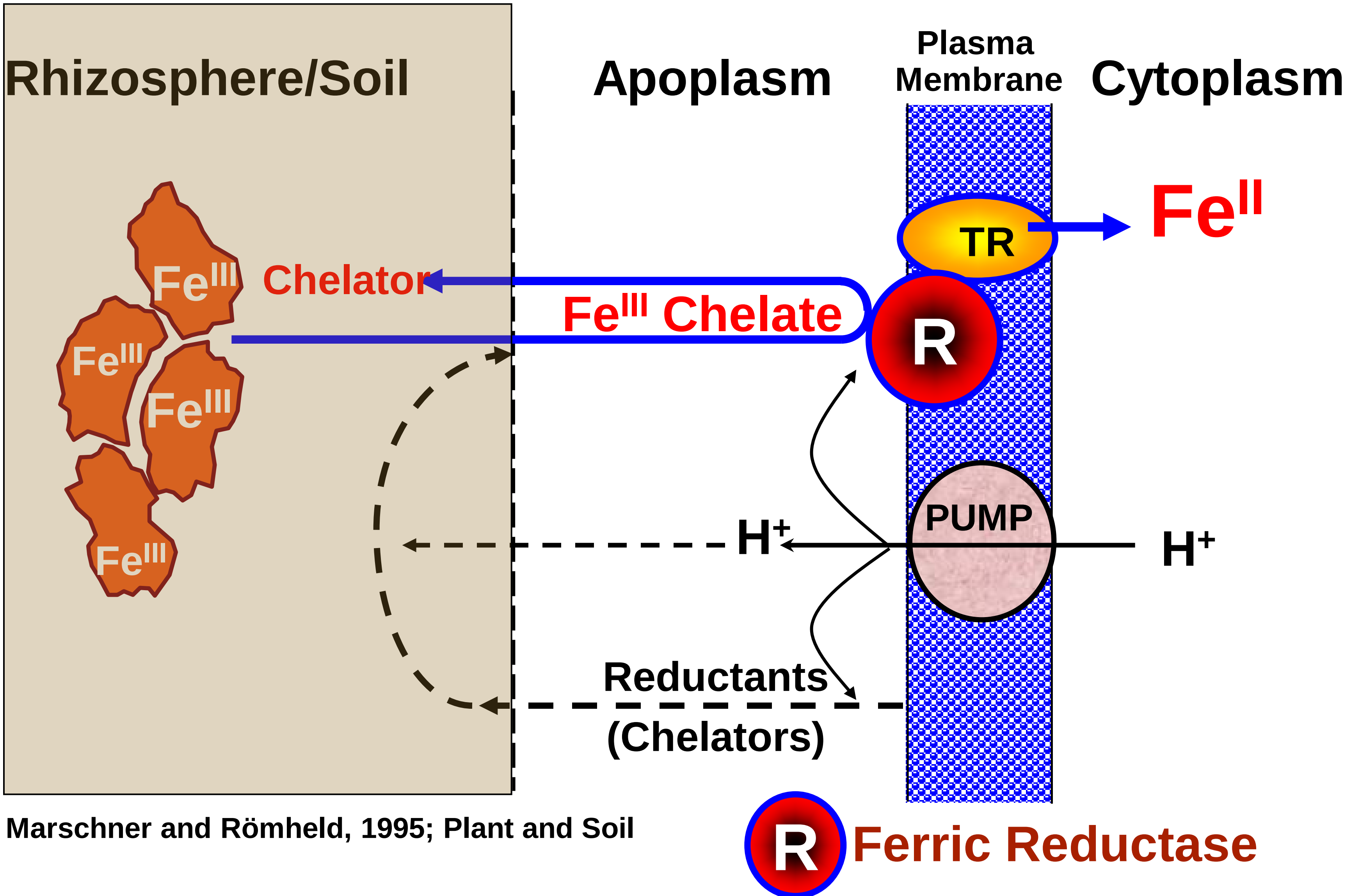


Application of glyphosate on target plants (weeds)/glyphosate resistant cultivars; very quick uptake by leaves.

Rapid translocation of glyphosate from shoot to root

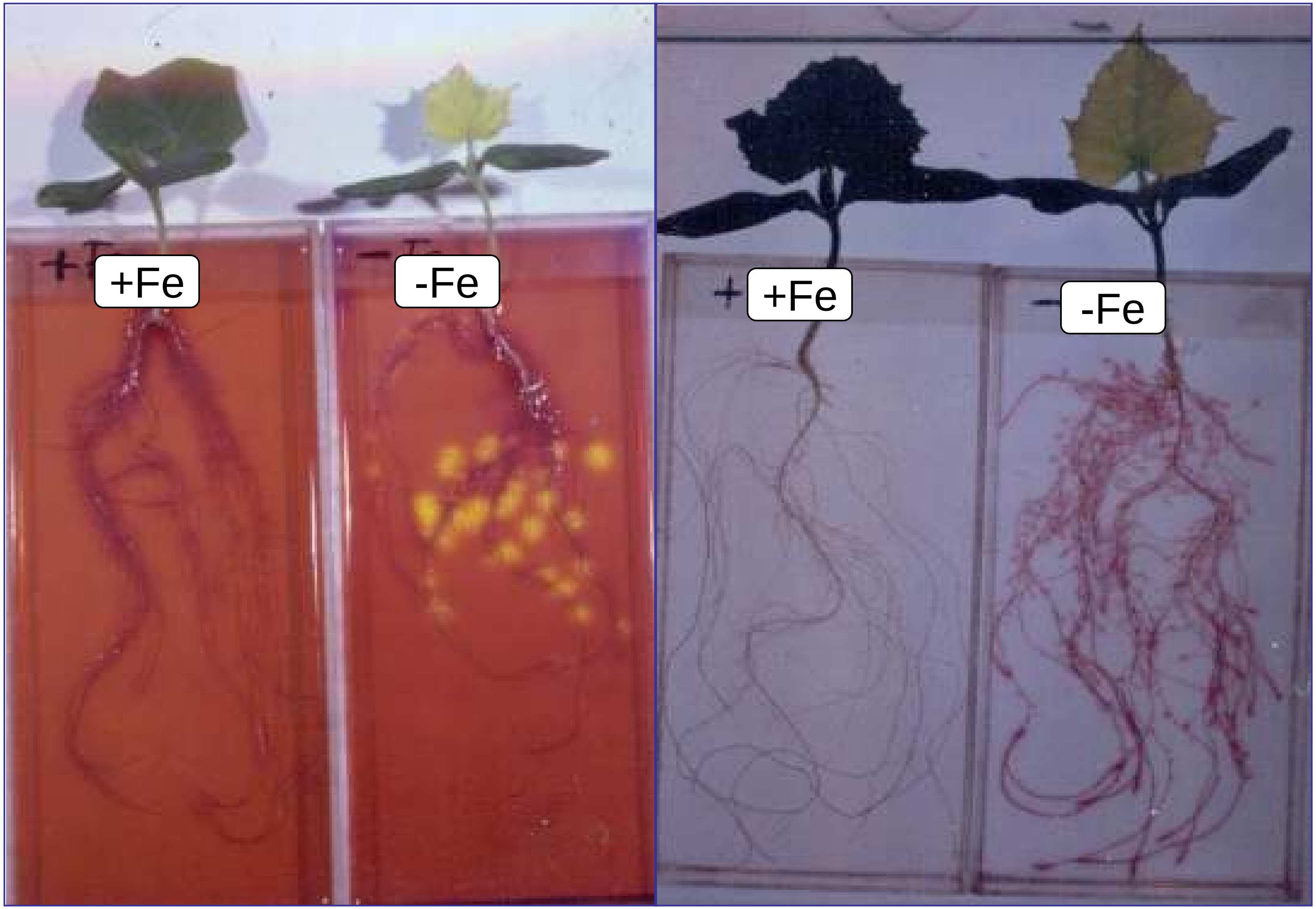
Release of glyphosate into the rhizosphere

Adaptive Root Responses of Strategy-I Plants to Fe Deficiency



Marschner and Römheld, 1995; Plant and Soil

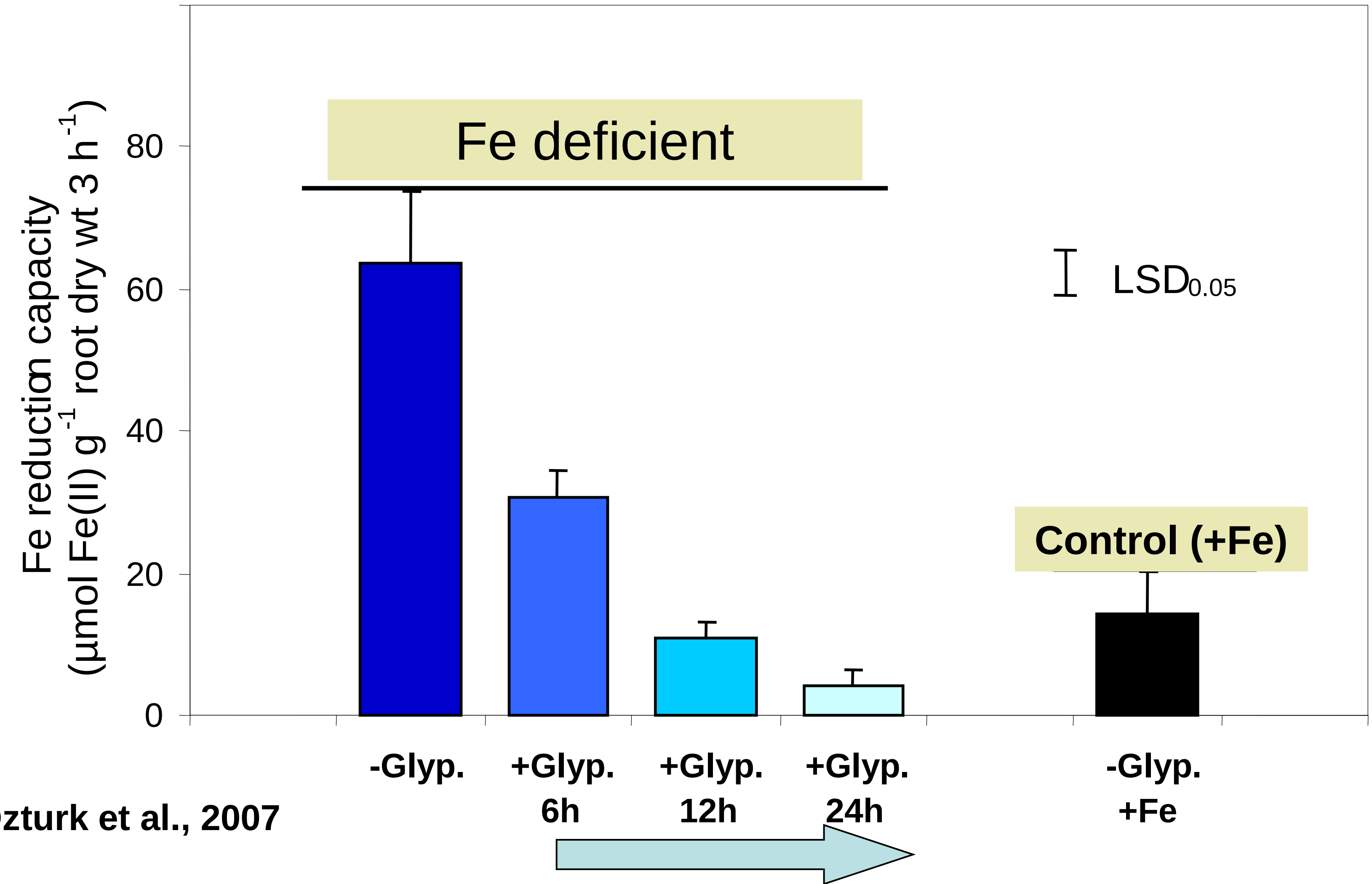
Effect of iron deficiency in cucumber on pH decreasing and reducing capacity of the roots



Romheld et al., 1981

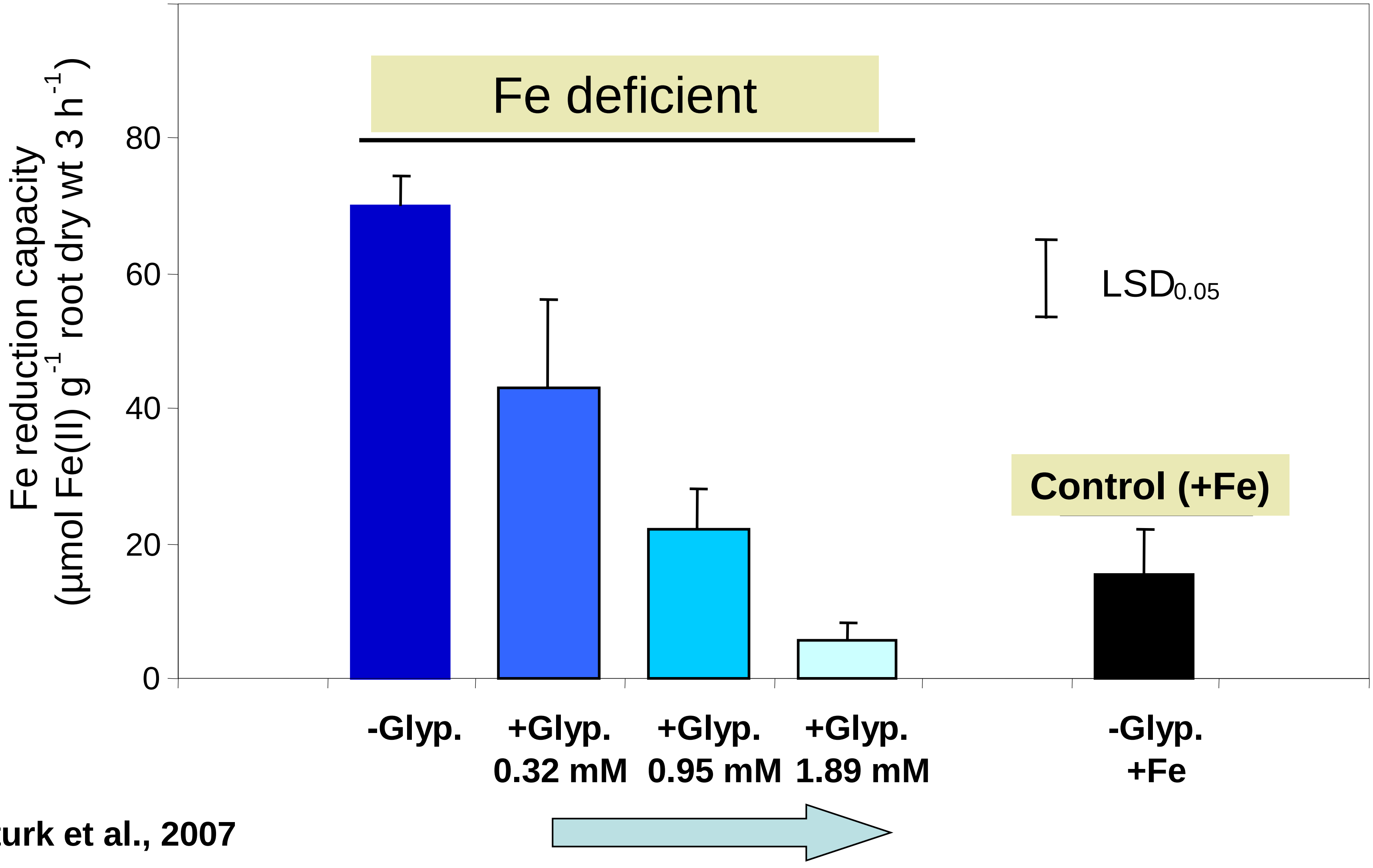
Effect of Glyphosate on Ferric Reductase

Time dependent inhibition of ferric reductase activity in Fe-deficient sunflower plants **(+Glyp: 1.89 mM** glyphosate or **6% of the recommended rate** for weed control)



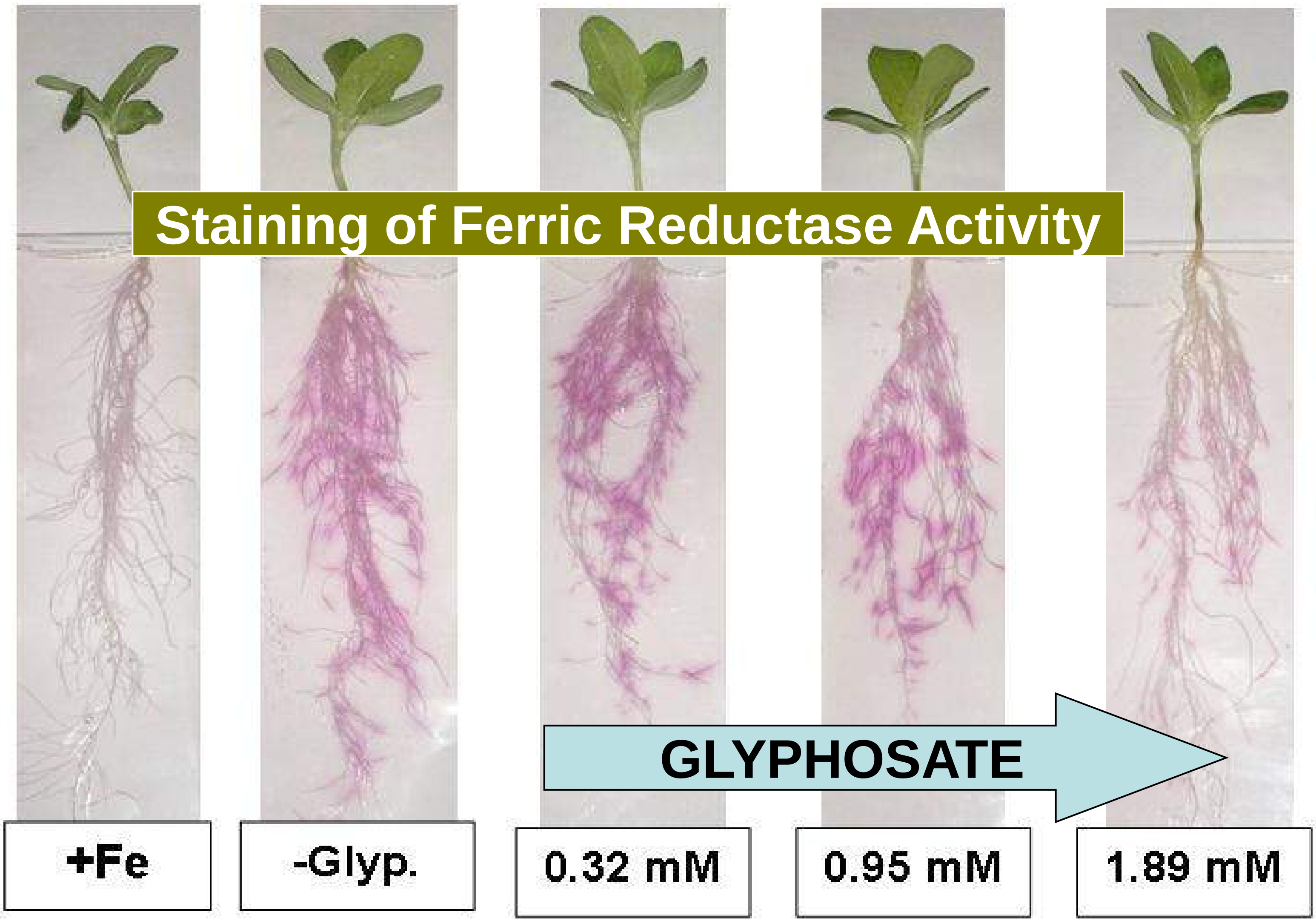
Ozturk et al., 2007

Dose dependent inhibition of ferric reductase activity
by glyphosate (+Glyp: 0.32, 0.95 and 1.89 mM



Ozturk et al., 2007

Foliar applications of glyphosate (Glyp) at 0.32 mM, 0.95 mM and 1.89 mM for 24h.

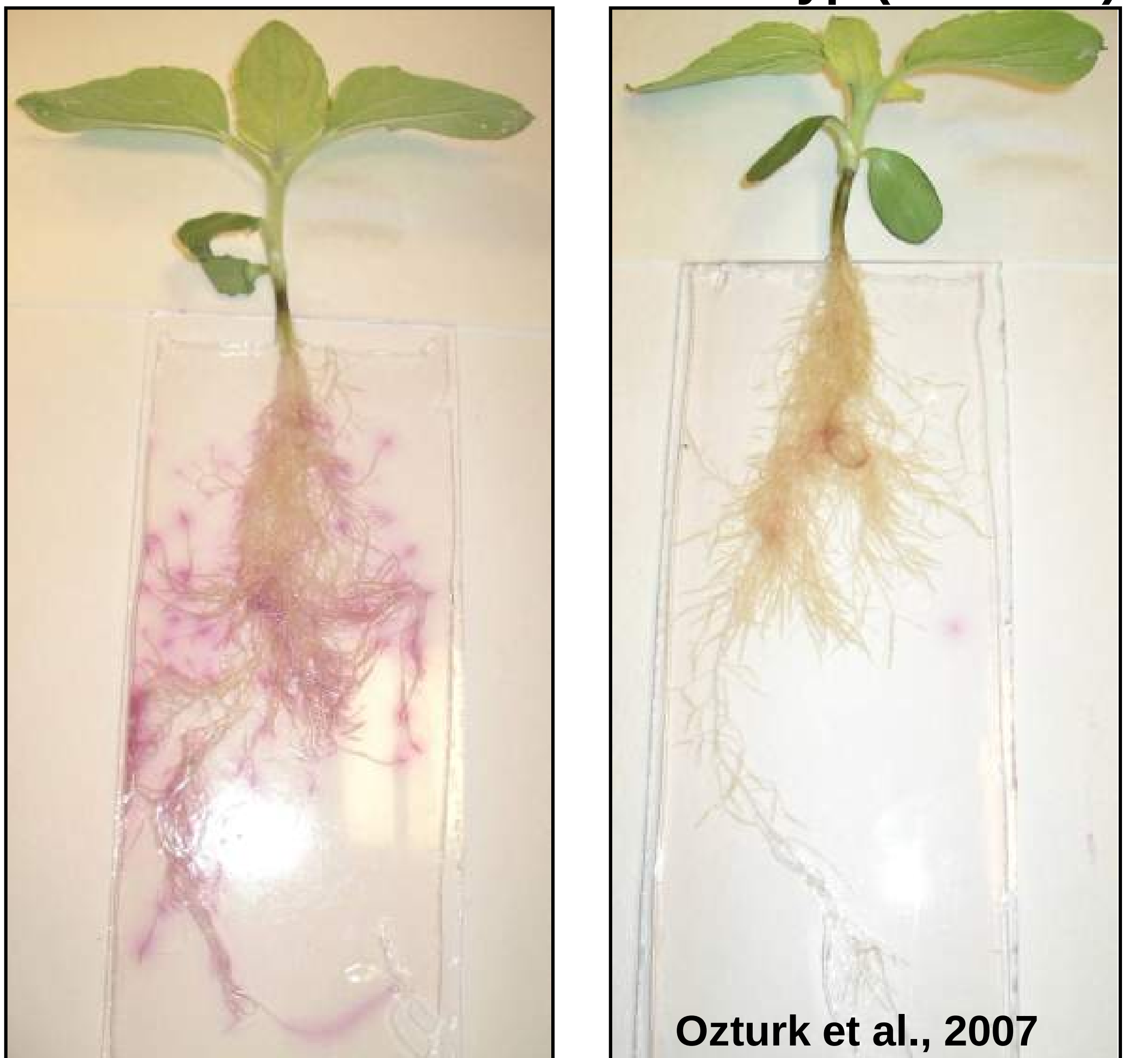


Ozturk et al., 2007

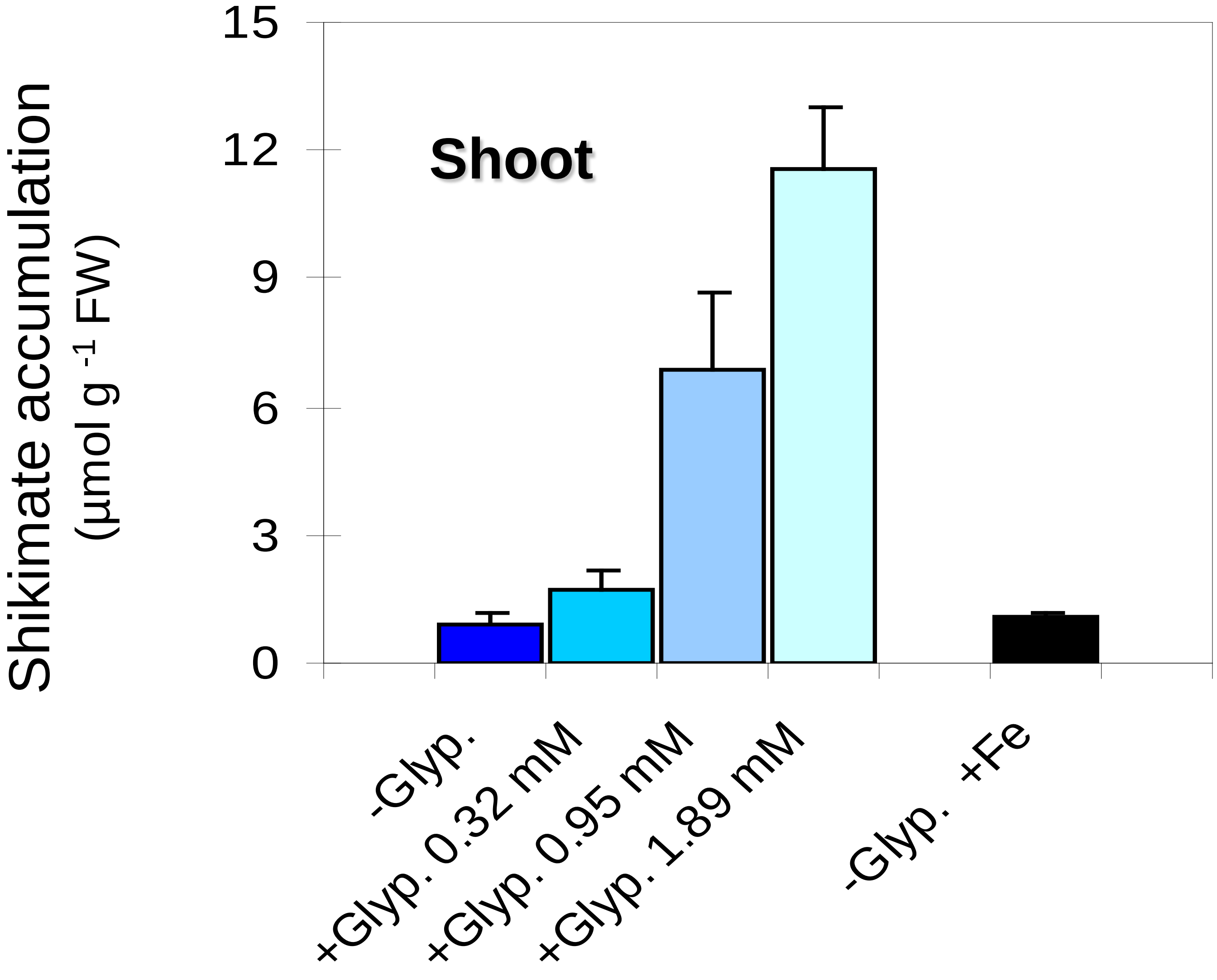
Fe Deficient Plants

Effect of foliar applied of glyphosate (1.89 mM) for 24h on ferric reductase activity.

-Fe | **-Fe +Glyp (1.89 mM)**



Dose Dependent Shikimate Accumulation



Ozturk et al., 2007

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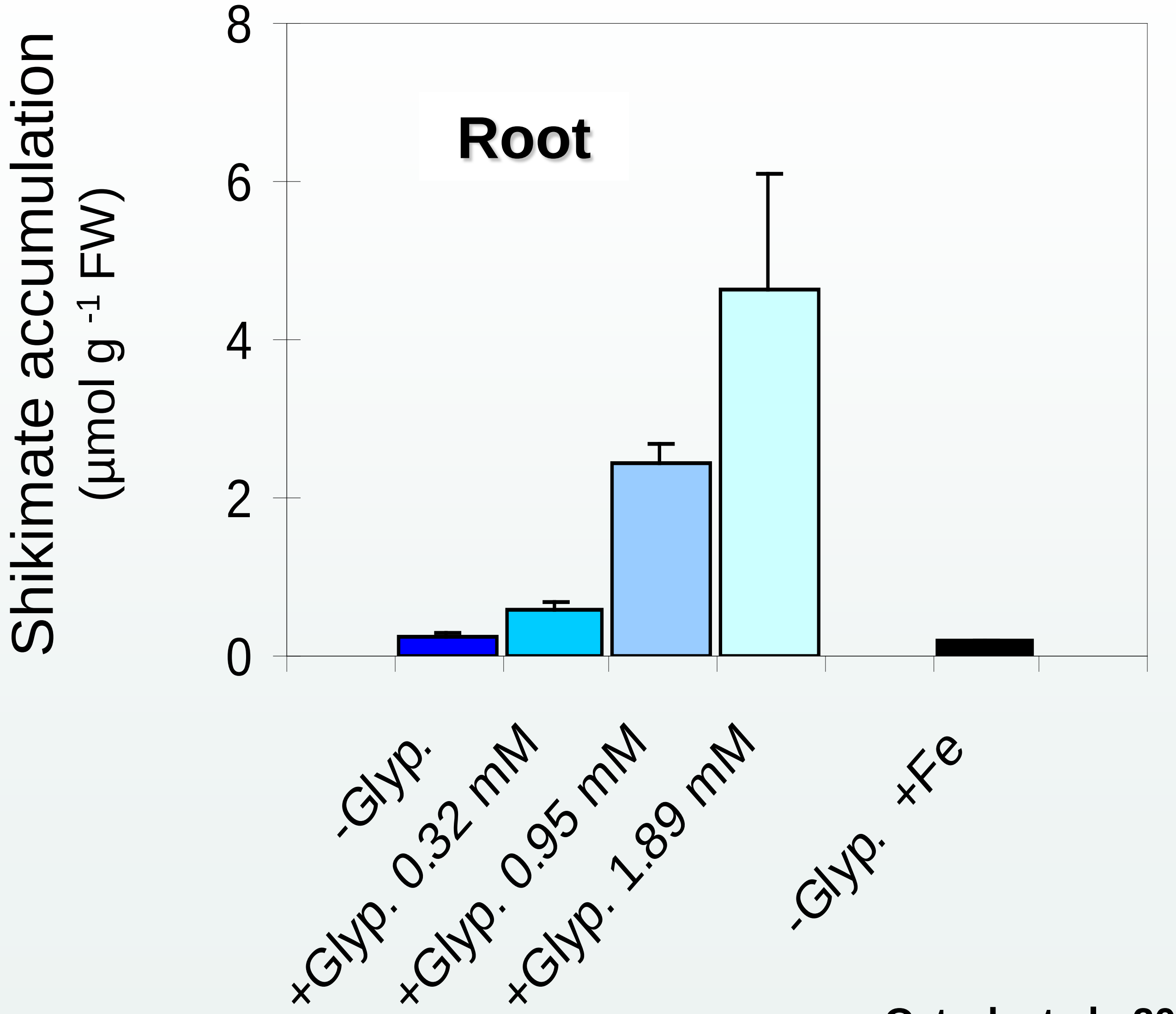

Ozturk et al., 2007

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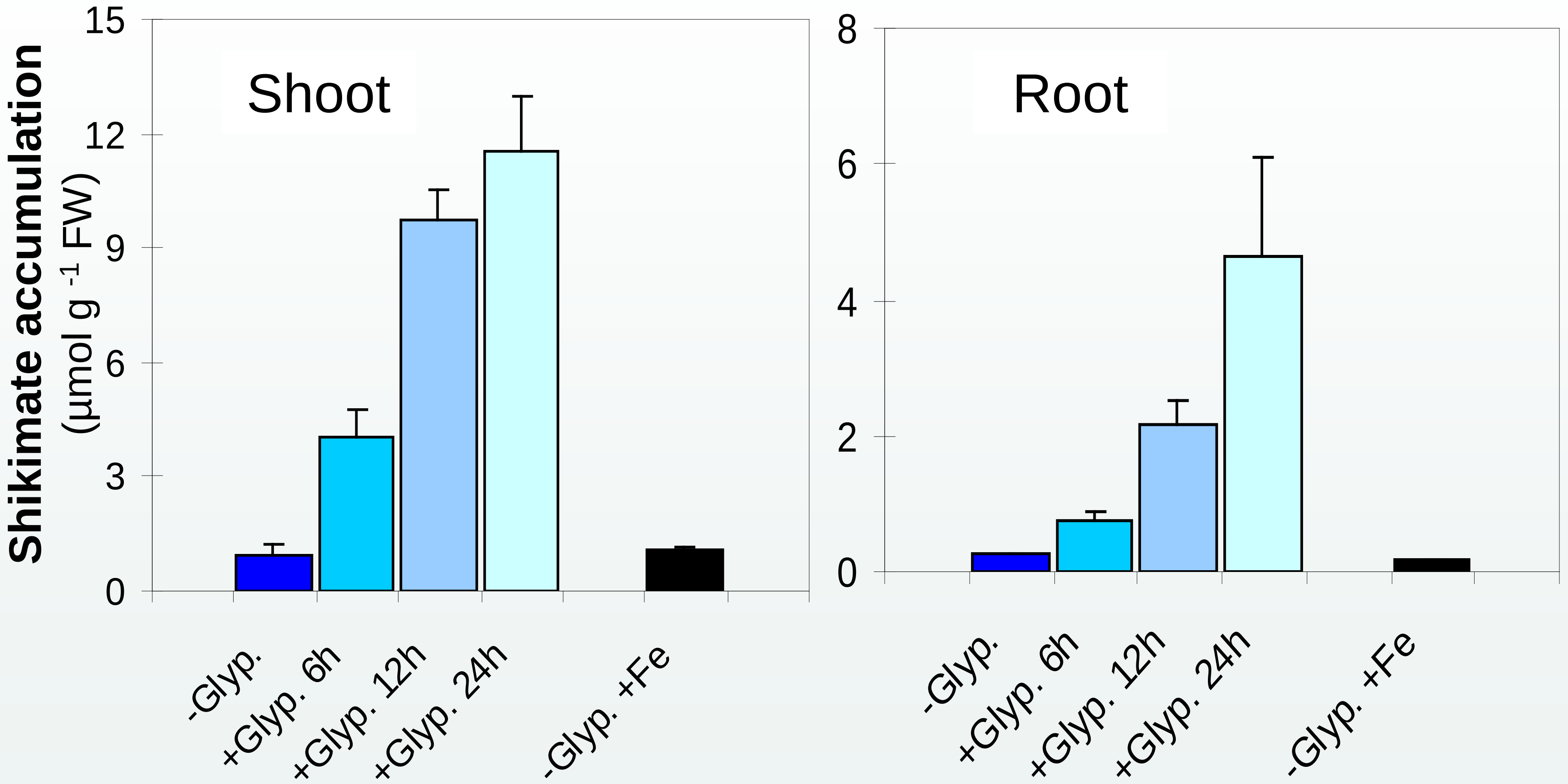
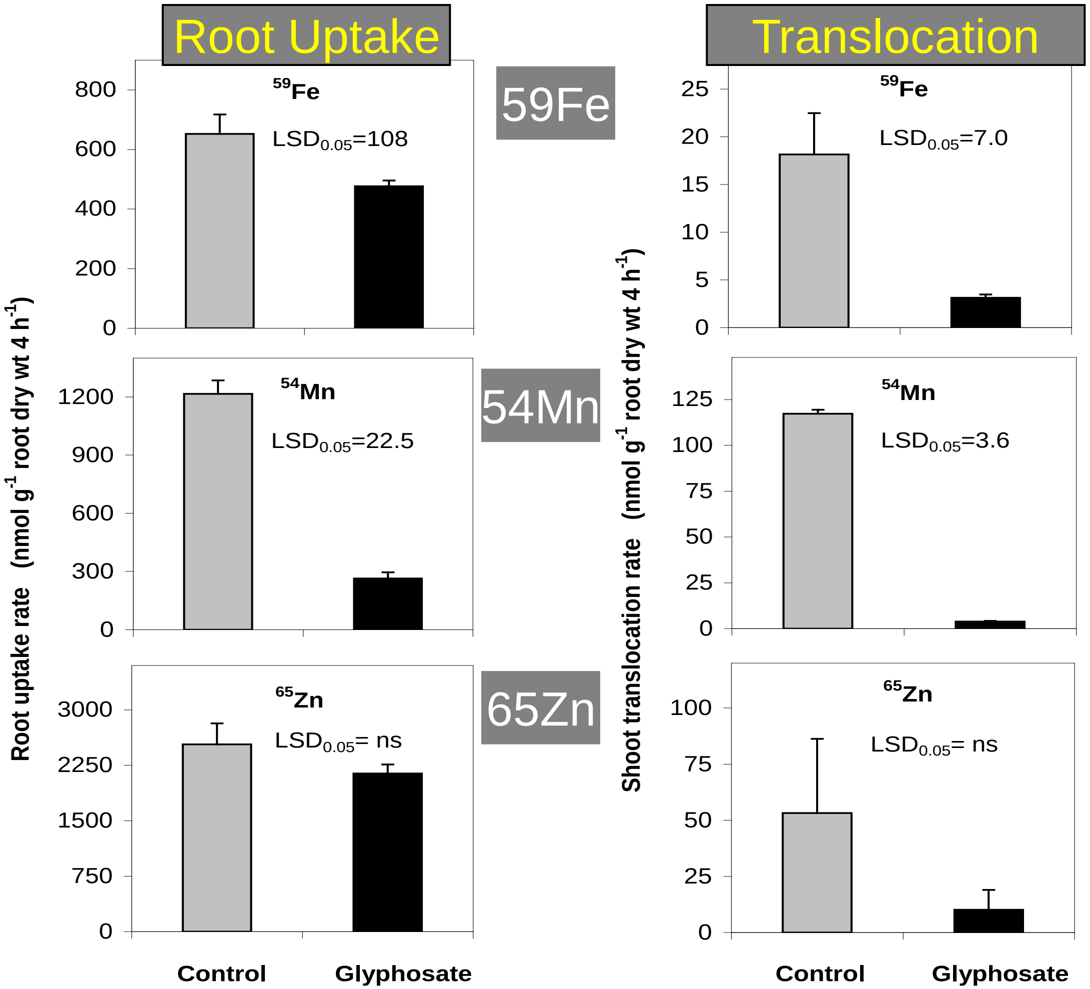


Ozturk et al., 2007

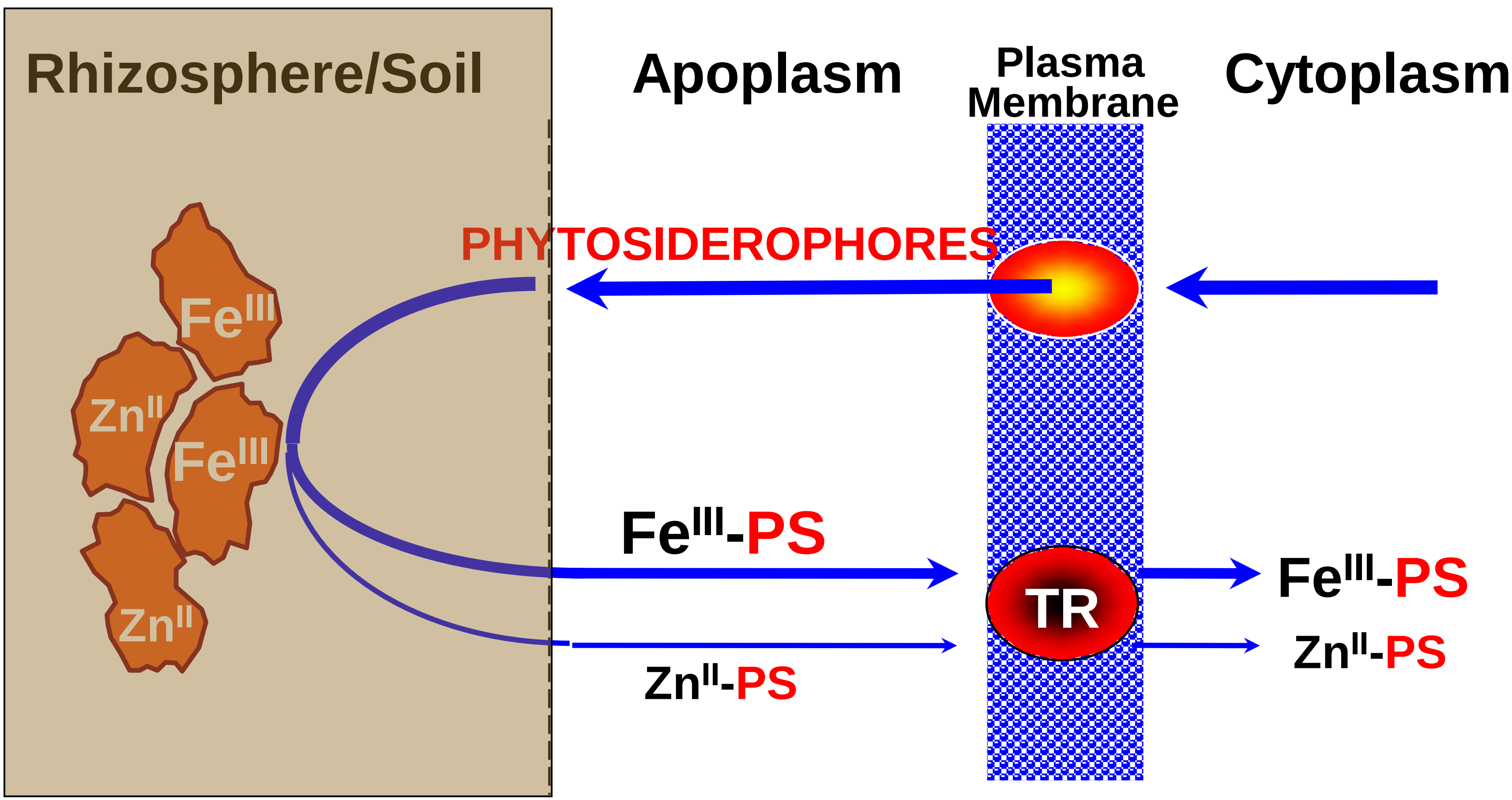
Short-Term Experiments: Glyphosate inhibits root uptake and root-to-shoot transport of micronutrients



Effect of 1.89 mM glyphosate (equivalent to 6 % of the recommended dosage for weed control in the field) on root uptake and shoot translocation of 59Fe, 54Mn and 65Zn in sunflower plants.

Eker et al., 2006: J. Agric. Food Chem. 26, 10019 -10025

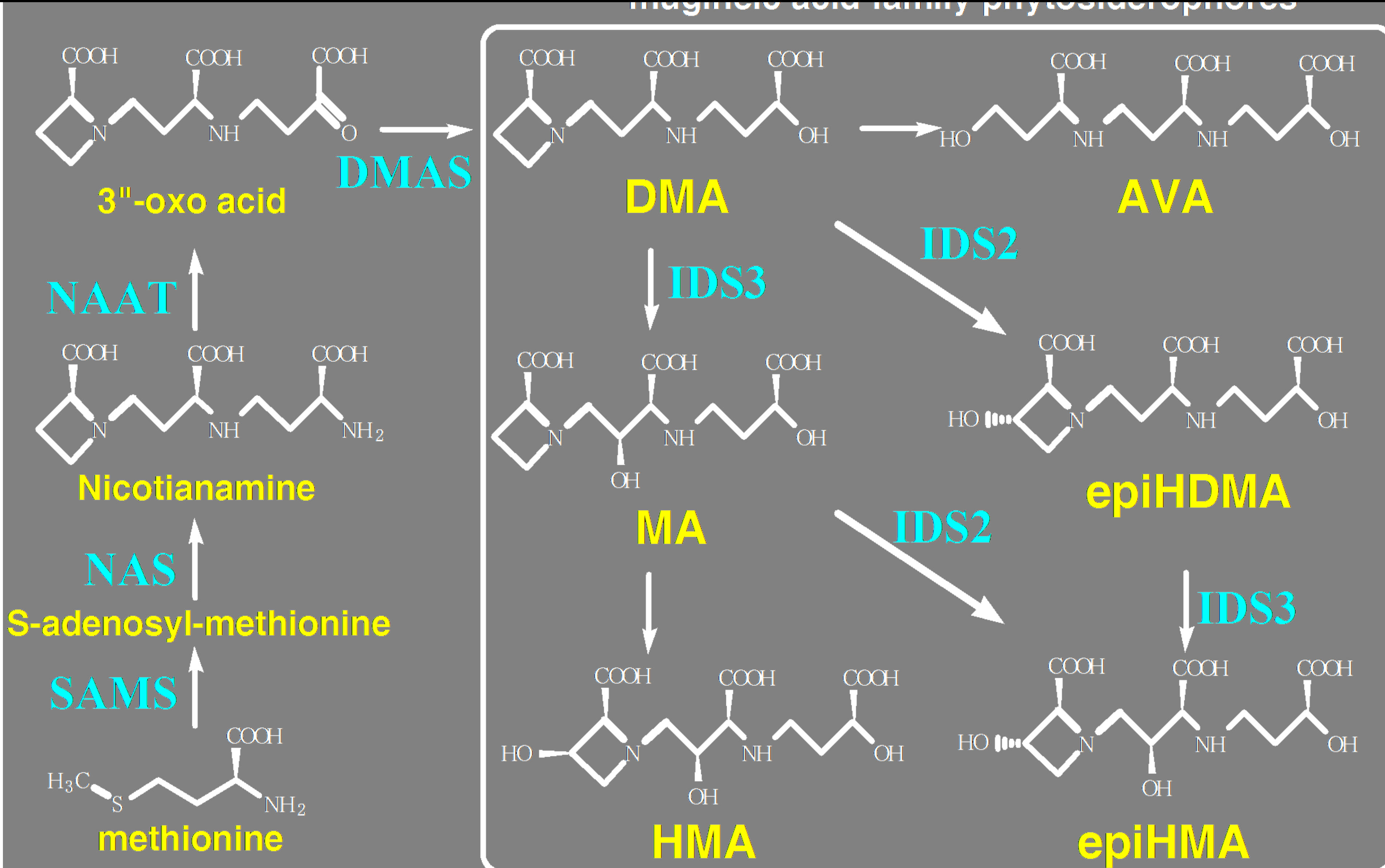
Adaptive Root Responses to Iron and Zinc Deficiencies in Cereals



TR: Transporter Protein

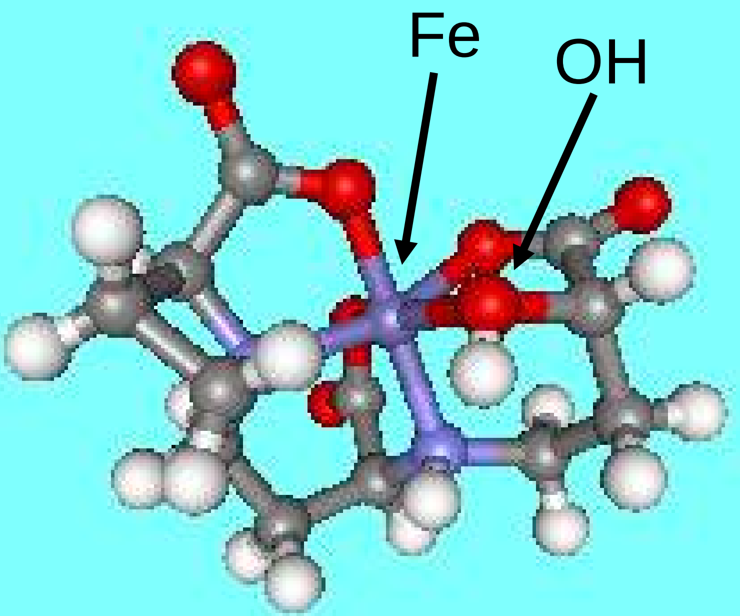
Marschner and Römheld, 1995; Plant and Soil

Mugineic Acid Family

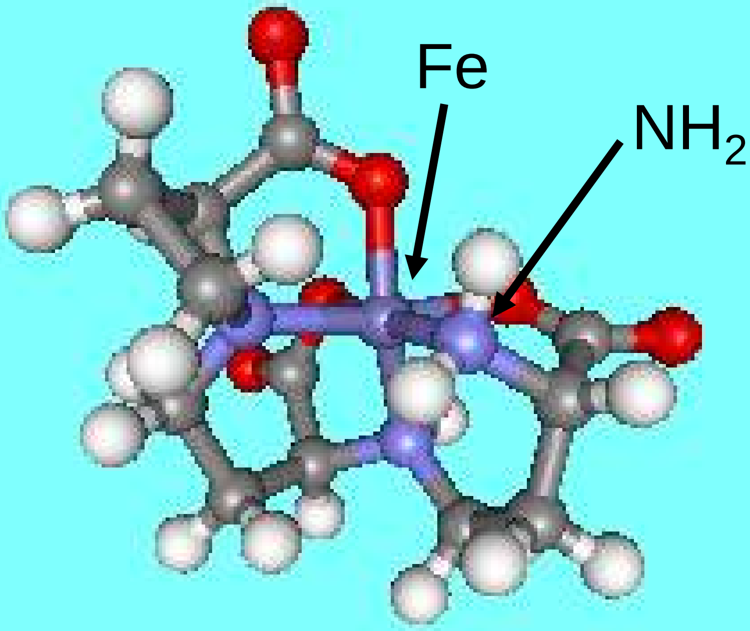


Biosynthetic Pathway of Mugineic Acid Family Phytosiderophores

Mori et al., 1990



Fe^{3+}-Deoxymugineic acid

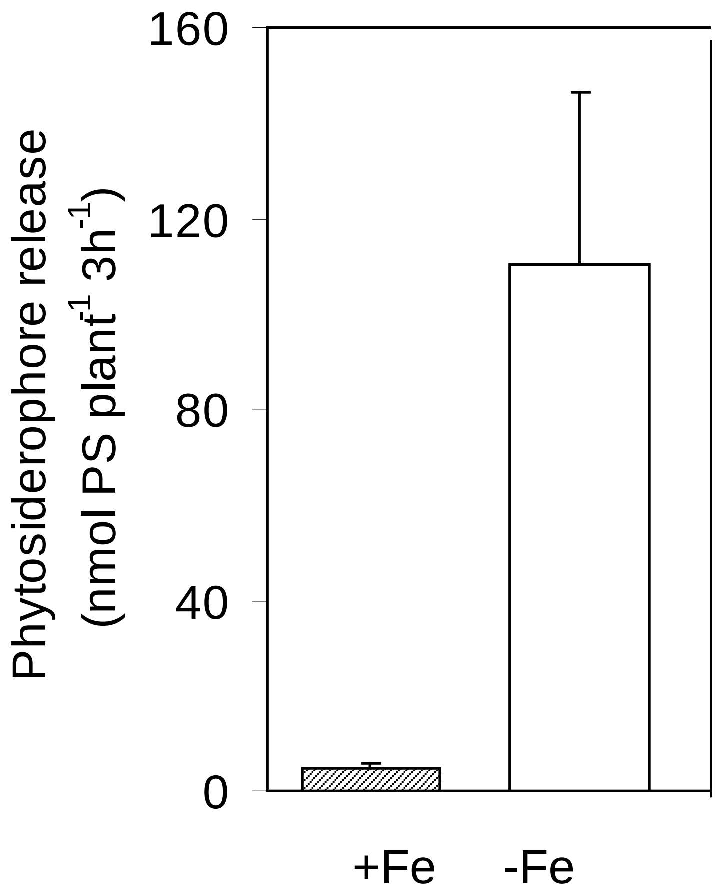


Fe^{3+}-Nicotianamine

Similar Stereochemical Structure between Fe^{3+}-DMA and Fe^{3+}-NA

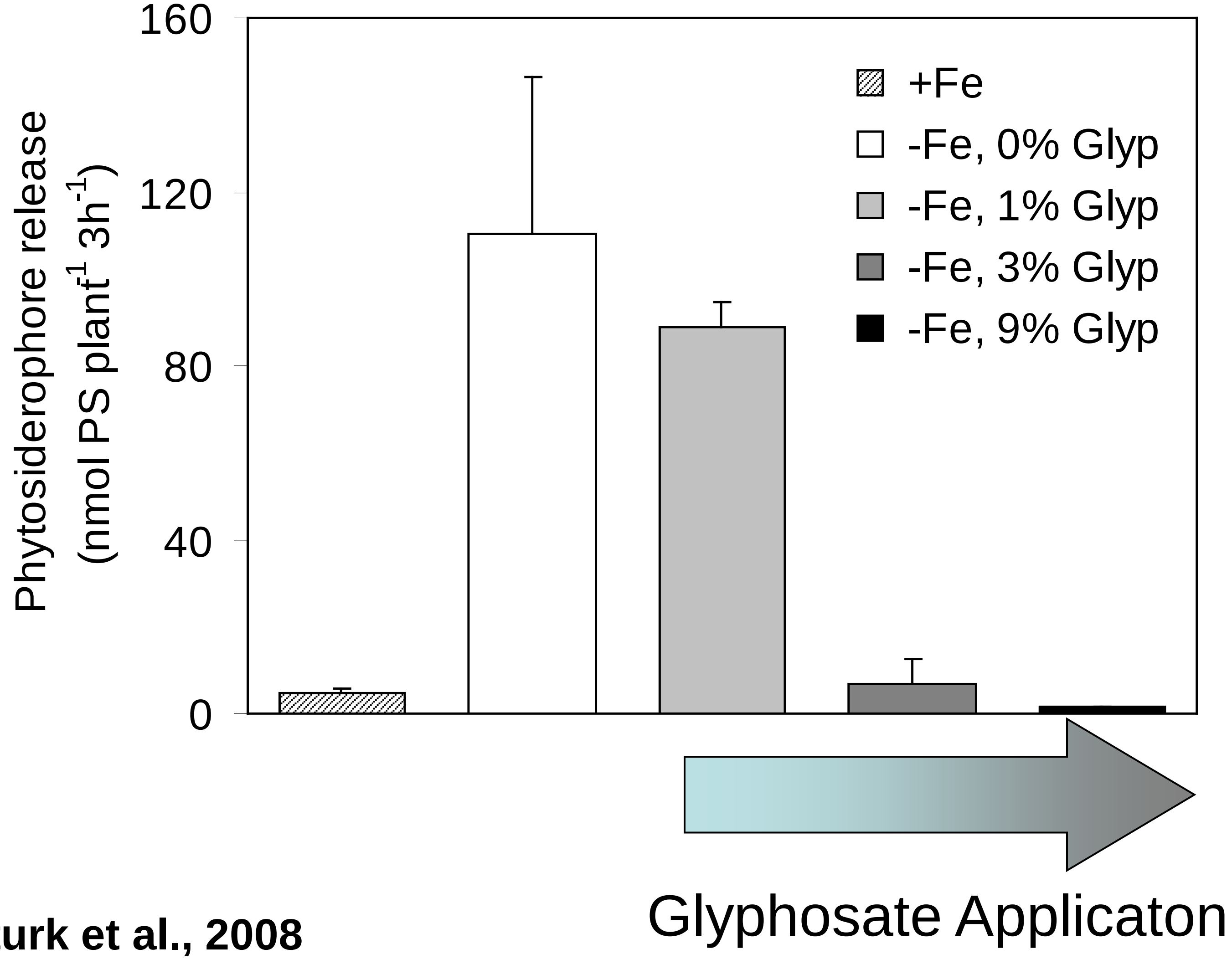
Mori, et al, 1990

Phytosiderophore Release from Roots



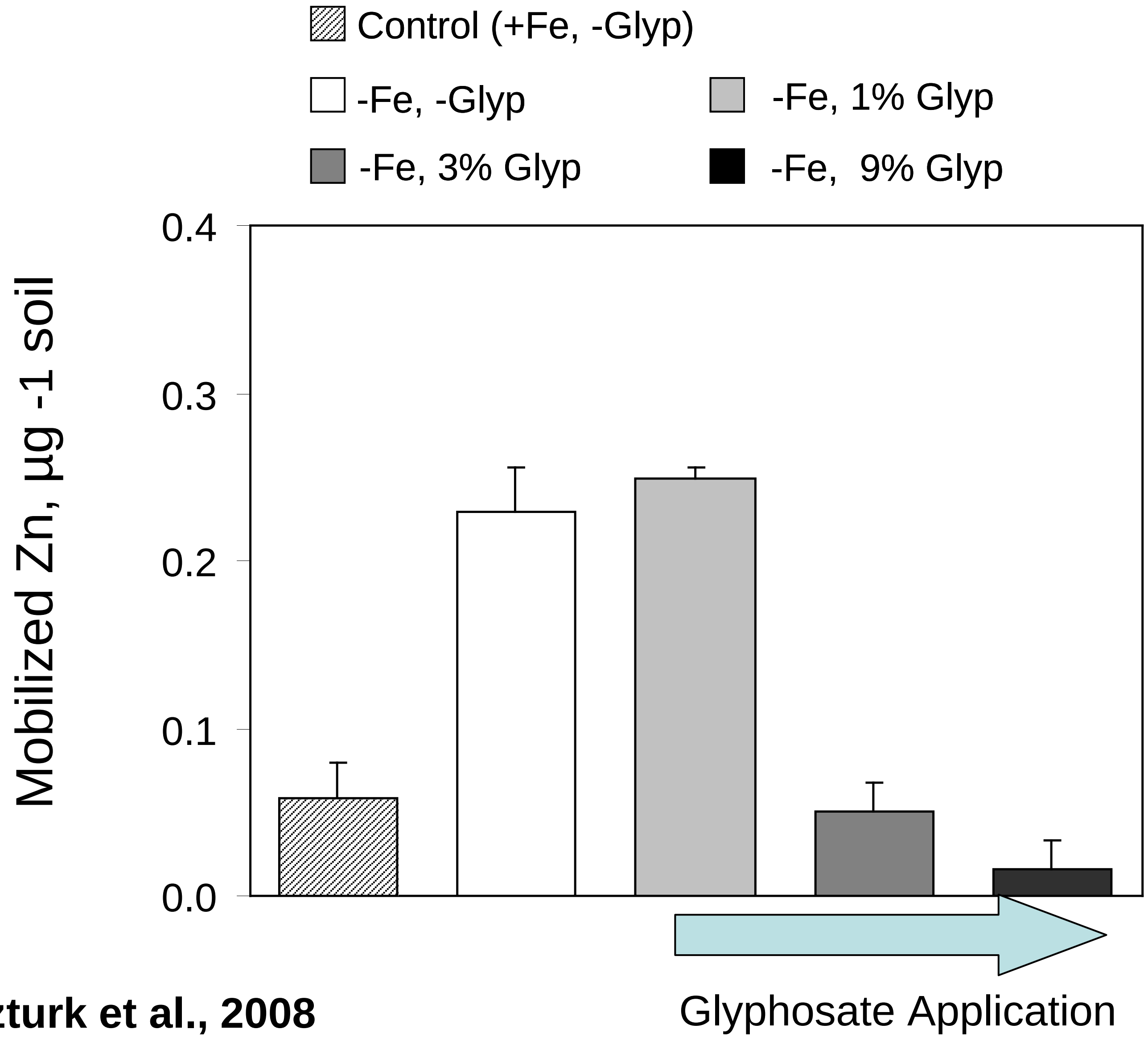
Ozturk et al., 2008

Phytosiderophore Release from Wheat Roots



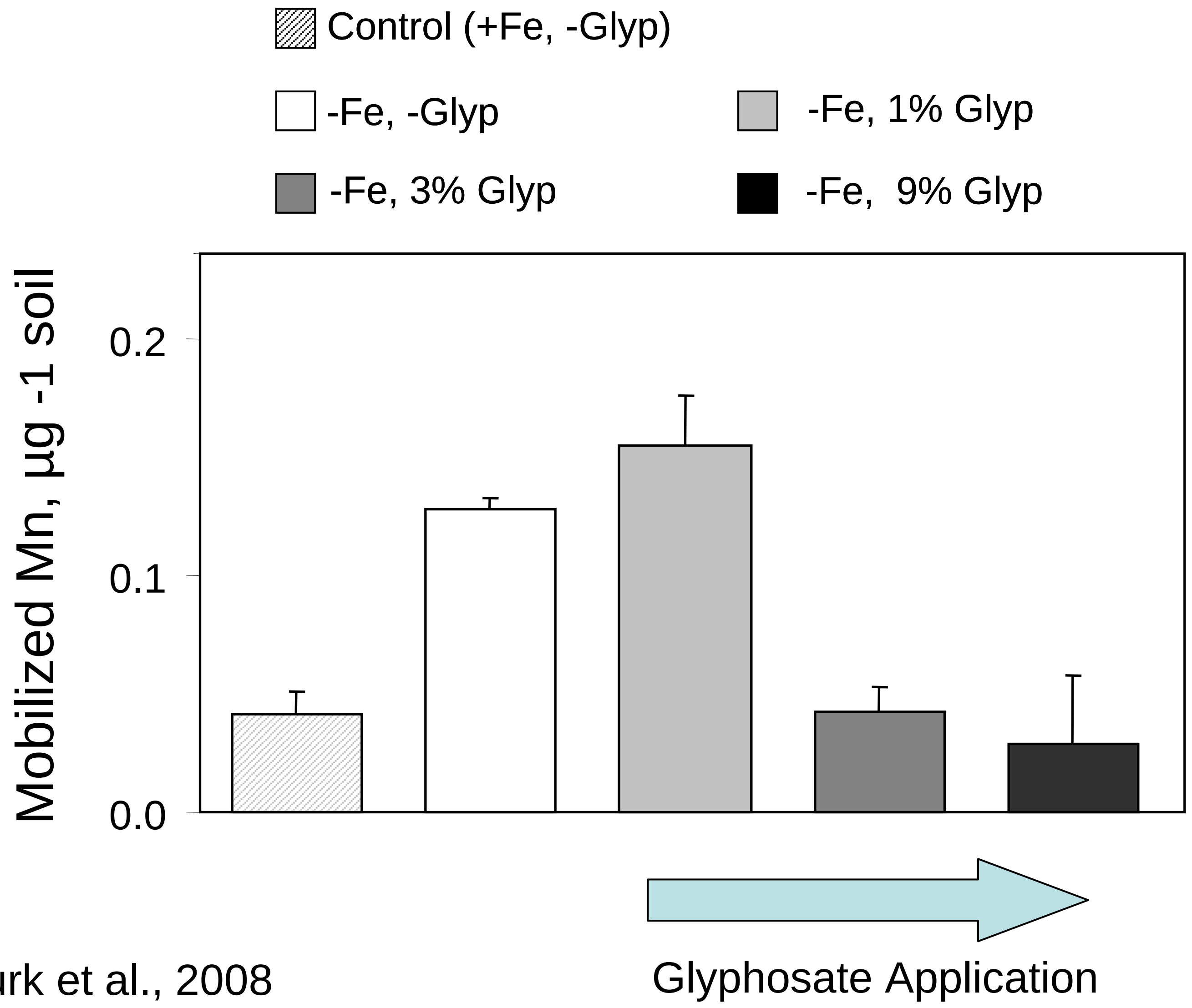
Ozturk et al., 2008

Mobilization of Zn from Calcareous Soil by Phytosiderophores



Ozturk et al., 2008

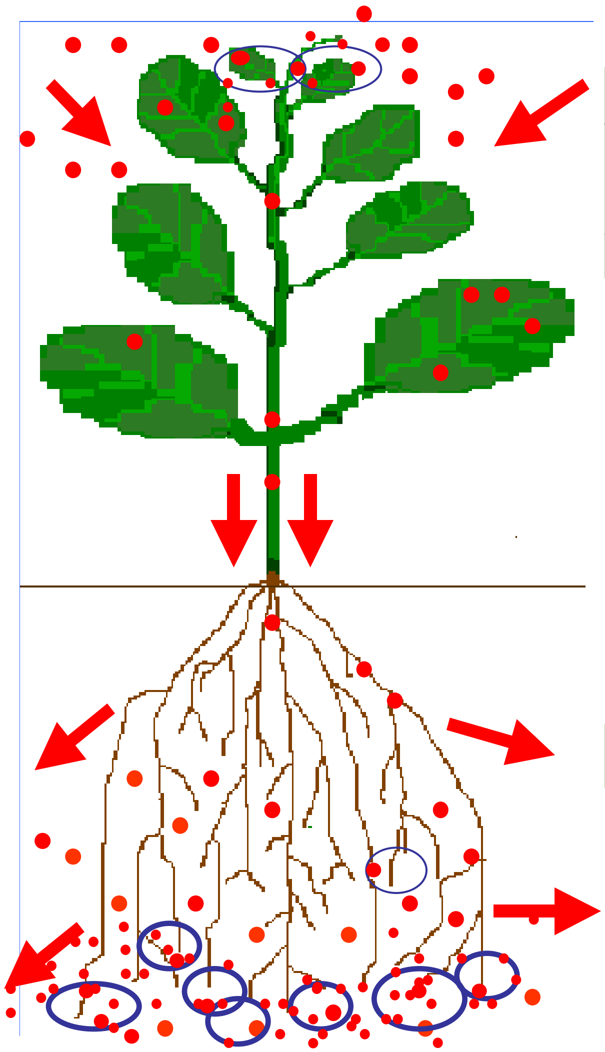
Mobilization of Mn from Calcareous Soil by Phytosiderophores



Ozturk et al., 2008

REMEMBER

Glyphosate is highly phloem mobile



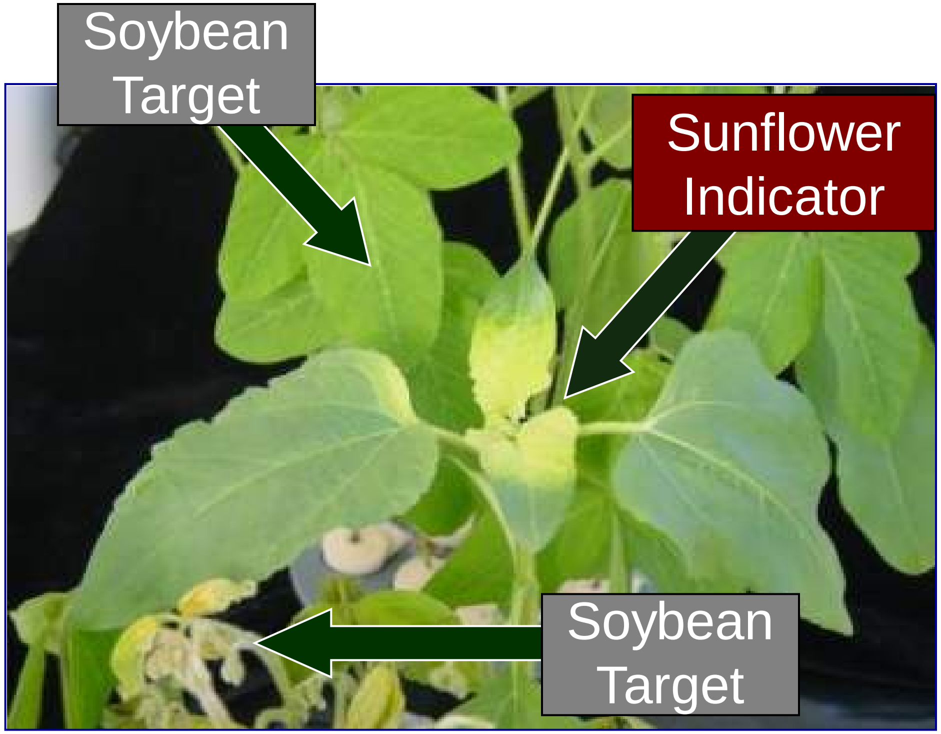
Application of glyphosate on target plants (weeds)/glyphosate resistant cultivars; very quick uptake by leaves.

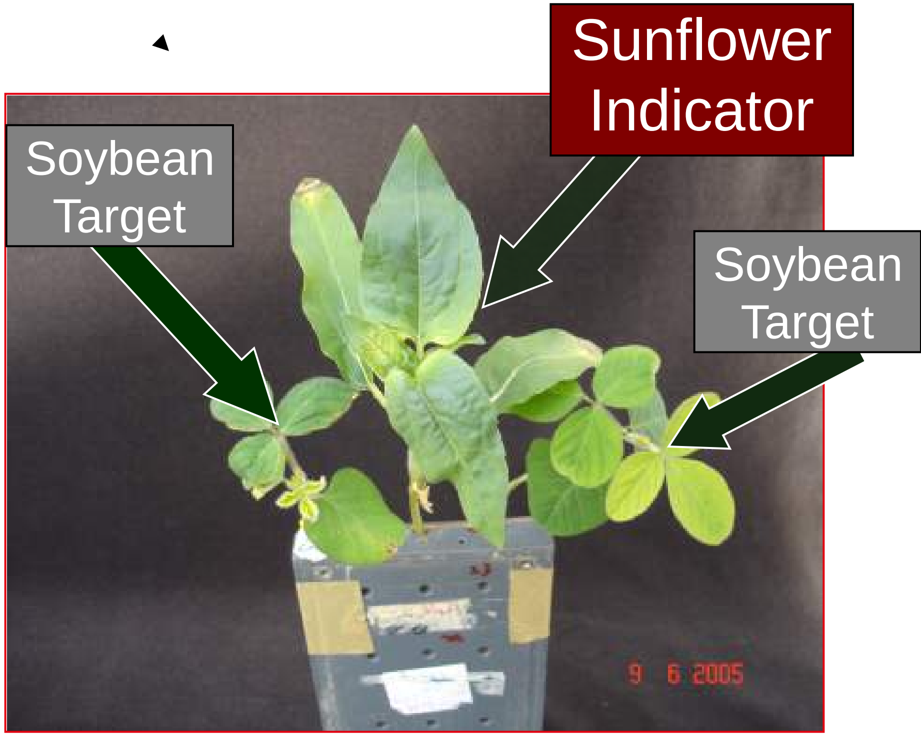
Rapid translocation of glyphosate from shoot to root

Release of glyphosate into the rhizosphere

Glyphosate applied to target plants is released into the rhizosphere

Induction of Fe deficiency chlorosis in non-target plants (sunflower)



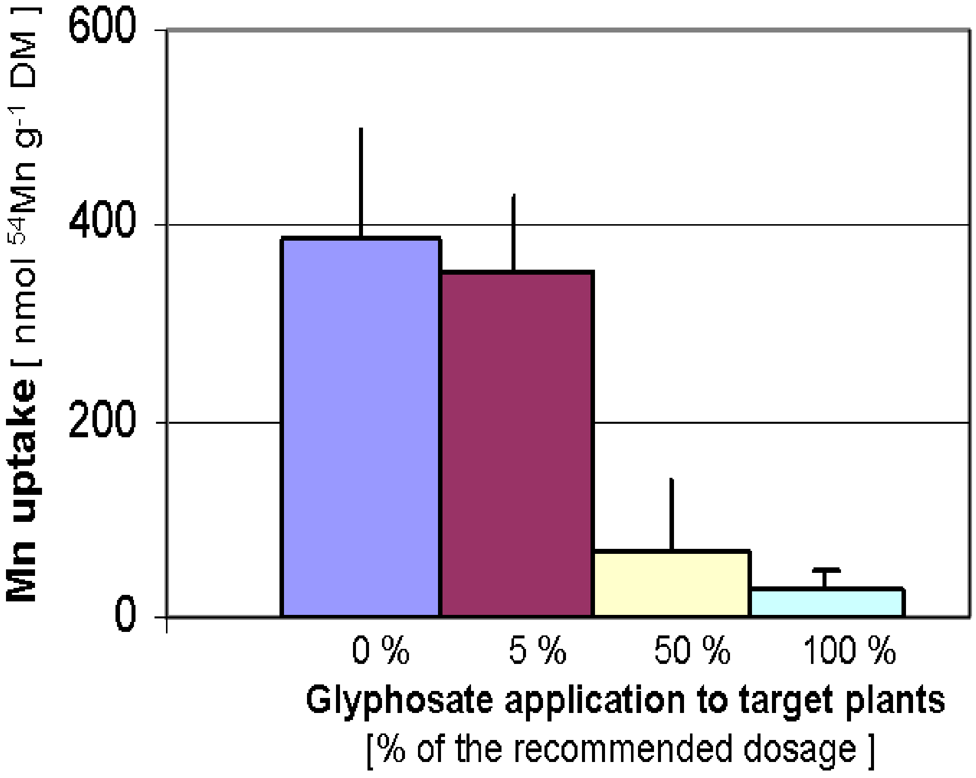


(Neumann et al., 2005, J. Plant Dis. Prot.)

Glyphosate application to target plants (soybean) → **Development of Fe deficiency symptoms in non-target plants …**

Glyphosate released in the rhizosphere reduces Mn uptake

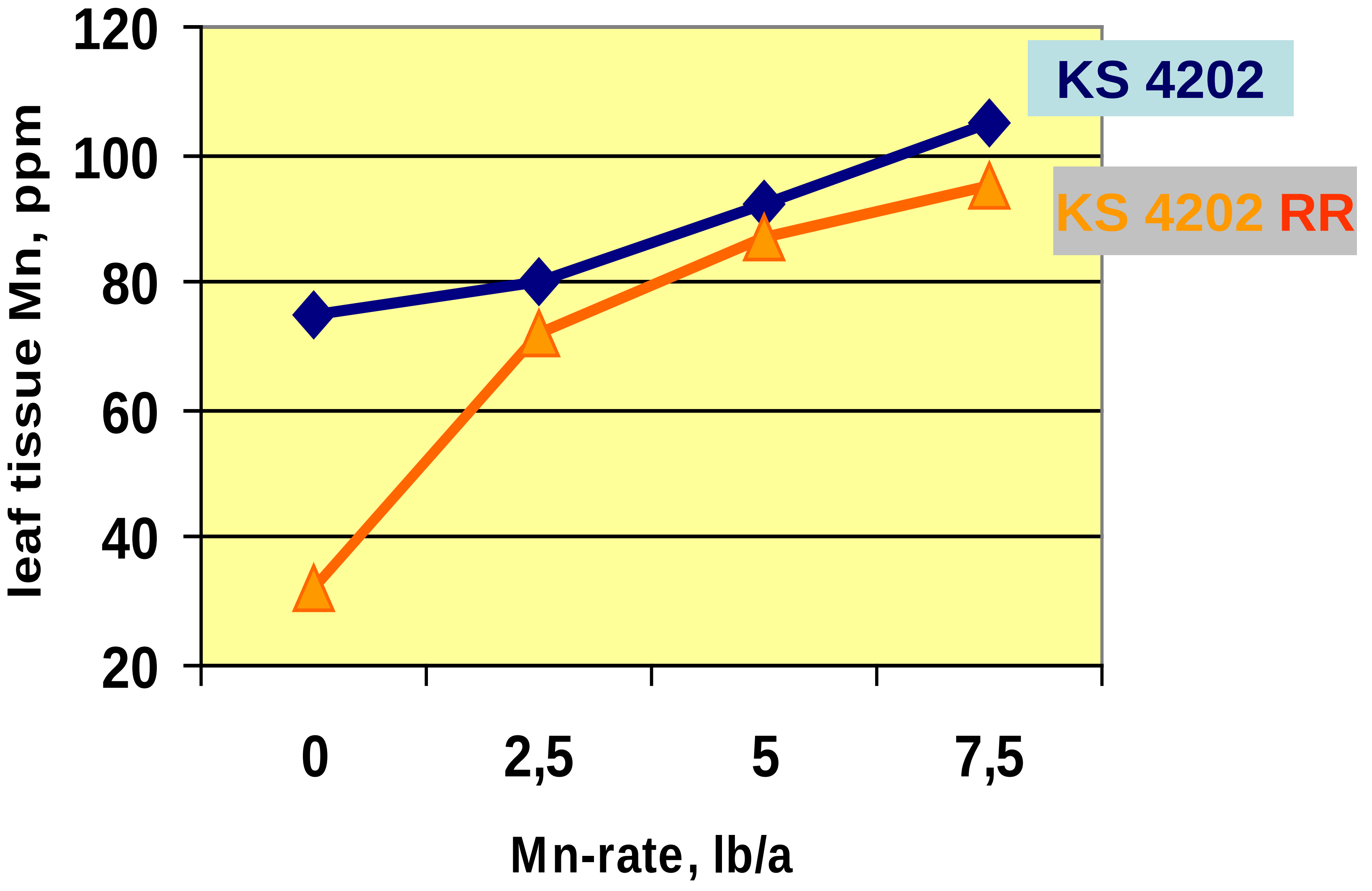
^{54}Mn in shoots



Inhibited Mn acquisition by non-target plants (sunflower) grown in nutrient solution together with glyphosate treated target plants (soybean) for 2, 4 and 6 days.

Neumann et al., 2005, J. Plant Dis. Prot.

Significantly lower Mn uptake / accumulation in RR-soybeans



(B.Gordon, 2006; Kansas State Univ.)

Inhibition of MnO_2 Reduction in Soil-filled Rhizoboxes after Glyphosate Treatment to Target Plants (soybean)

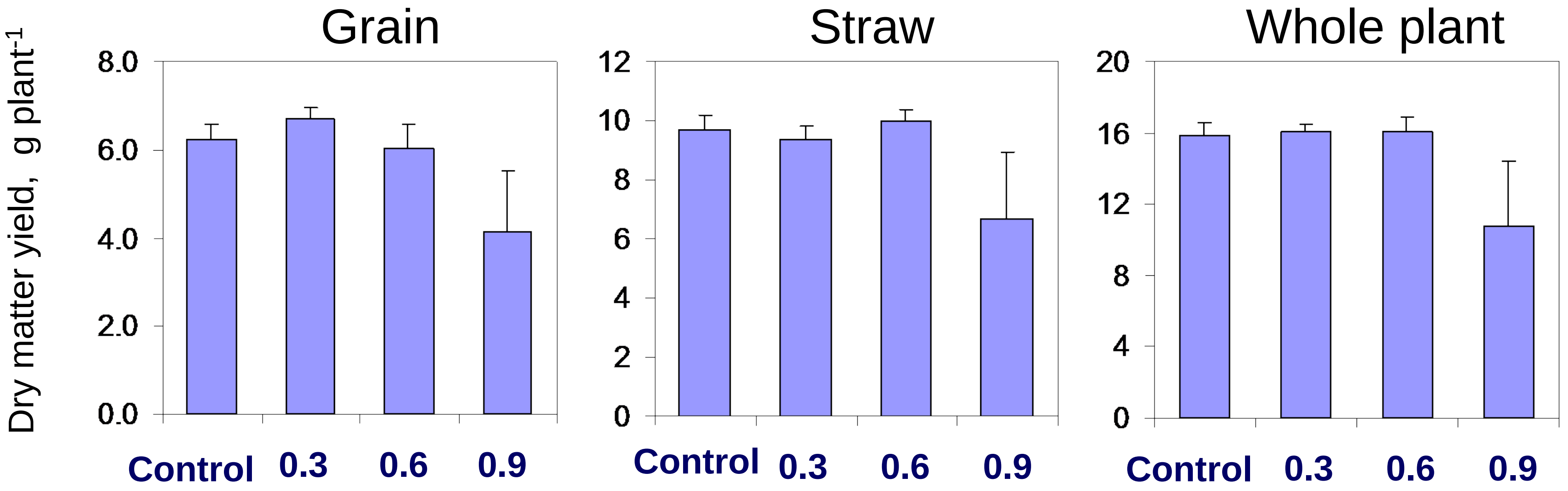
MnO_2 Reduction in Soil-filled Rhizobox Culture of sunflower (non-target) and RR-Soybean with and without foliar Glyphosate spray

(Neumann et al., 2005)

Glyphosate Reduces Grain Mn, Mg and Ca

Glyphosate Application, %

Grain, straw and whole plant dry matter yield as affected by drift rates of glyphosate in soybean

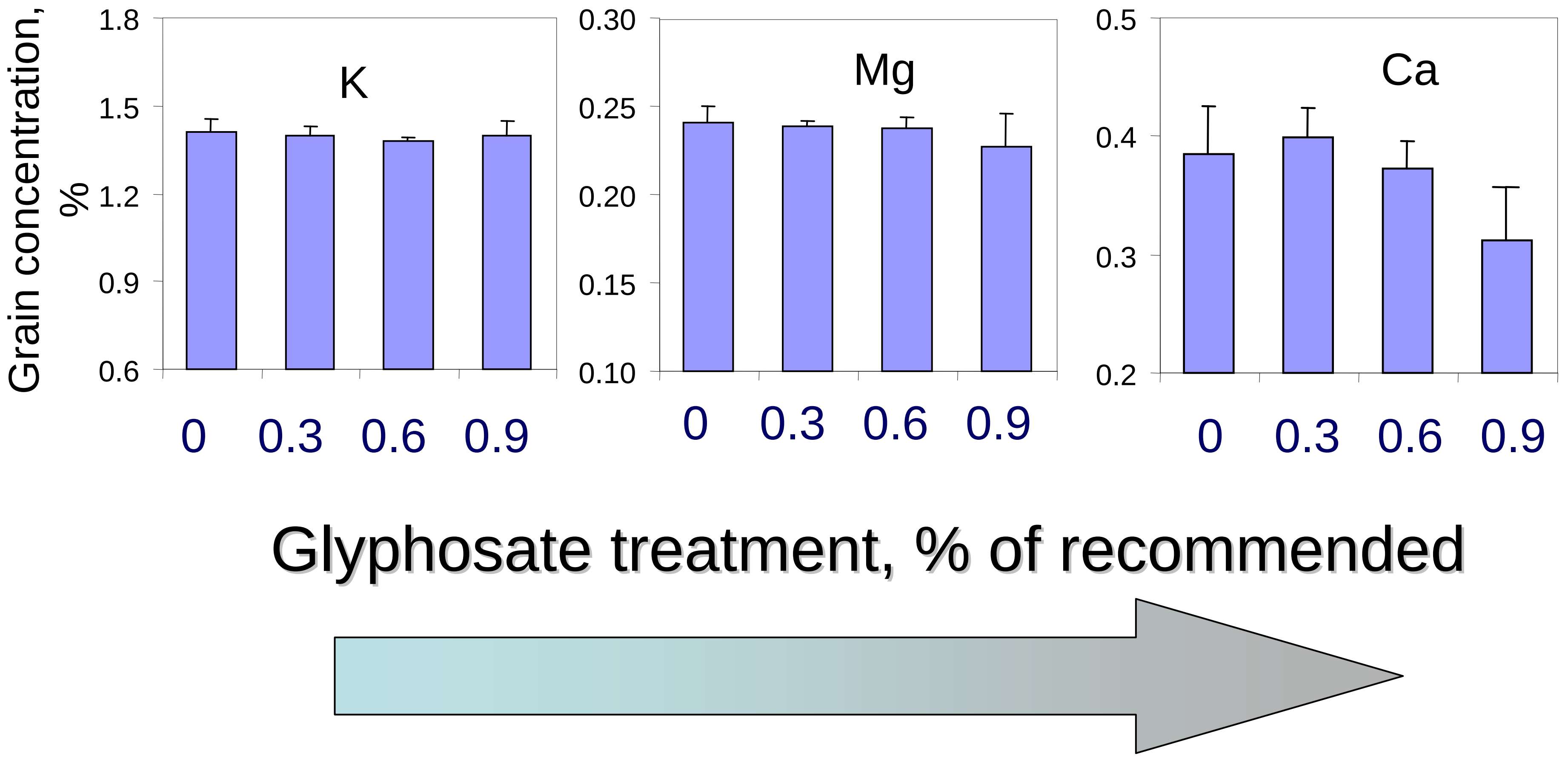


Glyphosate treatment, % of recommended

Yazici et al., 2008

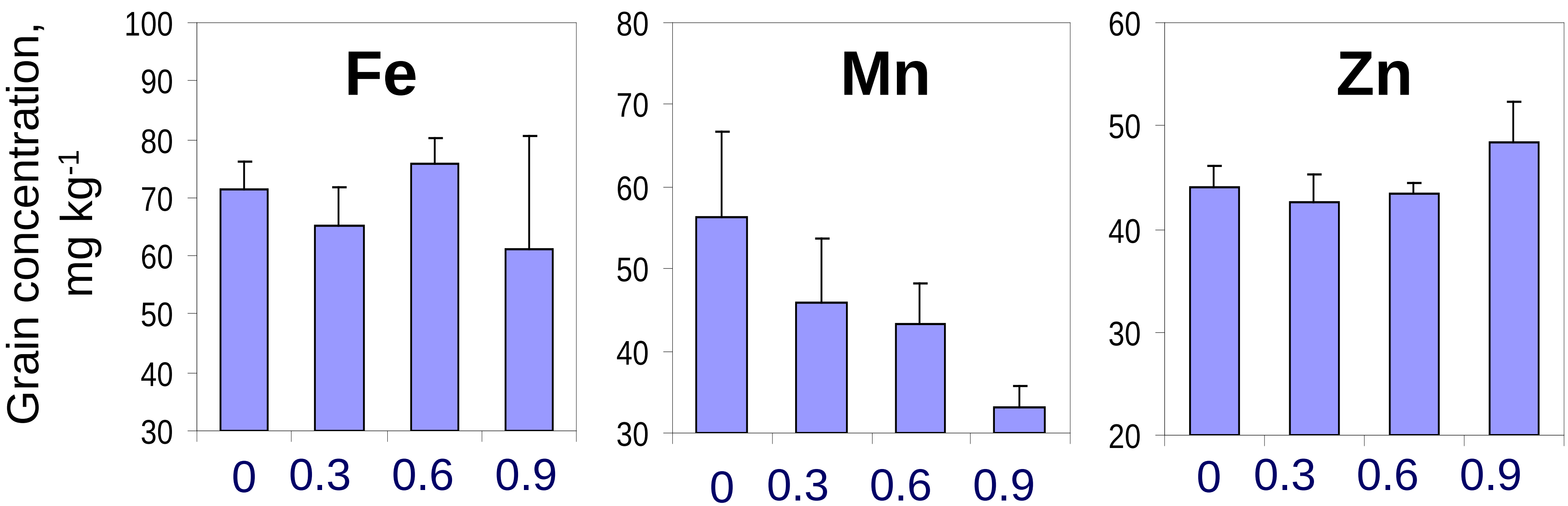
Glyphosate applied 3 times before flowering

Grain concentration of K, Mg and Ca as affected by drift rates of glyphosate in soybean



Yazici et al., 2008

Grain concentration of Fe, Mn and Zn as affected by drift rates of glyphosate in soybean

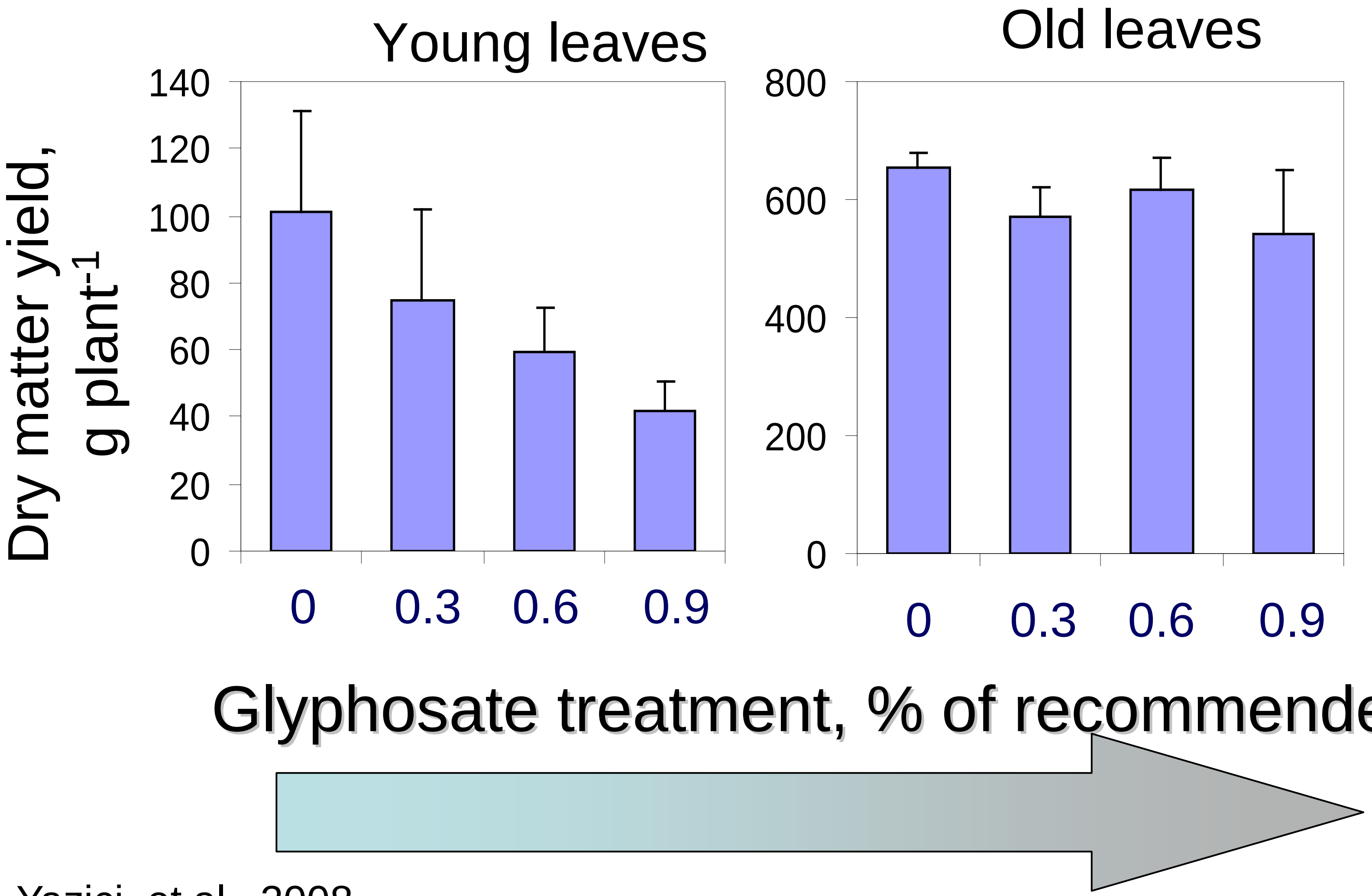


Glyphosate treatment, % of recommended

Yazici et al., 2008

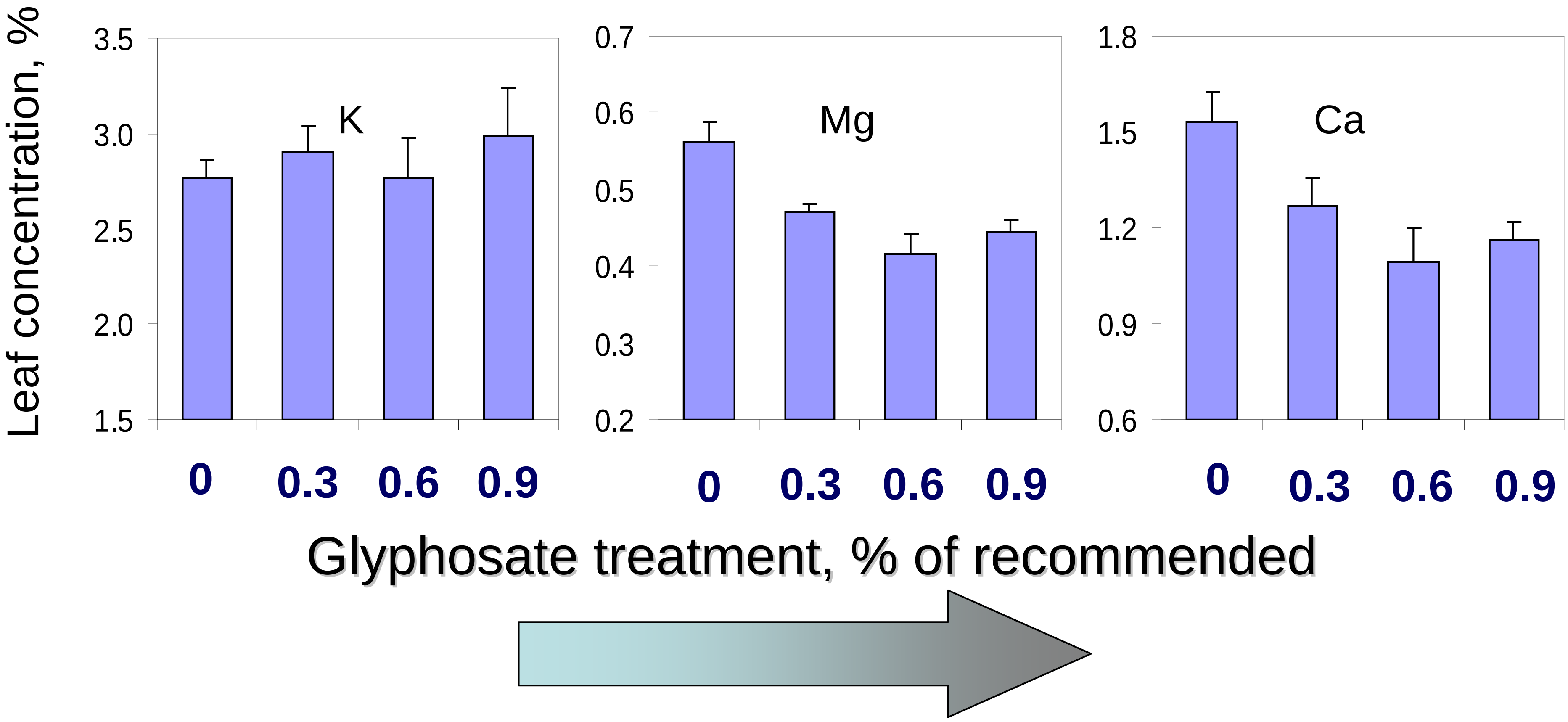
Seed Mn and Ca very important
for seed viability and seedling vigour

Dry matter yield of young and old leaves of soybean plants as affected by drift rates of glyphosate



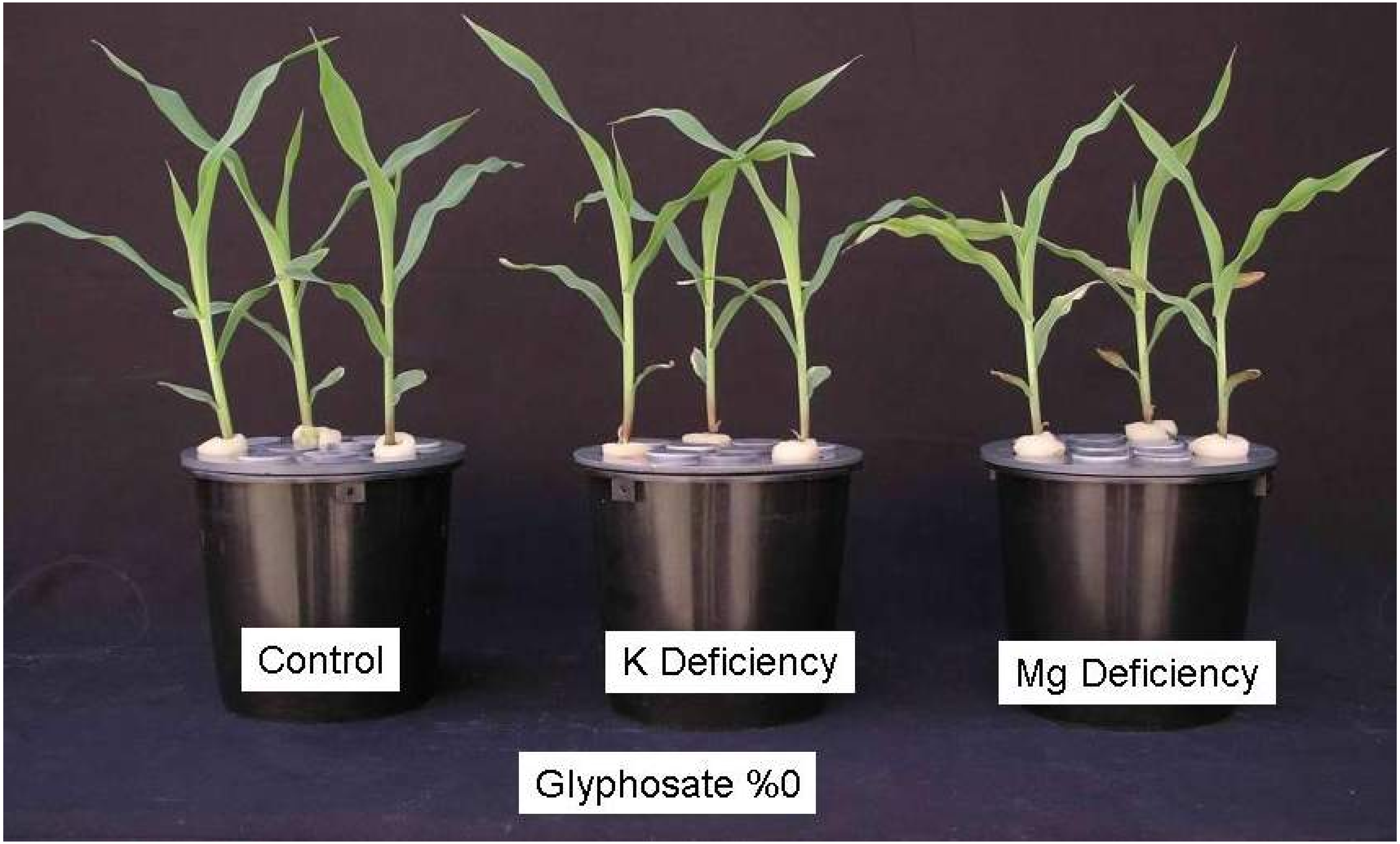
Yazici et al., 2008

Concentration of K, Mg and Ca in soybean leaves as affected by drift rates of glyphosate



Hande et al., 2008

Plants with low Mg are highly sensitive to glyphosate



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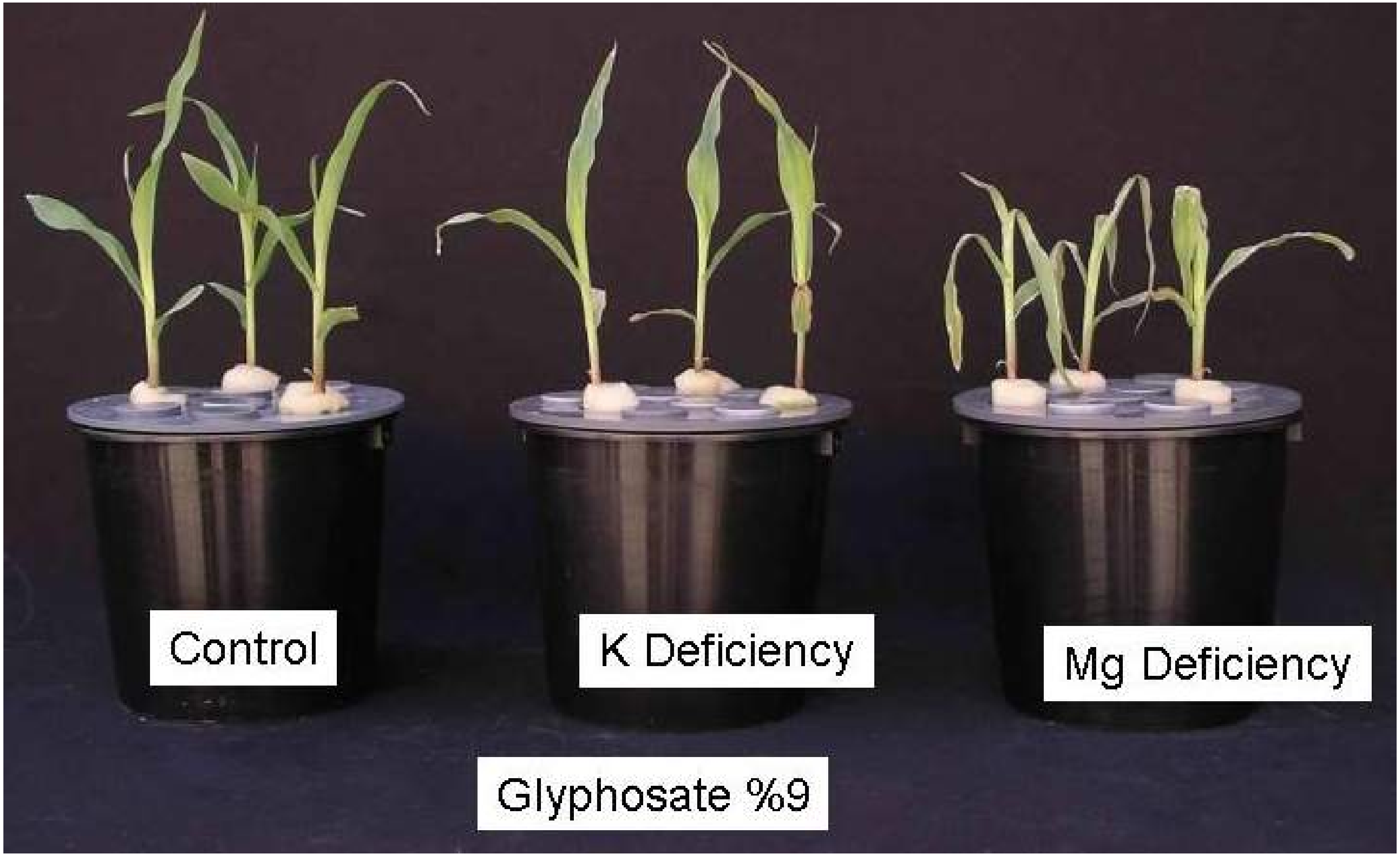
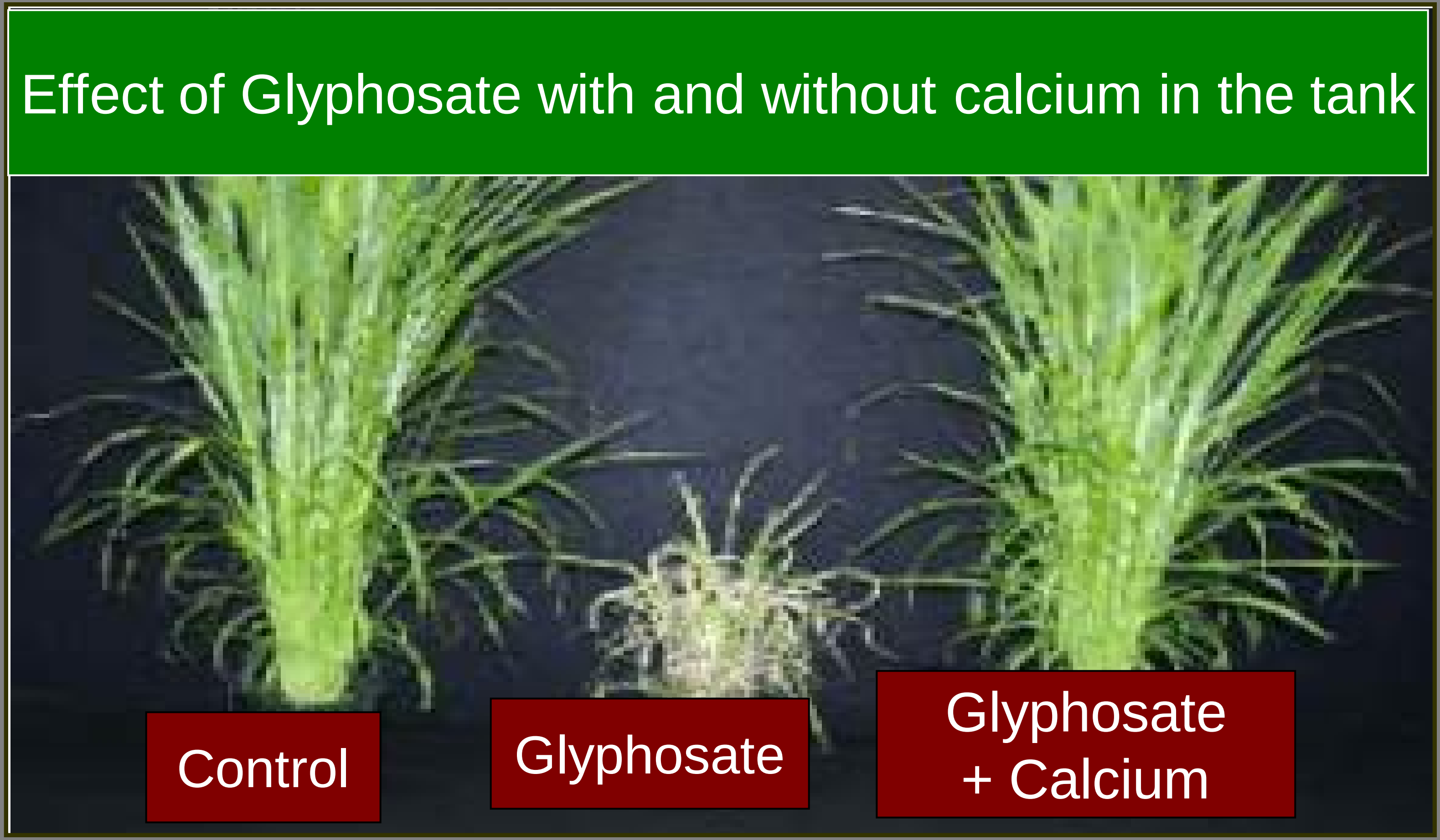


Hande et al., 2008

What is the effect of Glyphosate??

Effectiveness of Glyphosate



Glyphosate binds with the cations to form a strong complex which is not bio-available. Only unbound glyphosate act as a herbicide.

www.loveland.co.uk/ Gifs/X-Change-du-pont.gif

Glyphosate binds with the cations to form a strong complex which is not bio-available.

Only unbound glyphosate act as a herbicide.

Conclusions

- Routine glyphosate use in agricultural systems results in considerable side effects on plant growth and mineral nutrition of plants

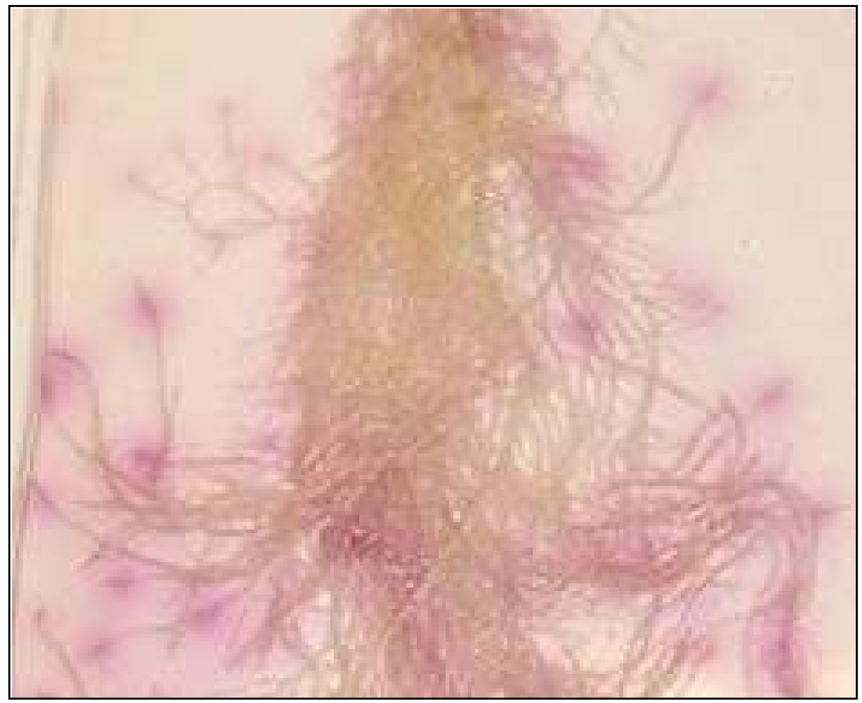
- Glyphosate is antagonistic to the uptake, transport and accumulation (tissue concentration) of Fe,Mn, Ca and Mg possibly due to the <u>formation of poorly soluble glyphosate-metal complexes (??)</u>

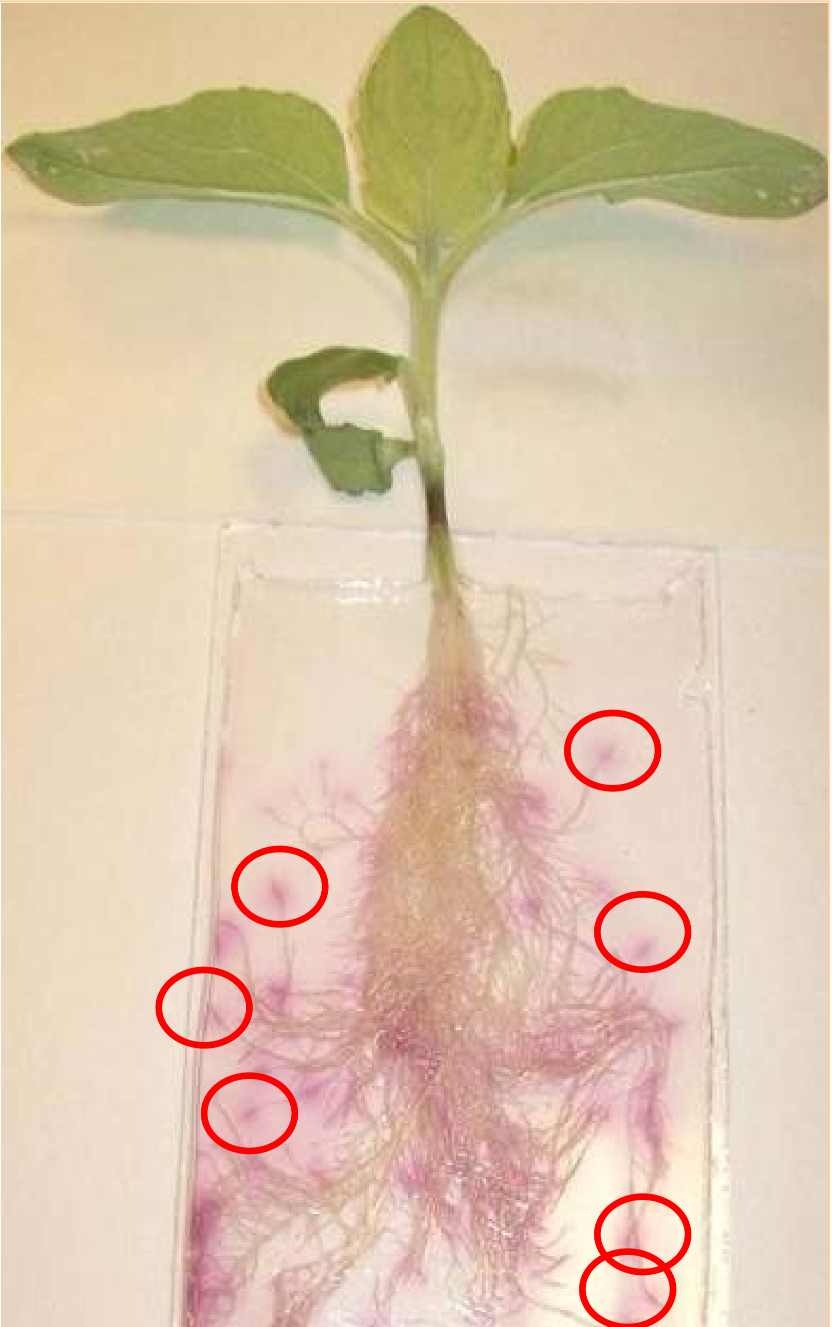
Conclusions-cont

- Glyphosate impairs genetic adaptation mechanisms of plants to Fe deficiency

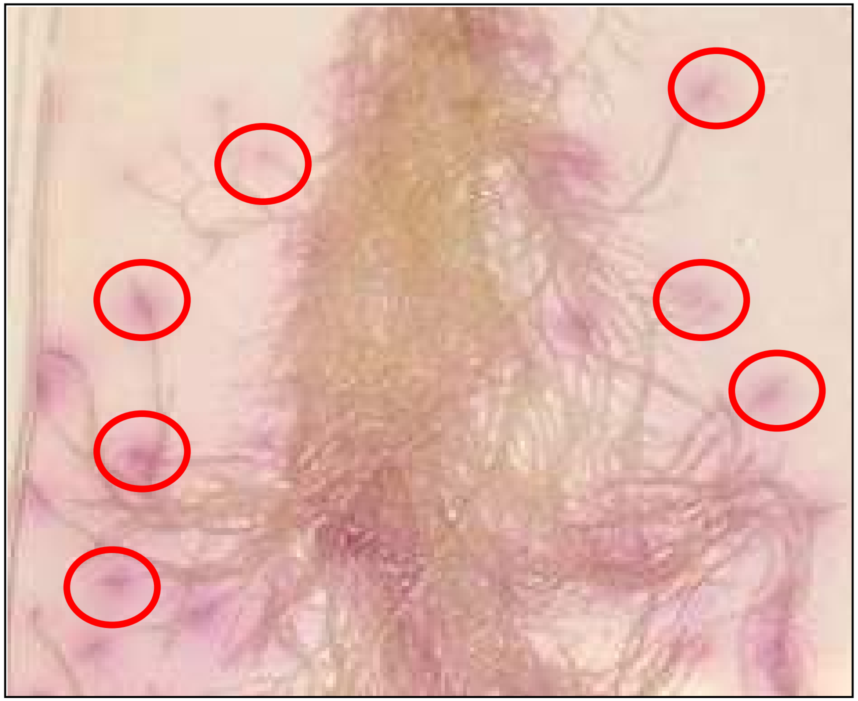
- Plants grown under low Mg are very sensitive to glyphosate

- A new risk assessment for glyphosate is urgently needed,



Root Tips:
Co-localization of Ferric Reductase and Glyphosate Accumulation



Leading 10 Health Risk Factors in Developing Countries, % Cause of Disease Burden

WHO, 2002

Underweight	14.9%
Unsafe sex	10.2%
Unsafe water	5.5%
Indoor smoke	3.7%
Zinc Deficiency	**3.2%**
Iron deficiency	**3.1%**
Vitamin A def.	3.0%
Blood pressure	2.5%
Tobacco	2.0%
Cholesterol	1.9%

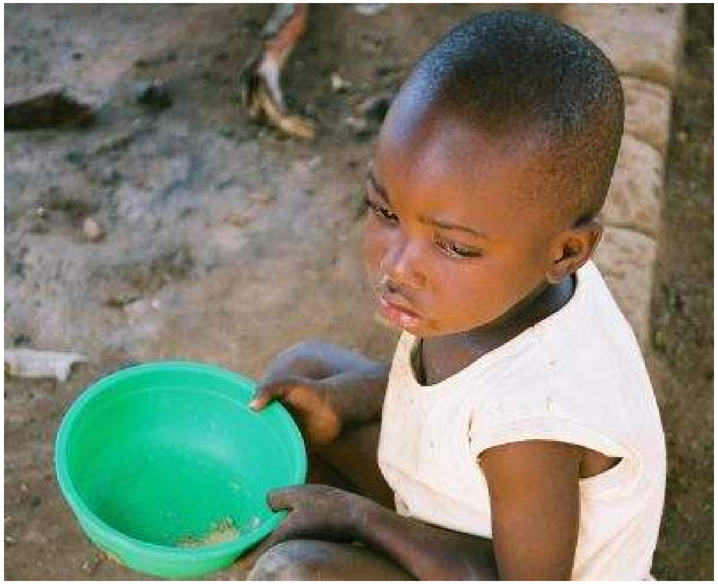
Copenhagen Consensus-2004

Worldwide Panel of Distinguished Economists
including Nobel Prize-Winners

Top Four Global Challenges

- Control of HIV/AIDS
- **Providing micronutrients (Fe, Zn..) to human populations**
- Trade Liberalization
- Control of Malaria

Source:: http://www.copenhagenconsensus.com)



Interference of glyphosate with root uptake and transport of micronutrients may also represent a potential threat to human nutrition and human health

Sabancı Üniversitesi

G. Neumann

L. Ozturk
Sabanci University

M.Atilla YAZICI
B. Hande CANDAN

T. Tesfamariam
Fanghua Ye
C. Weishaar

K. Stock-de Oliveira Souza
E. Landsberg
S. Kohls
University Hohenheim (U.H.)

(S. Bott: Uni.Hohenheim)

V. Römheld T. Yamada I. Cakmak

Obrigado…

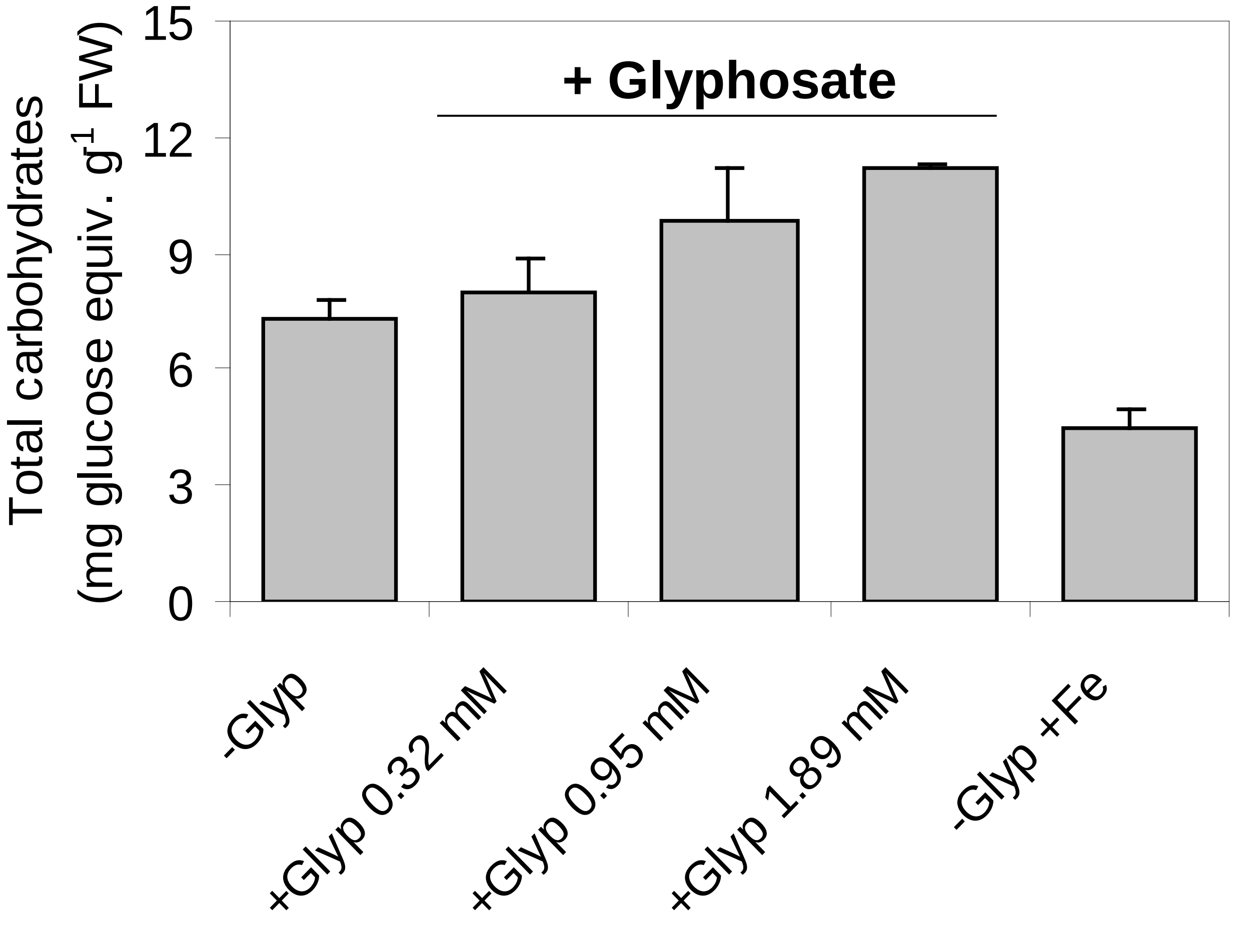
Sabanci University

Shoot and root dry matter production and chlorophyll level as influenced from glyphosate application for 24 h

Treatments		Dry matter production Shoot	Root	Chloropyll
		(mg plant^{-1})		(SPAD)
-Fe	-Glyp.	208 ± 16	58 ± 8	21.2 ± 1.0
	+Glyp. 0.32 mM	202 ± 16	55 ± 8	21.3 ± 0.7
	+Glyp. 0.95 mM	208 ± 15	56 ± 11	21.7 ± 1.4
	+Glyp. 1.89 mM	194 ± 23	53 ± 9	21.8 ± 2.3
+Fe	-Glyp.	226 ± 30	61 ± 13	39.2 ± 1.9
$LSD_{0.05}$		24	12	2.3

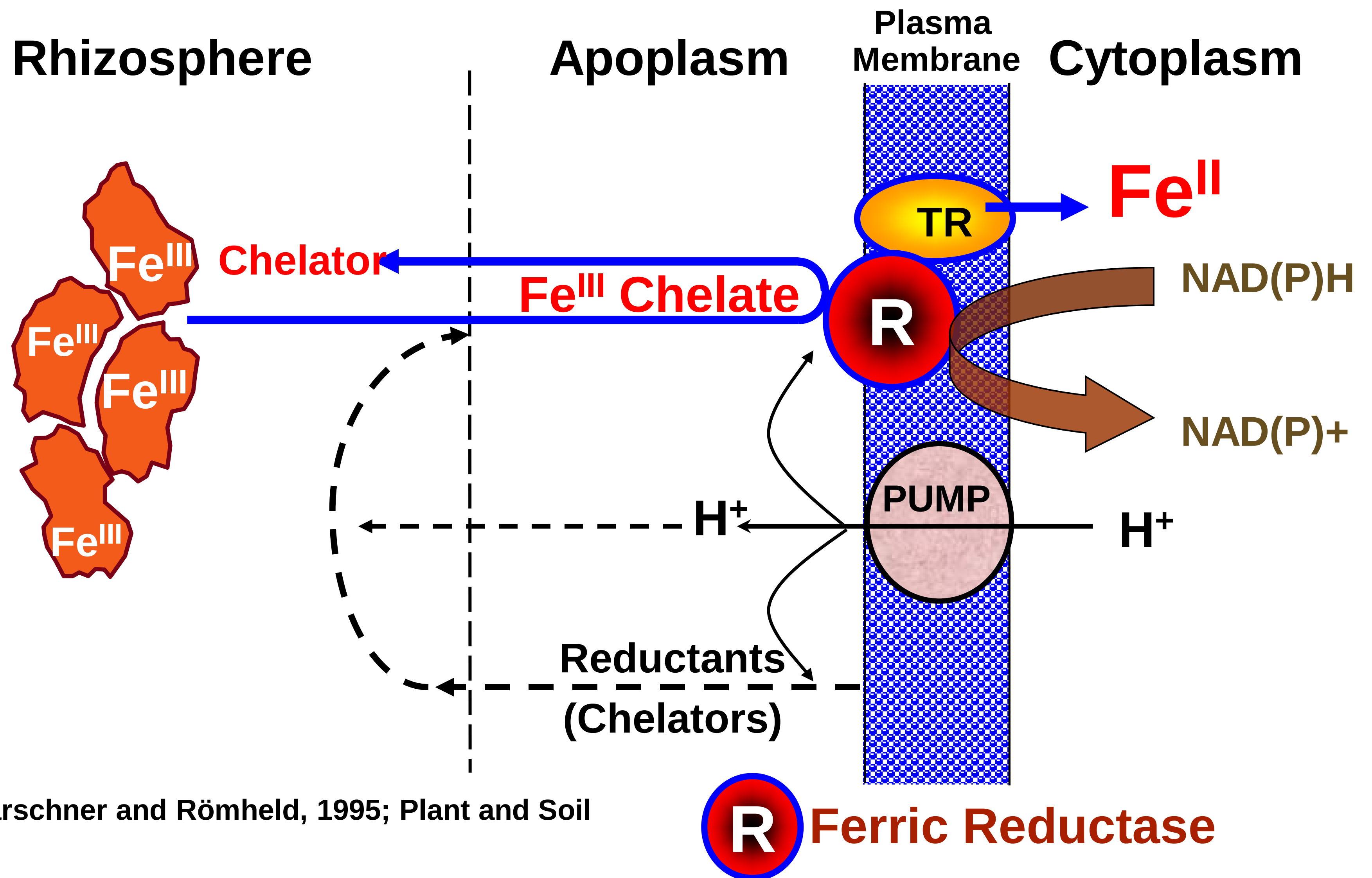
Ozturk et al., 2007

Carbohydrates in Apical Parts of Roots



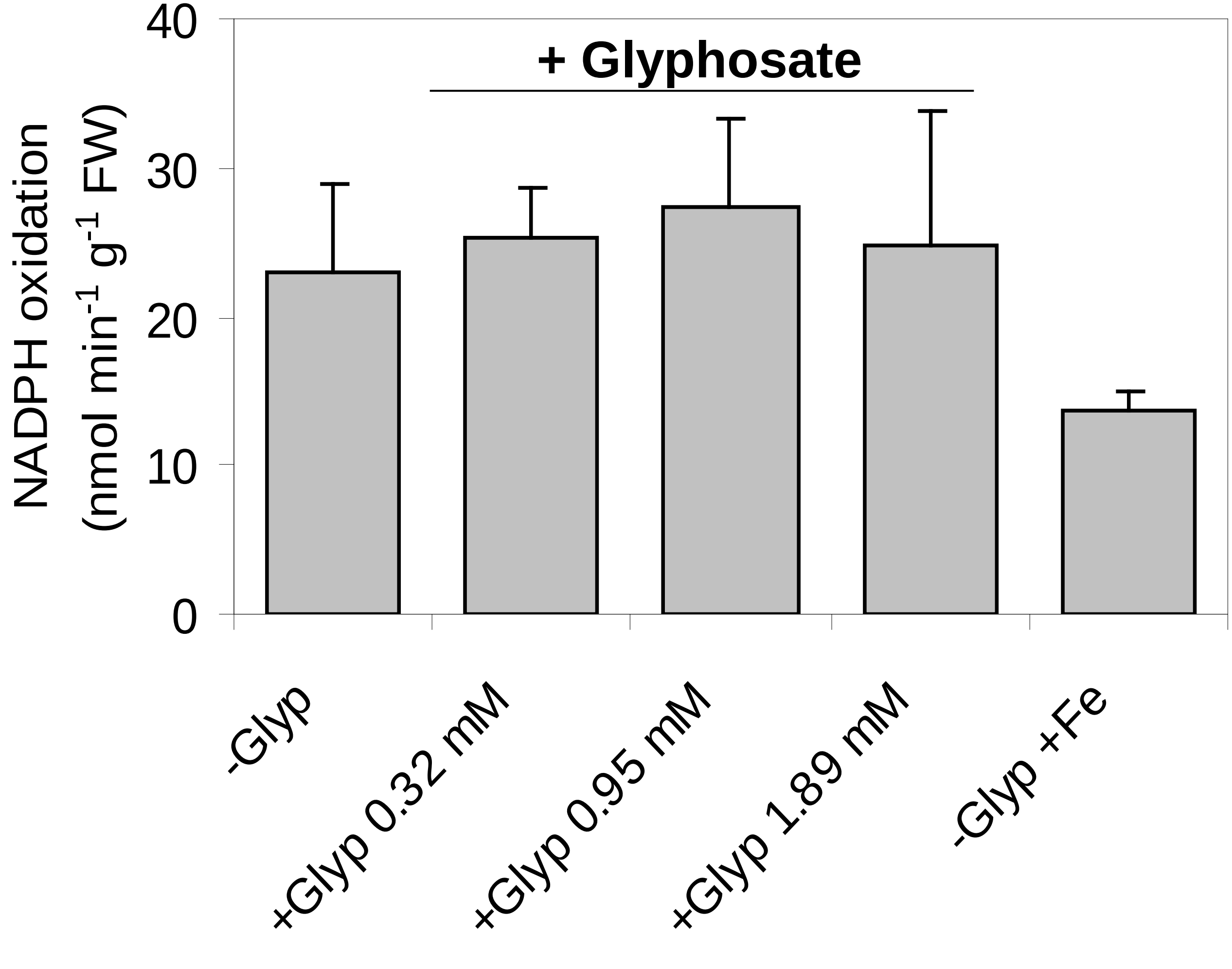
Ozturk et al., 2007

Root Responses to Fe Deficiency in Strategy-I Plants



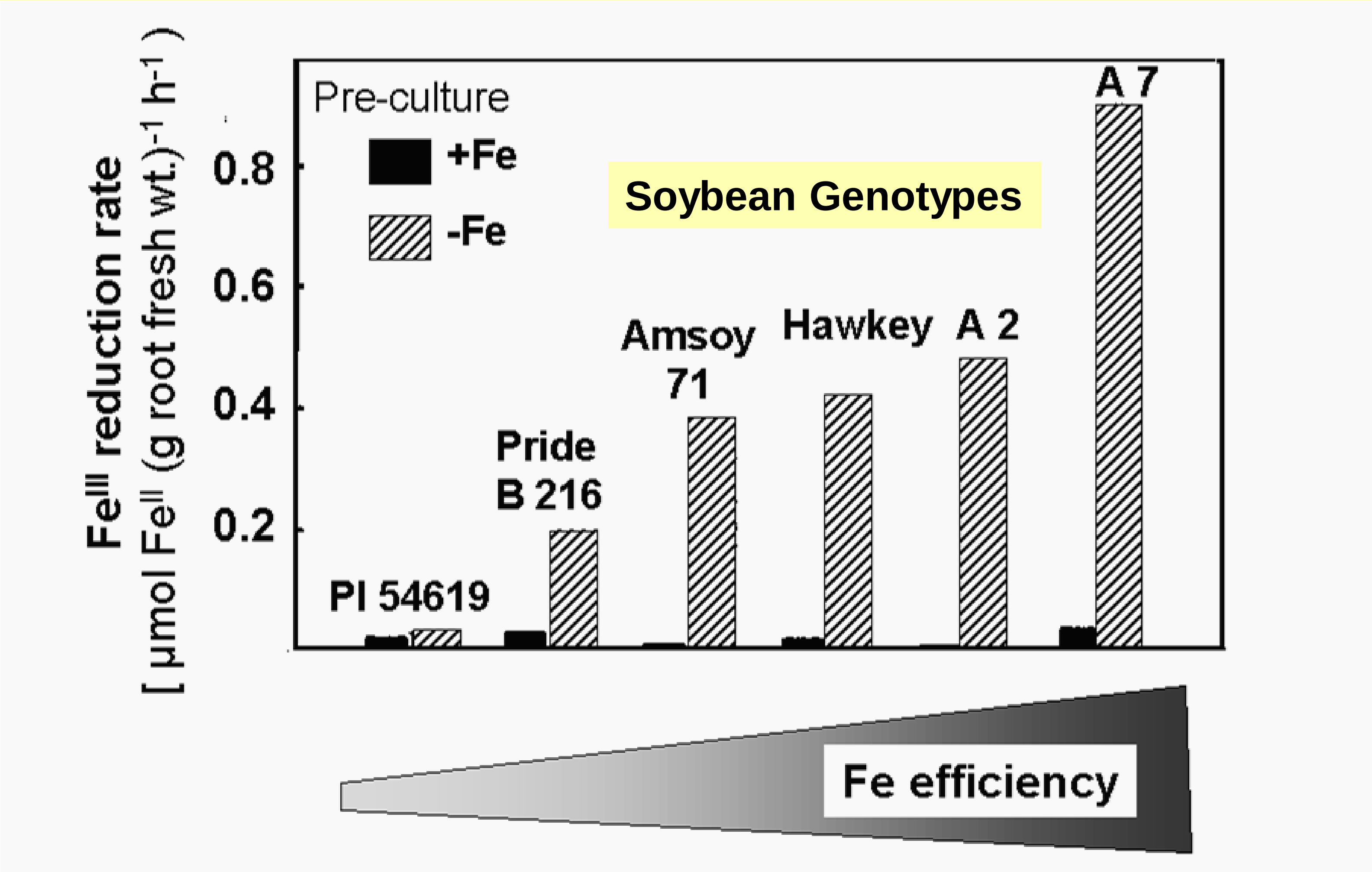
Marschner and Römheld, 1995; Plant and Soil

Capacity of Roots to Oxidize NADPH



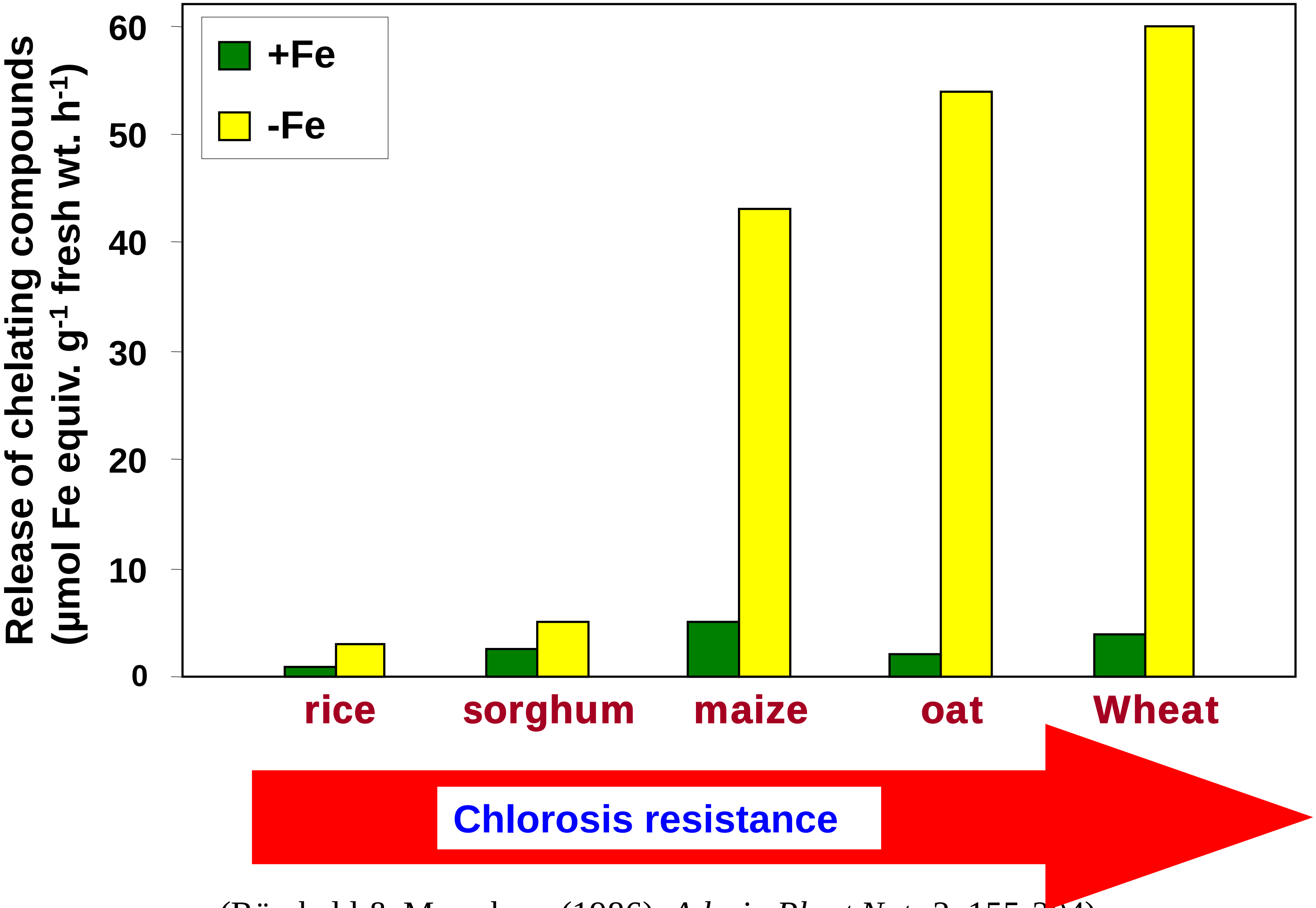
Ozturk et al., 2007

Close Relationship between Fe Deficiency Tolerance and Ferric Reductase Activity in Soybean



Marschner and Romheld, 1995

Release of Phytosiderophores from Roots Correlate with Tolerance Fe Deficiency Chlorosis



(Römheld & Marschner (1986): *Adv. in Plant Nutr* 2, 155-204)