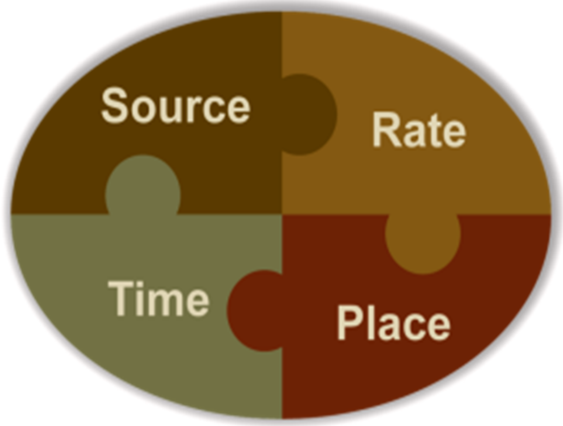
The influence of Magnesium and its various chemical forms on the nutrient uptake of plants

Andreas Gransee

Nutrients to consider and their application

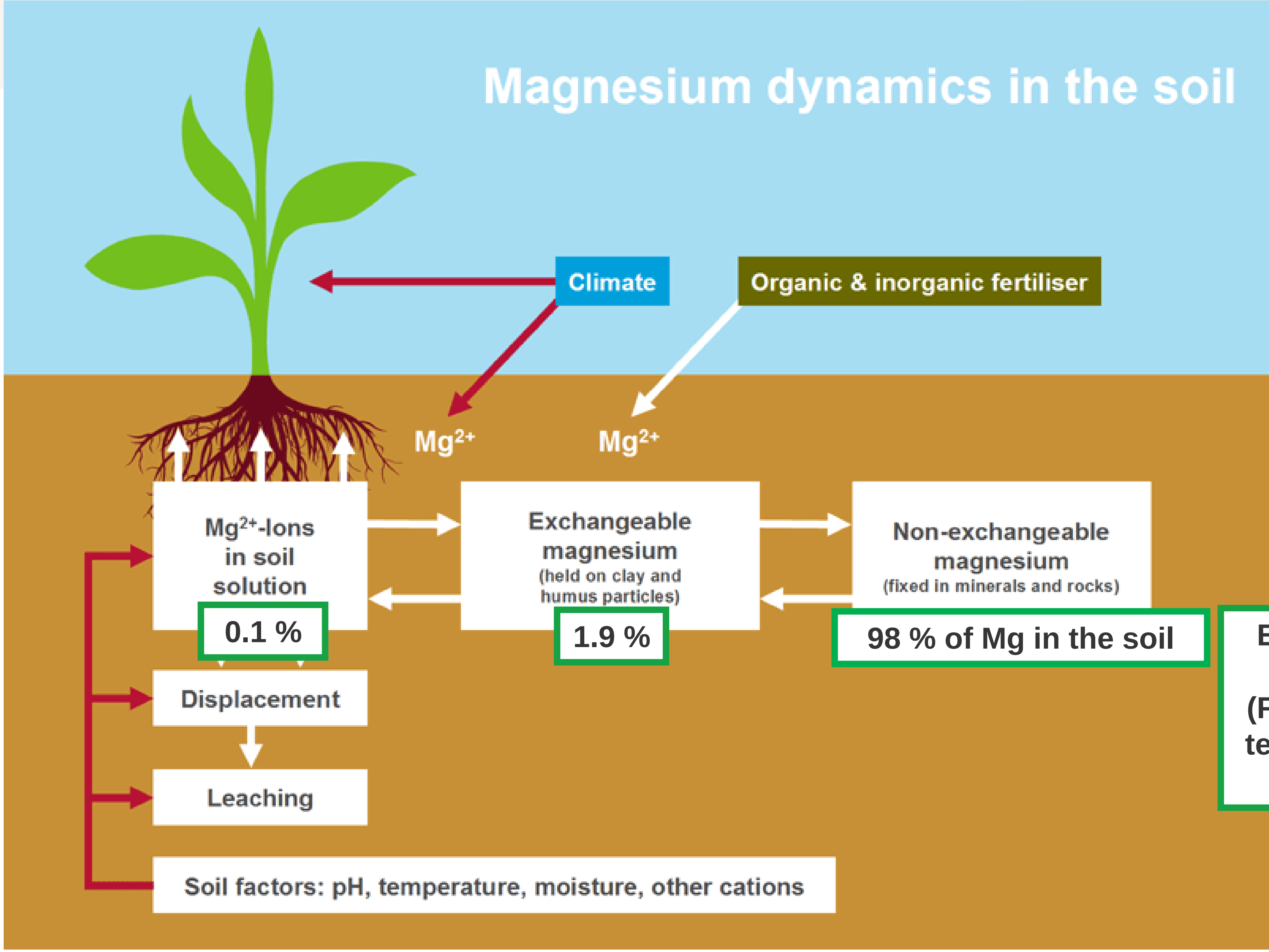
- In total 14 nutrients have been identified to be essential for plant growth
  → N, P, K, Mg, Ca, S, Fe, Mn, Cu, Zn, Mo, Ni, B, Cl

- Fertiliser *management* 4R principle (IPNI):
  - **R**ight rates,
  - **R**ight source,
  - **R**ight placement,
  - **R**ight timing



- Nutrient interactions (e.g. N x S, K x Mg, N x K, Mg x Ca)

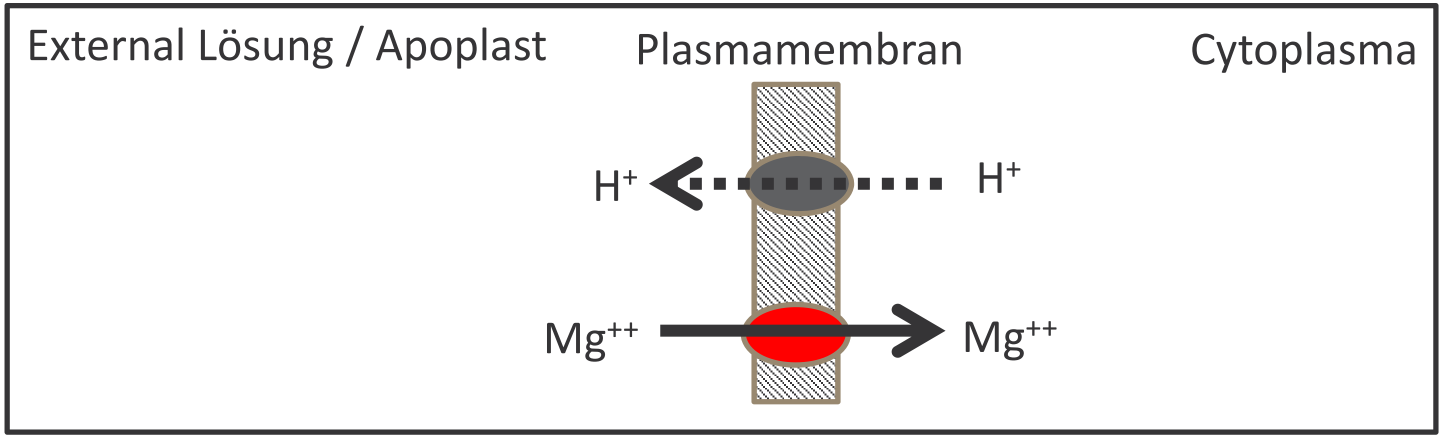
Magnesium Fractions



Estimations by Arvalis (French national tecnical institute of cereals)

Magnesium uptake by plants

- **Uptake in the actual sense means uptake into the plant cell, hence transport across the plasma membrane**
- **External concentration of Mg higher than within the cells, therefore**
- **Uptake along an electrochemical gradient**
- **H^+-ATPasen pump H^+ out of the cell and thereby create an electrical and chemical gradient**



Mg Mobility in Soils

- Hydrated radius of Mg
- Mass flow
- Leaching
- Cation Exchange Capacity (CEC)
- pH-value
- **Antagonisms**

Depending on soil type and pedogenesis

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MAGNESIUM INTERACTION/ ANTAGONISM

Nutrients in the plant
Synergism and antagonism of nutrients

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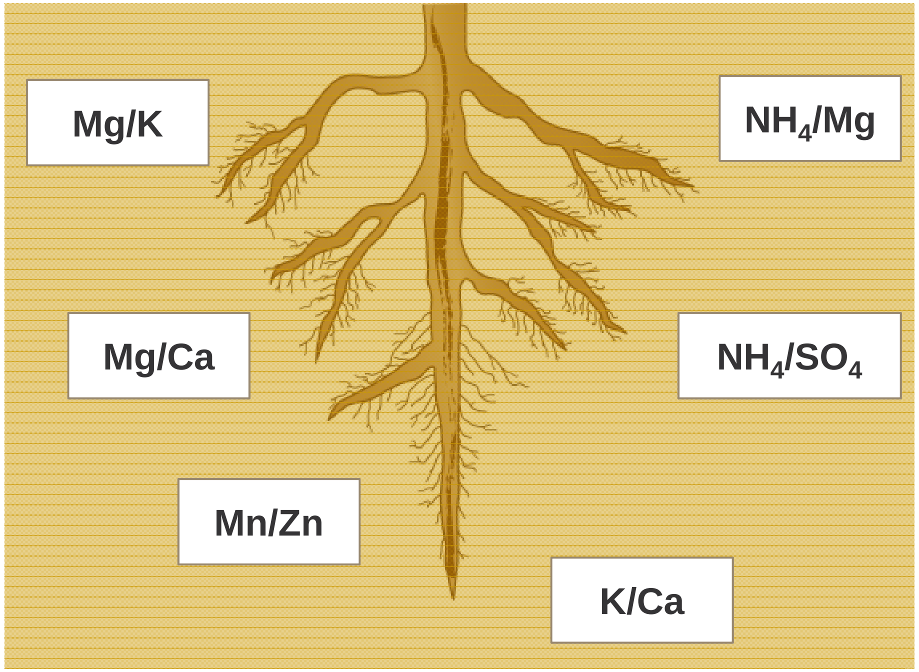
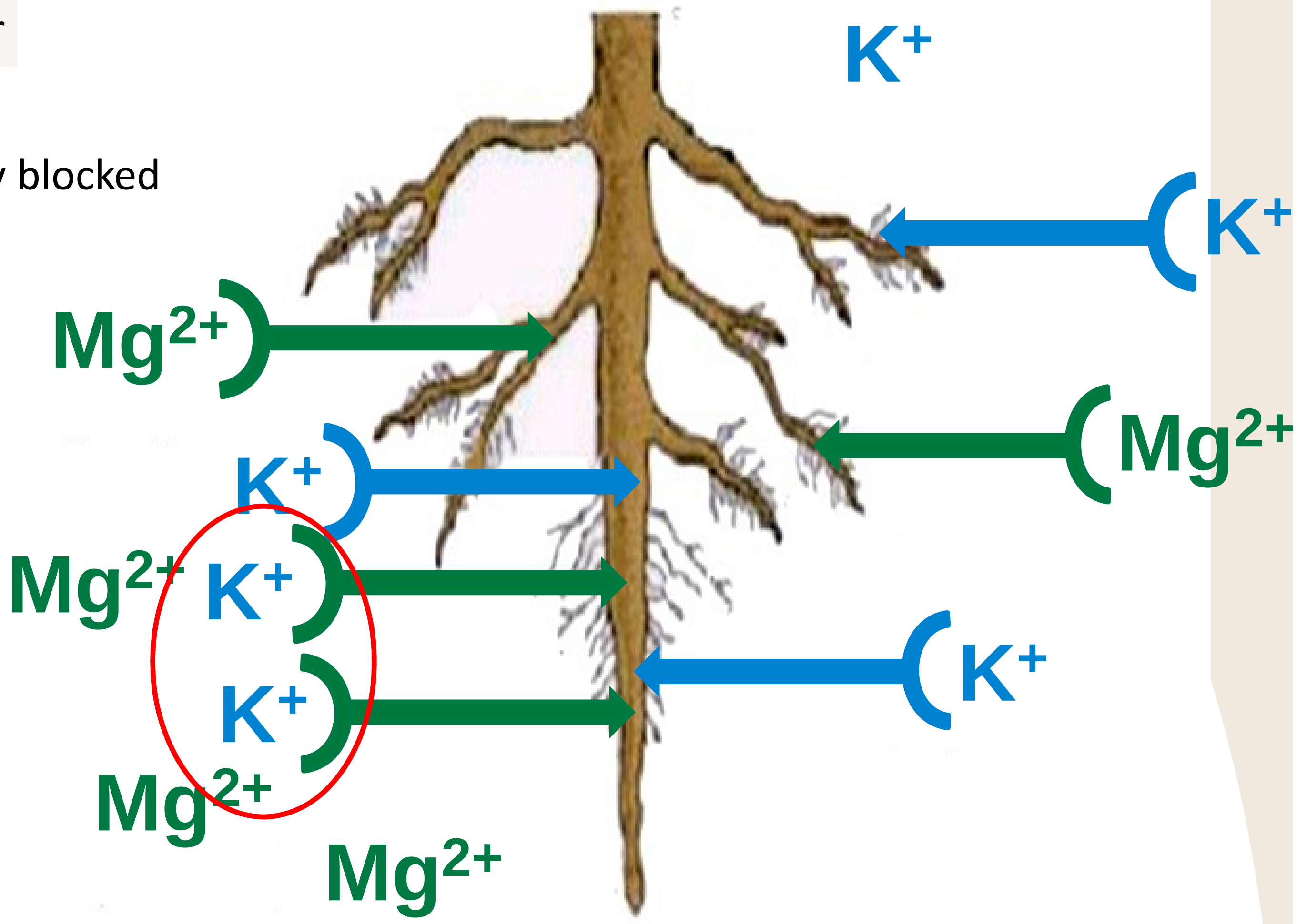


Nutrient	Inhibition	Support
NO_3	P	Ca, Mg, K
NH_4	Ca, Mg, K	P, SO_4
K	Ca, Mg, NH_4	NO_3
Mg	Ca, K, NH_4	NO_3
Na	Ca	
Cl	NO_3	Ca
Fe	Mn	

Antagonism: K reduces Magnesium uptake…

Mg^{2+} uptake via
unspecific transporter

→ these are increasingly blocked by high K supply

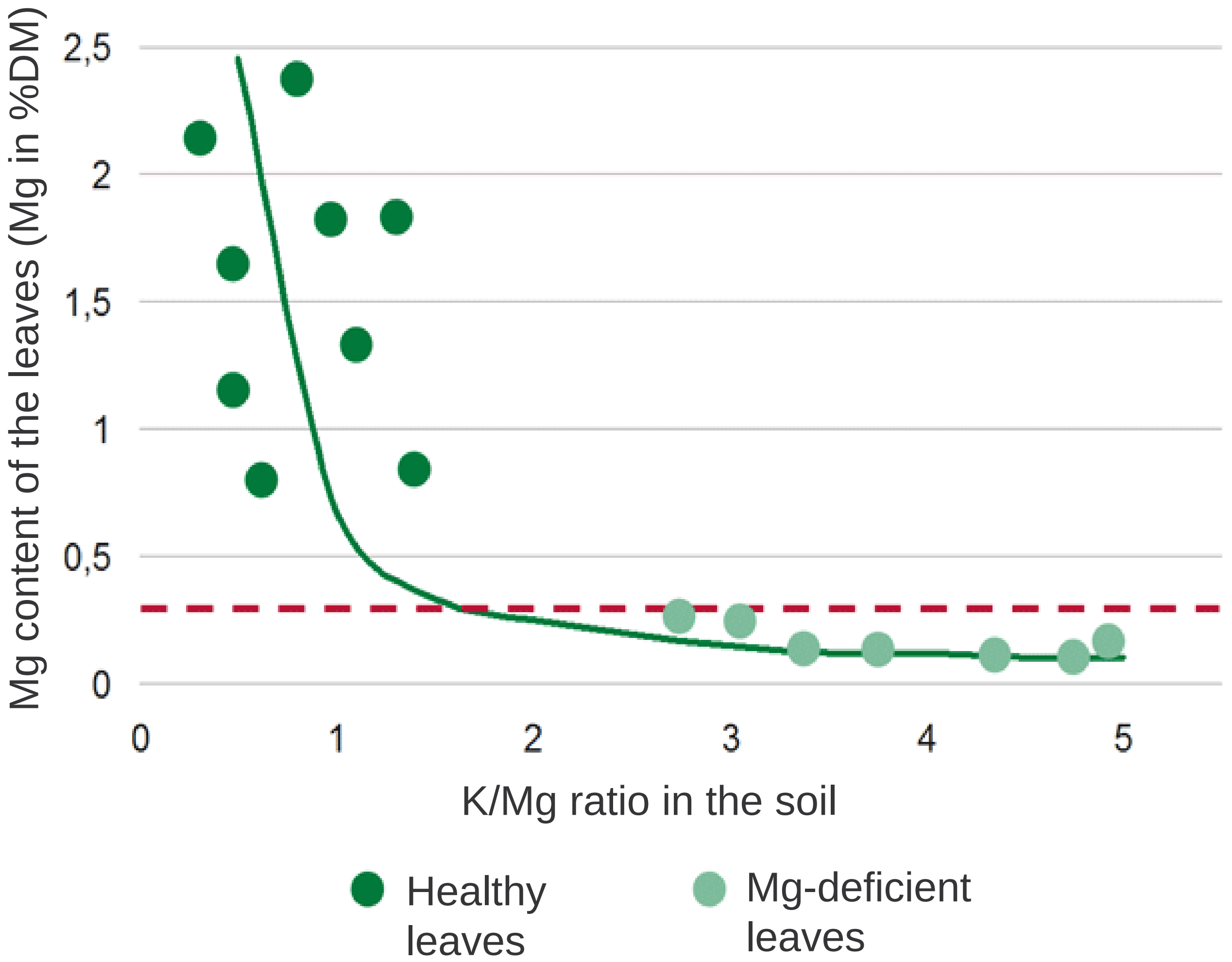


K uptake
via **specific**

K transporter

K delivery via diffusion
Mg delivery via mass flow

Potassium and Magnesium Need to Be in Balance Antagonism K-Mg



Quelle: Nach W. ZORN, TLL Jena, 2005.

Effect of an increased Mg-application on the uptake of K and Ca

Mg concentration in nutrient solution (mg Mg/L)	Shoot (g TM)	Content in plant		
		Mg	K	Ca
		% in plant dry mass		
1.5	5,39	0,09	3,50	1,74
3	6,25	0,12	3,38	1,80
6	5,35	0,16	3,41	1,72
12	5,37	0,21	3,42	1,54
60	6,11	0,47	3,24	1,24
120	7,87	0,63	3,44	0,88
240	4,42	0,77	3,44	0,59

(Daten verändert nach Seggewiss, 1986)

Effect of an increased Mg-application on the uptake of K and Ca

Ca concentration (mg/L)	Mg uptake rate [µg (g root dm* h)$^{-1}$]	K uptake rate [µg (g root dm * h)$^{-1}$]
0,25	3,80	24,49
0,5	5,06	36,09
2	25,70	150,67
3	52,59	226,56
5	57,41	400
10	62,49	433,42
20	46,46	355,25
30	30,76	336
R^2	0,66*	0,77*

(Daten aus Fageria 2009, adaptiert von Fageria 1973)

MAGNESIUM ENHANCES NUTRIENT UTILISATION

NITROGEN

Mg Fertilisation Enhances Nutrient Utilisation Efficiency in sugar beets

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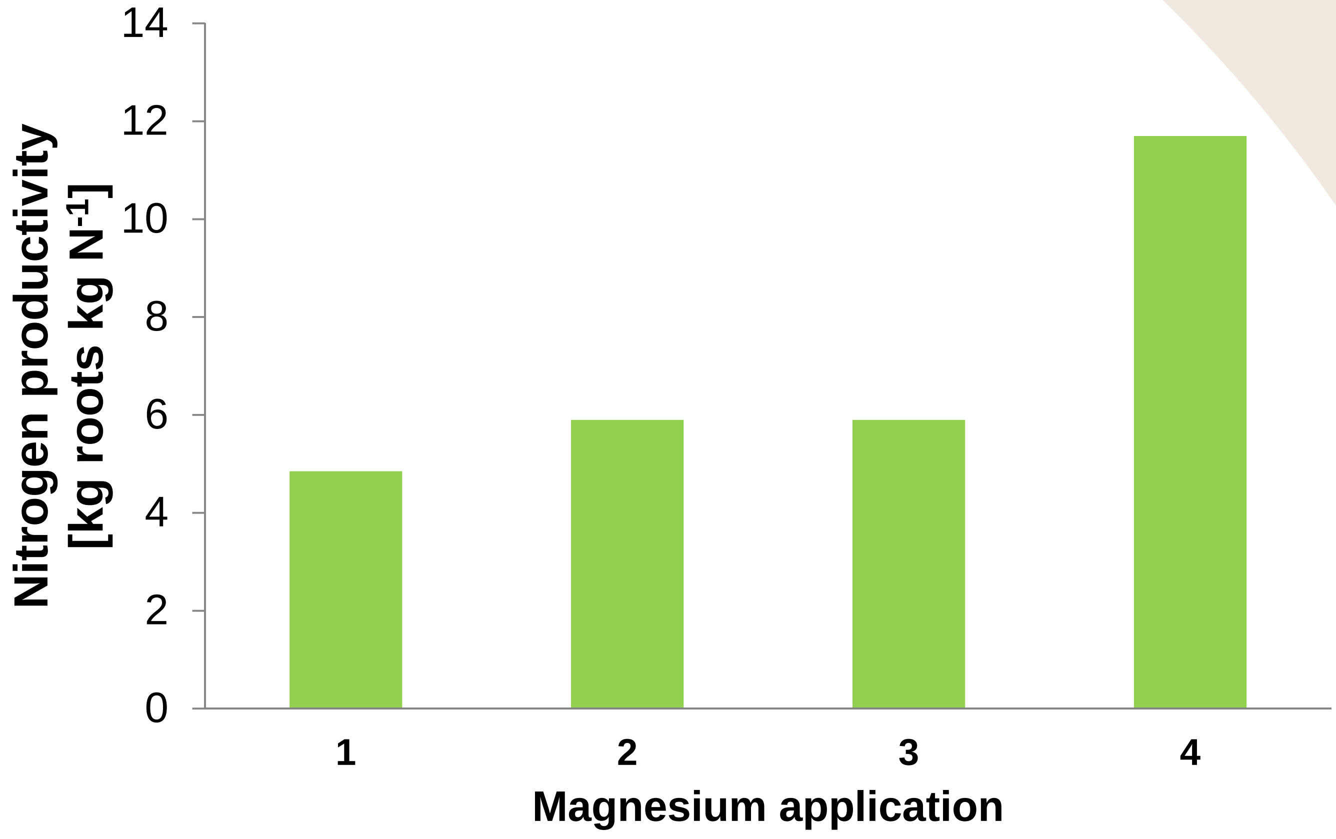
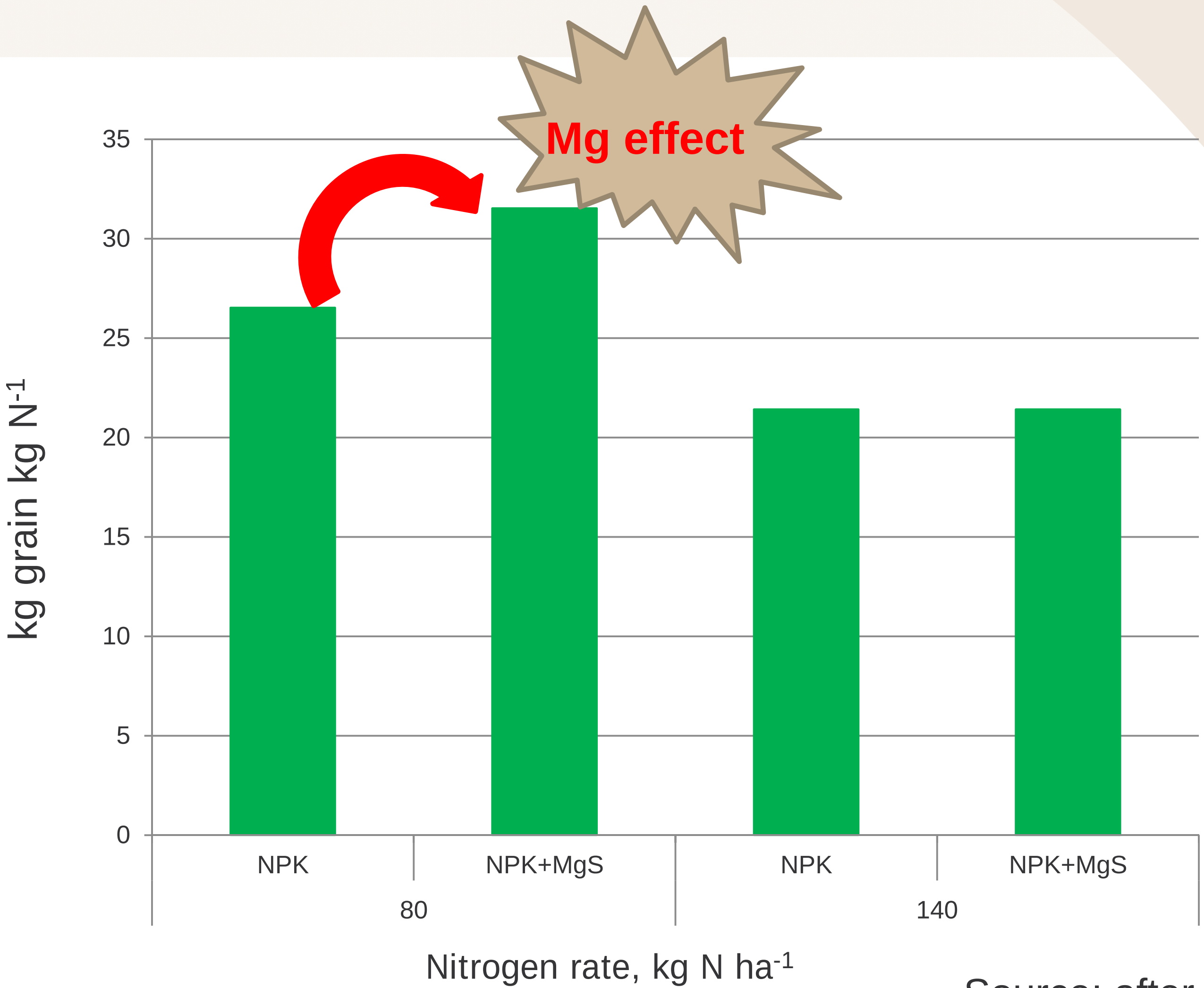


Modified after Grzebisz et al., 2010

Effect of magnesium on the background of nitrogen rates on nitrogen use efficiency in maize



Source: after Potarzycki, 2010

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ZINC

Interaction of Mg and Zn
Two nutrients to be managed together

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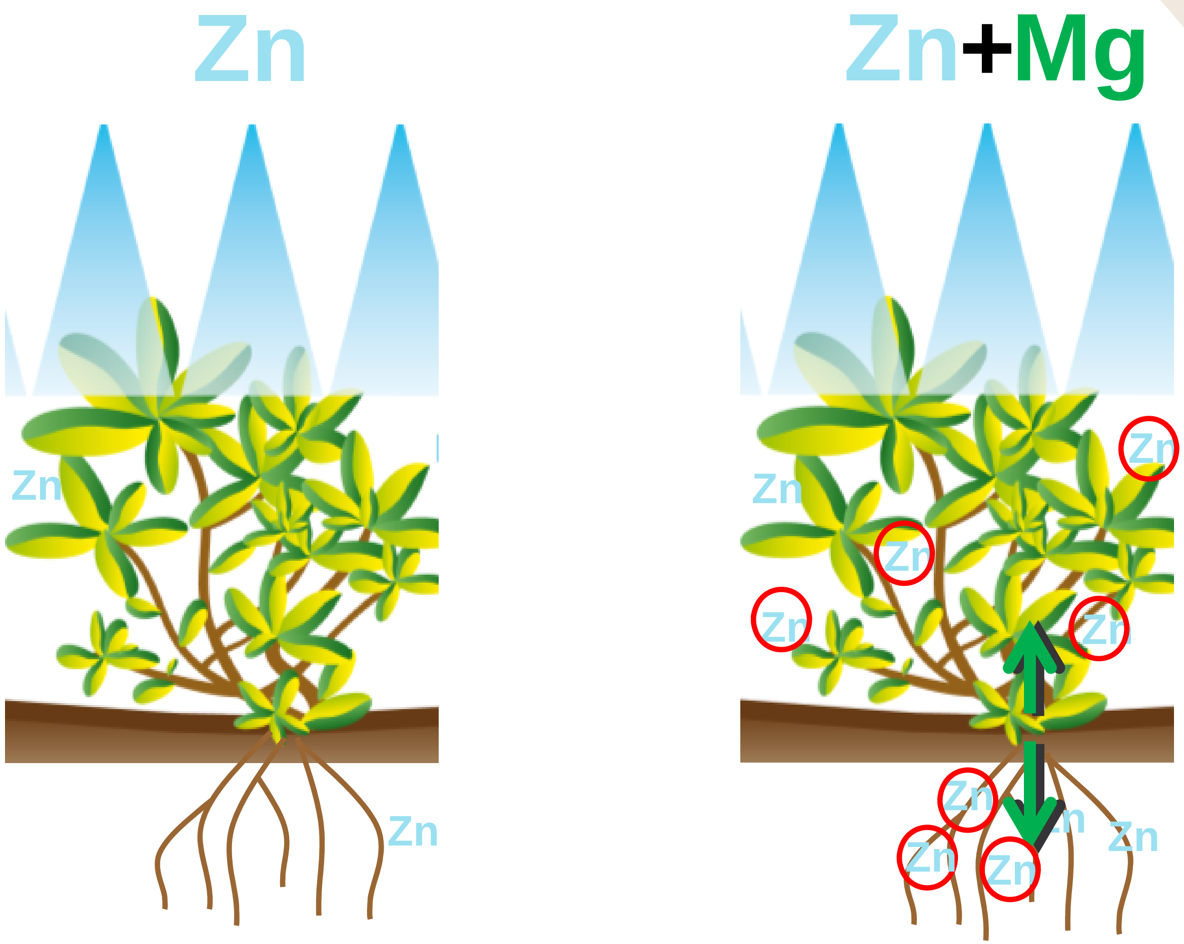
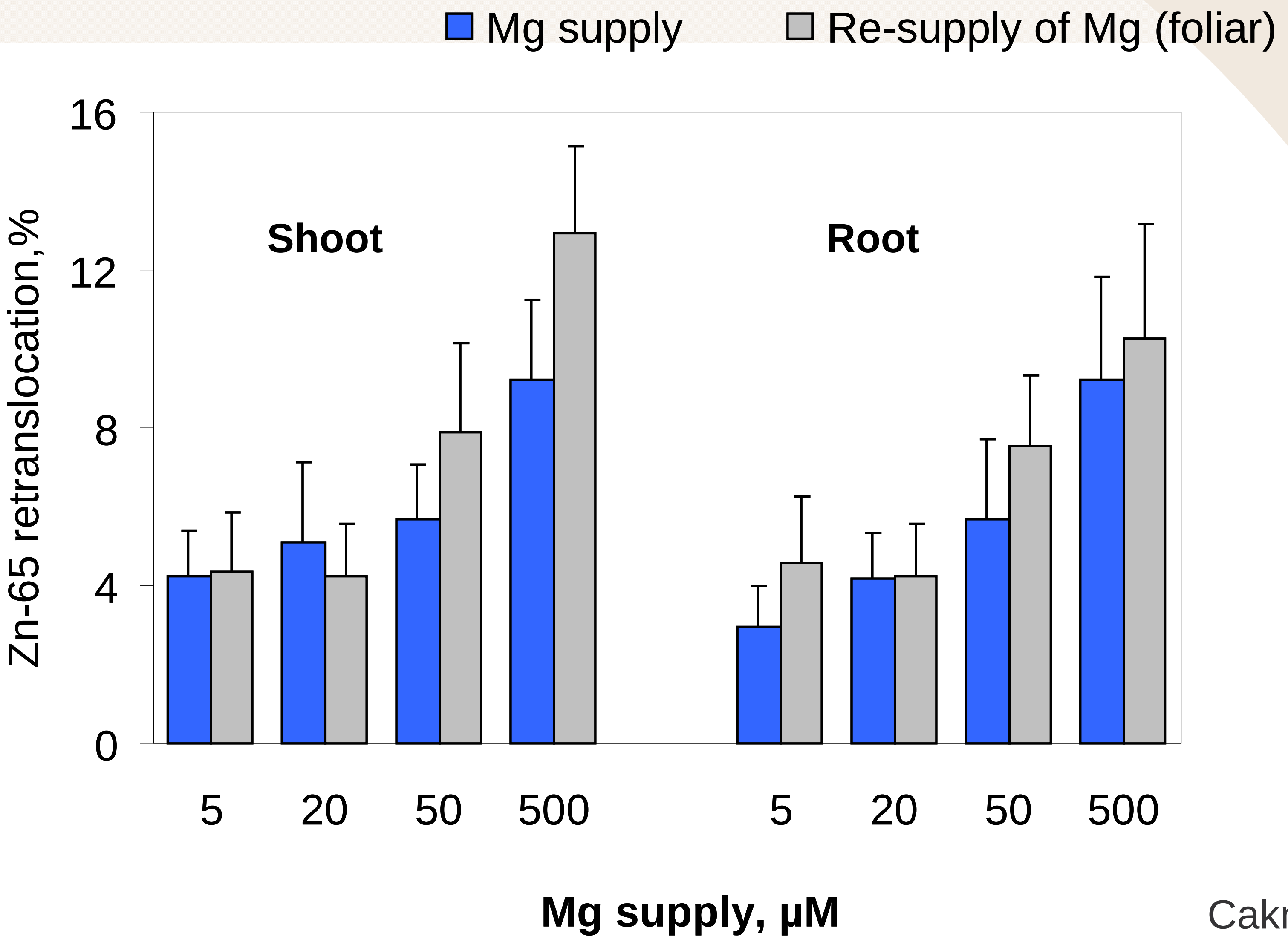
Foliar Application of Zinc

Foliar Application of Zinc and Magnesium



Research results from Ozturk, Sabanci University

Interaction of Mg and Zn
Two nutrients to be managed together



Cakmak 2013

The effect of Mg + Zinc on grain yield of maize

- Brody, Poland, 2006 - 2008, n = 3 -

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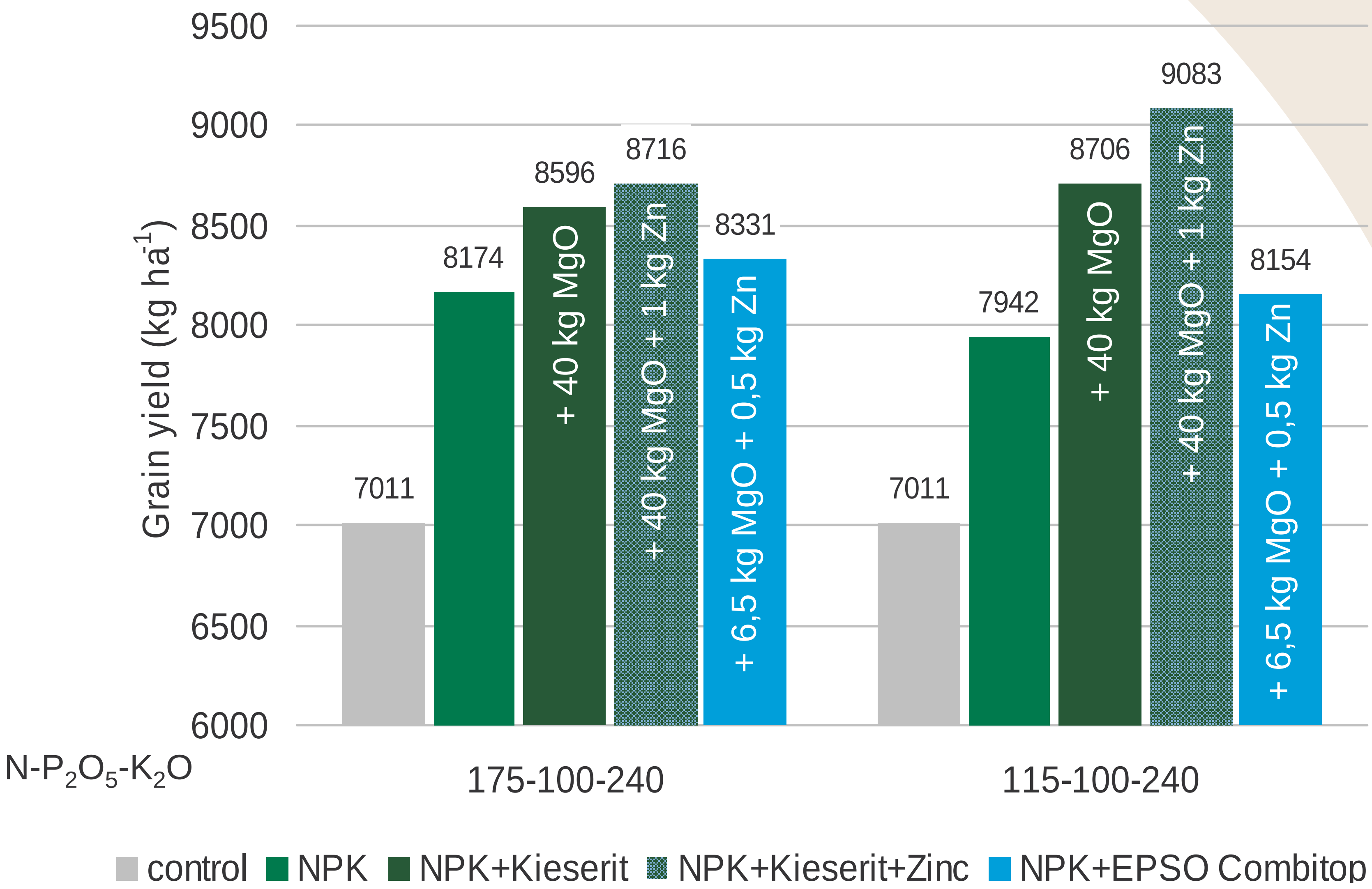

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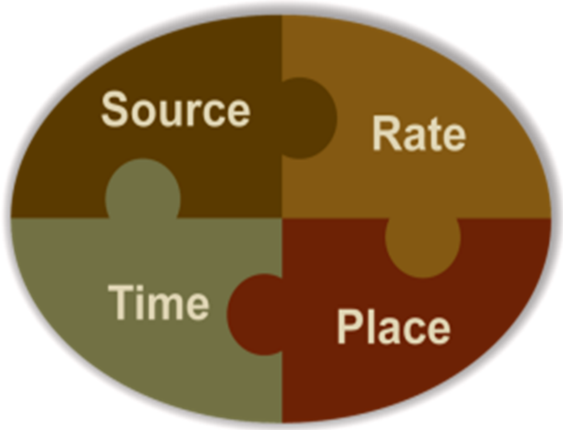

- Nutrient interactions (e.g. N x S, K x Mg, N x K, Mg x Ca)

MAGNESIUM FORMS AND THEIR SOLUBILITY

Forms of magnesium in fertilizers and their solubility in water

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Solubility in water

Mineral	Formula	g/l solution*	
Kieserite	$MgSO_4 \times H_2O$	342	1
Magnesite	$MgCO_3$	0,017	3
Magnesium Oxide	MgO	0,006	1
Dolomite	$CaMg(CO_3)_2$	0,01	4
Magnesium Hydroxide	$Mg(OH)_2$	0,009	2
Struvite	$MgNH_4PO_4 \times 6 H_2O$	0,169	5
Magnesium Chloride	$MgCl_2$	542	1

Remarks

- Magnesium fertilizers vary substantially in their solubility in water

1: Taschenbuch für Chemiker u. Physiker
2: UEIC 2012/Ullmann's Encyclopedia of Industrial Chemistry
3: P. Benezeth et al.: Experimental Determination of the Solubility of Magnesite
4: H.C. Helgeson: Thermodyn amics oh Hydrothermal Systems at Elevated Temperature
5: M. Bhuiyan et al.: A Solubility and Thermodynamic Study of Struvite

Magnesium dynamics in the soil – high soil exchangeable Mg

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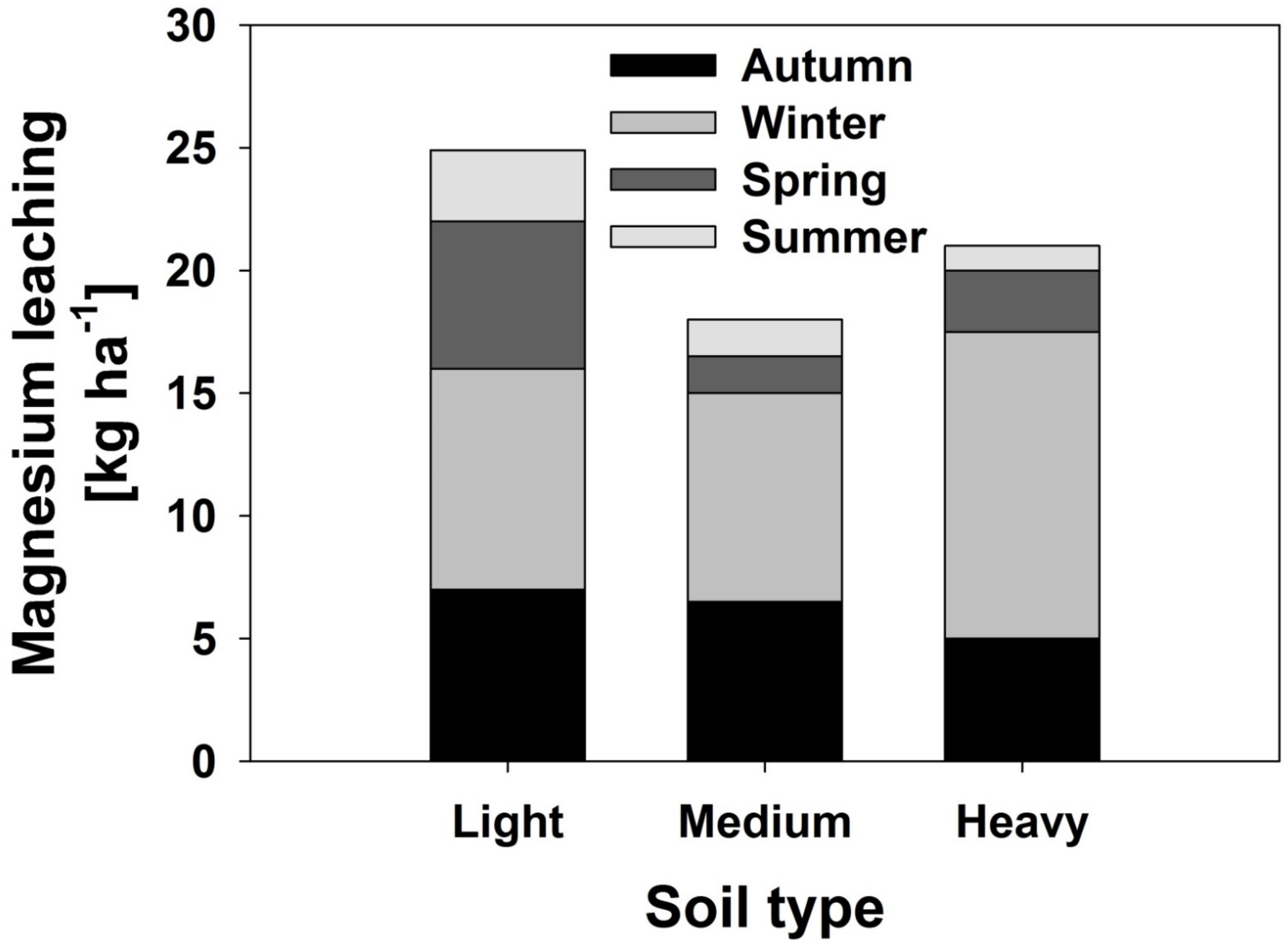
Leaching of Mg can be considerably high due to its comparable high mobility in the soil

Leaching can reach **20-30 kg ha^{-1} a^{-1}** depending on:

- **Amount of drainage water**
- **H^+ concentration (soil pH)**
- **Ca^{2+} concentration (liming)**
- **HCO_3^- concentration (microbial activity)**
- **Cation Exchange Capacity (CEC)**

Soil agronomic class influences magnesium leaching



adapted from Grzebisz, 2011

Soil application of Magnesium

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Soil correctives

- Quantity depending on target parameter (pH)
- Low solubility in water
- Mg content of minor importance
- Availability uncertain
- Distribution heterogeneous

↓

Indirect action

↓

Soil Application

Magnesium containing salts

- Primary focus on magnesium
- High solubility and direct availability
- Homogenous distribution of nutrients

↓

Direct action

↓

Soil Application | Leaf Application/ Hydroponics

Mg is Crucial for Root Growth
Foliar Fertilisation

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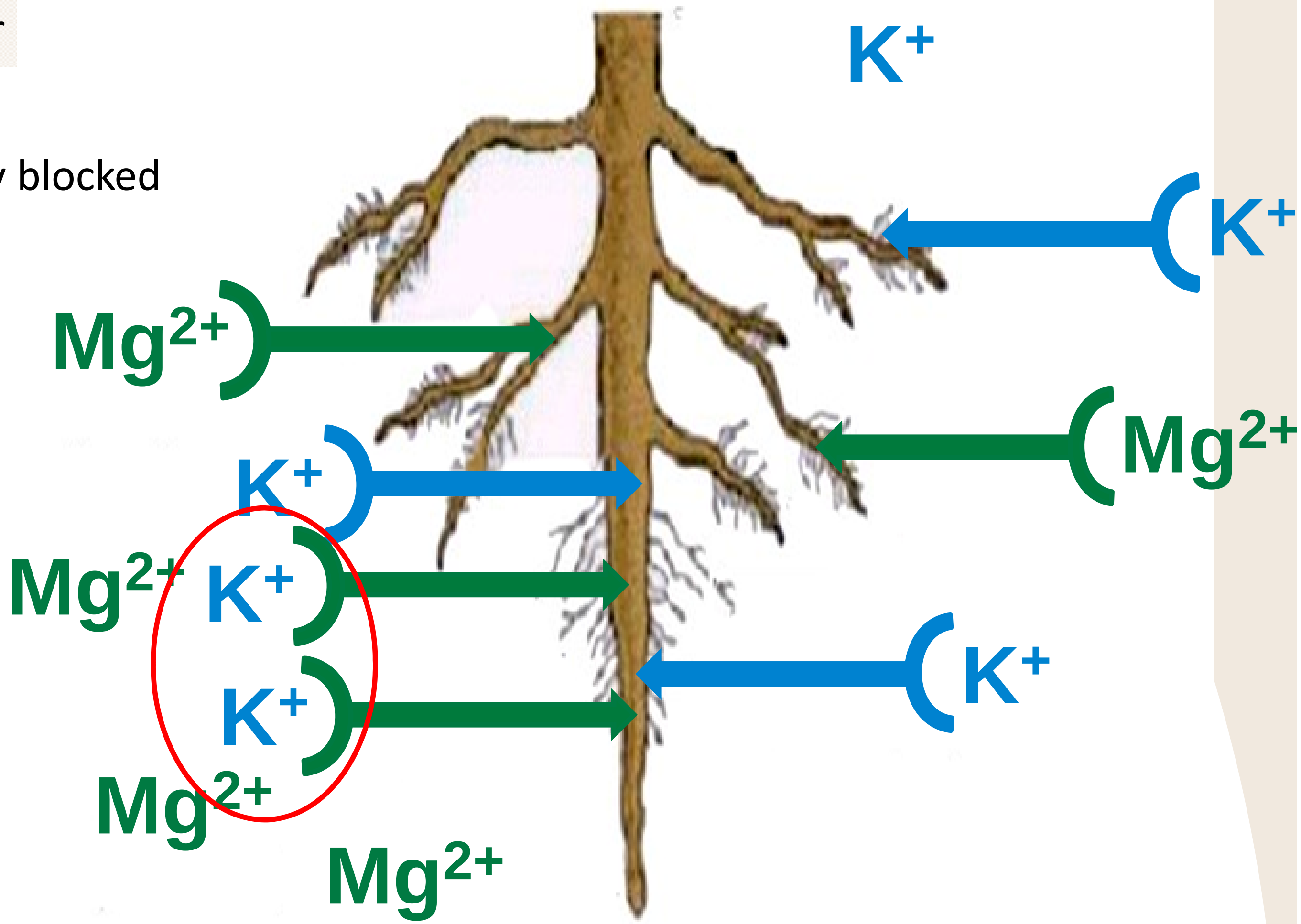
Cakmak

Antagonism: K reduces Magnesium uptake…

Mg^{2+} uptake via **unspecific** transporter

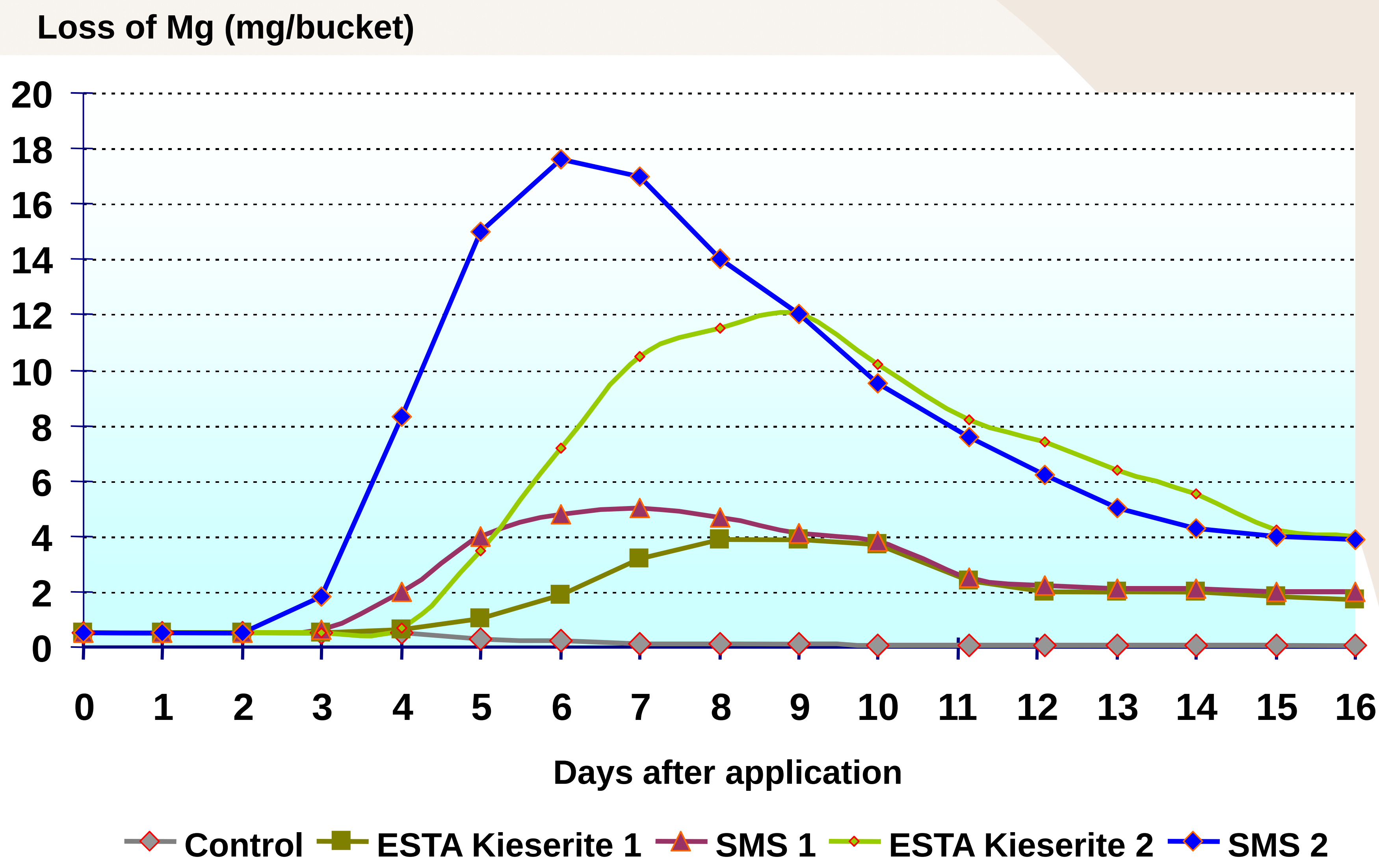
→ these are increasingly blocked by high K supply



K uptake via **specific** K transporter

K delivery via diffusion
Mg delivery via mass flow

Magnesium losses through leaching



source: Härdter et al., 2003

Cumulative loss of magnesium through leaching

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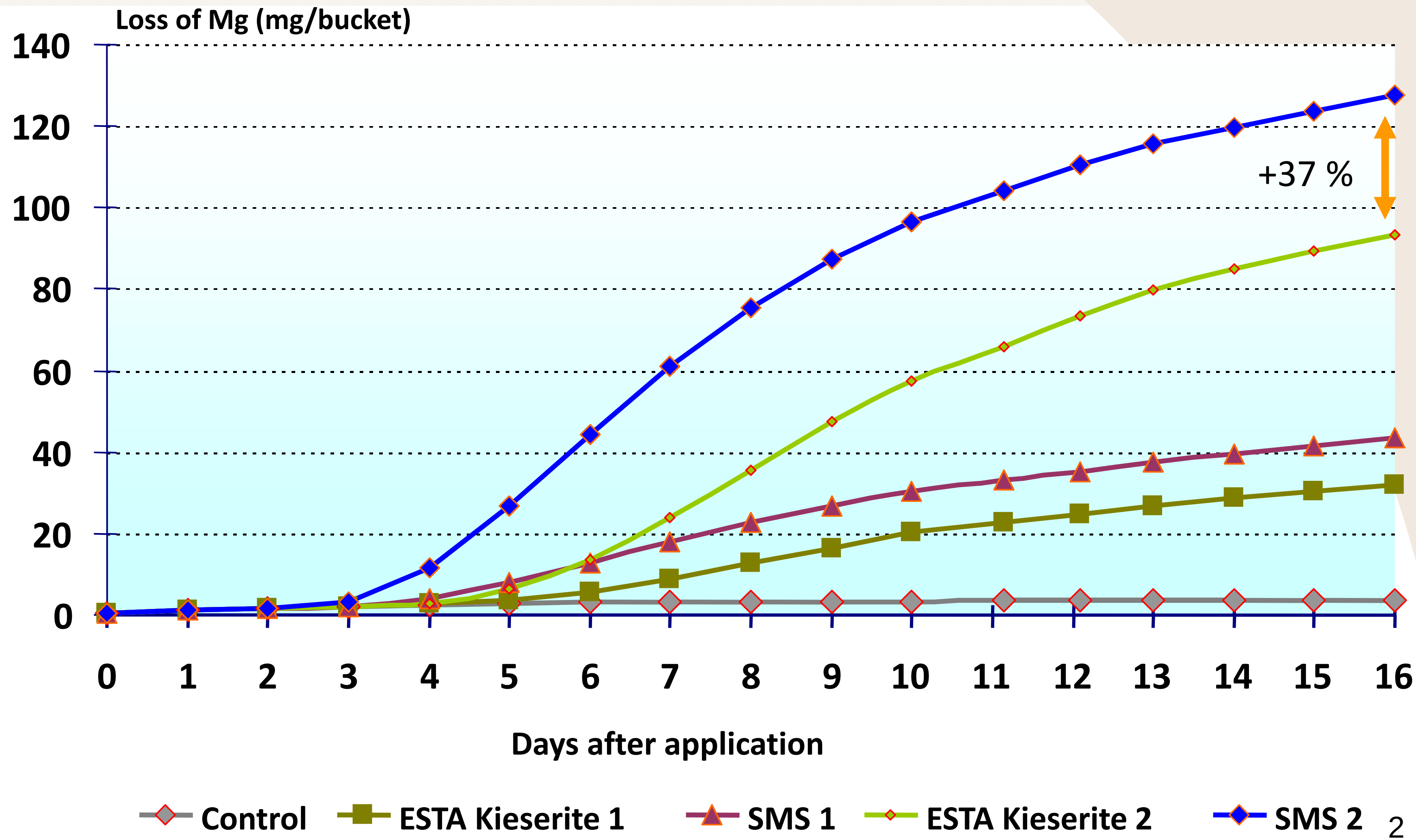
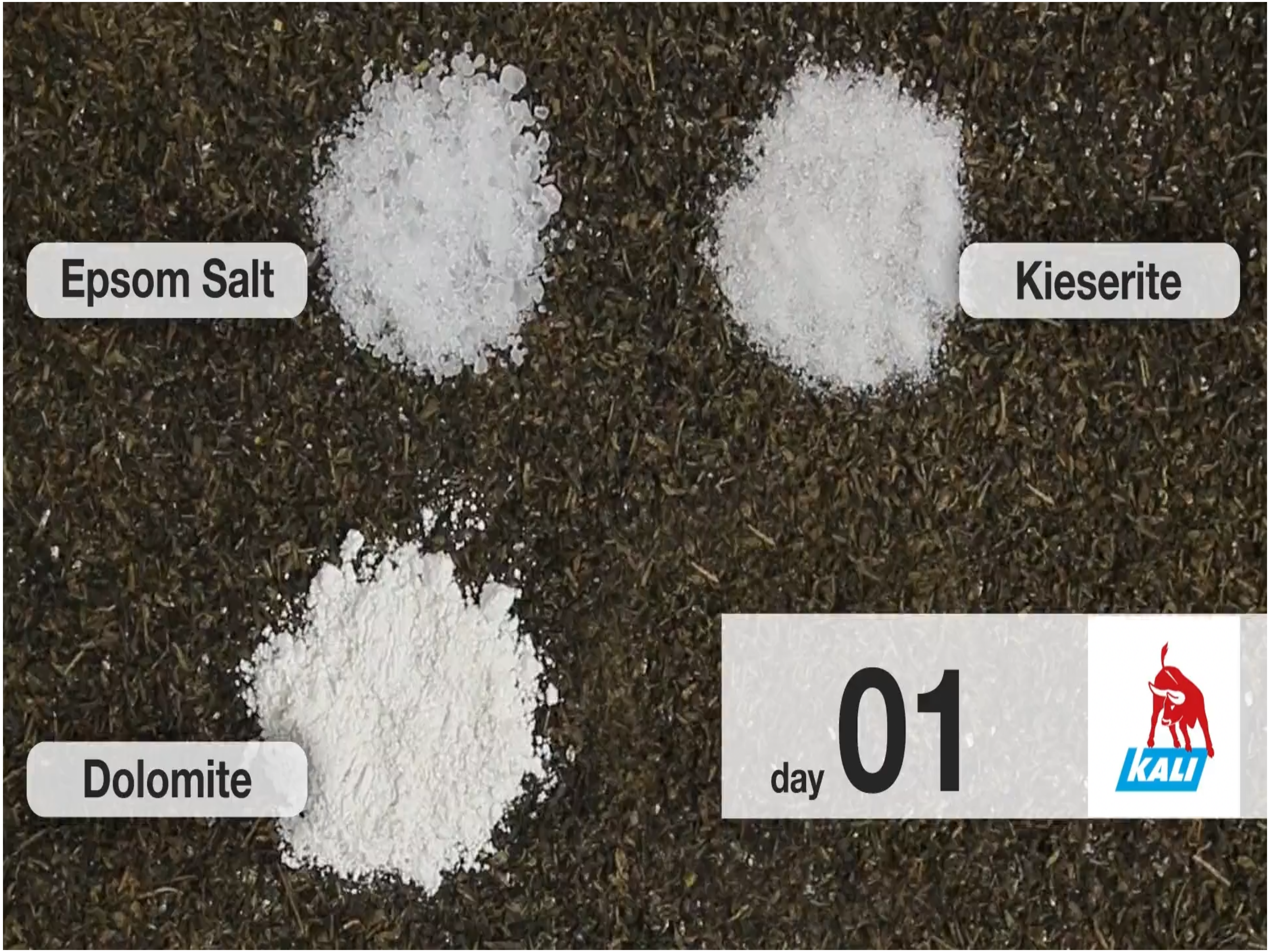


Source: Härdter et al., 2003


Epsom Salt
Kieserite
Dolomite
day 01
KALI

HOW TO FERTILISE MAGNESIUM?

Magnesium saturation in the soil and grain yield

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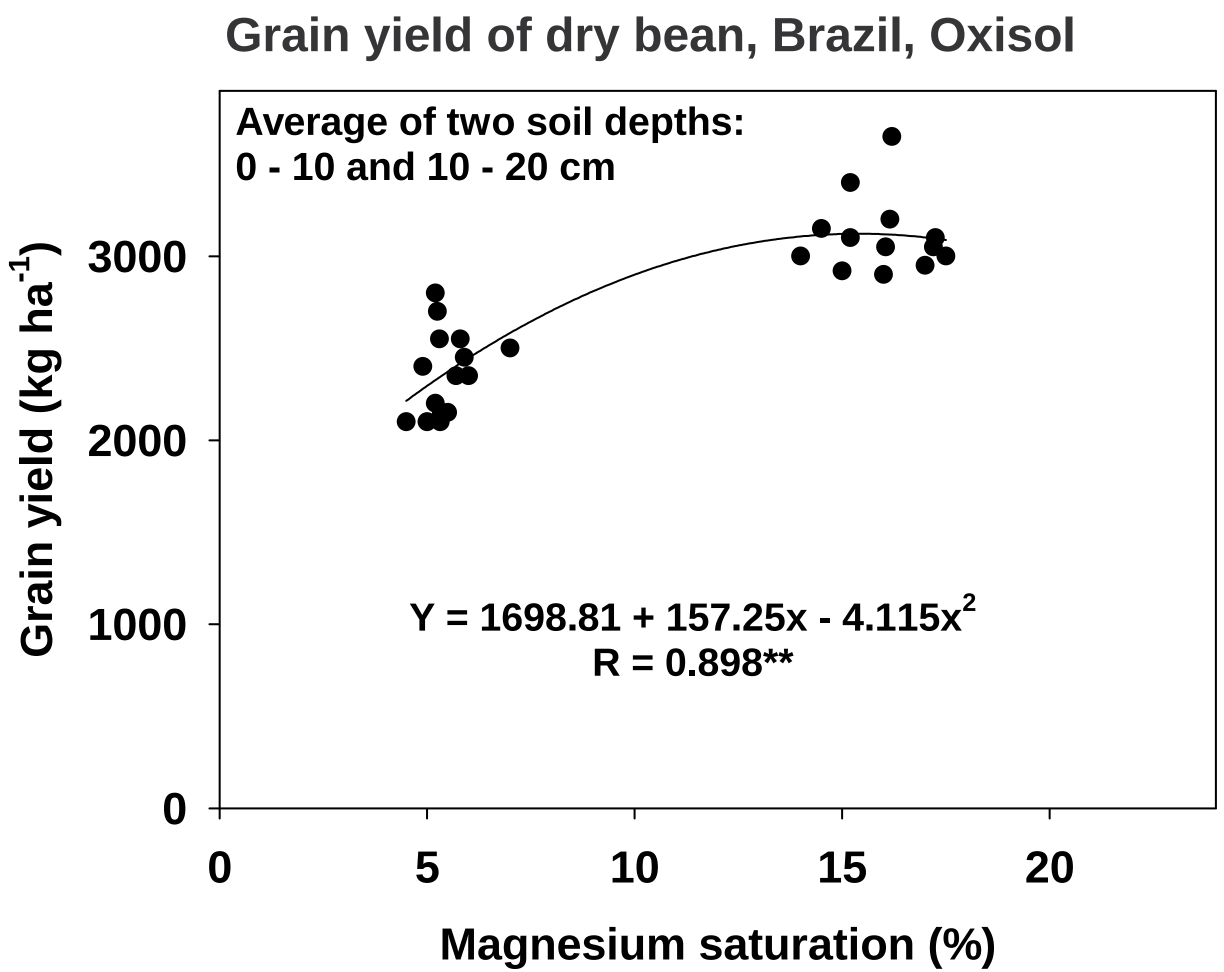
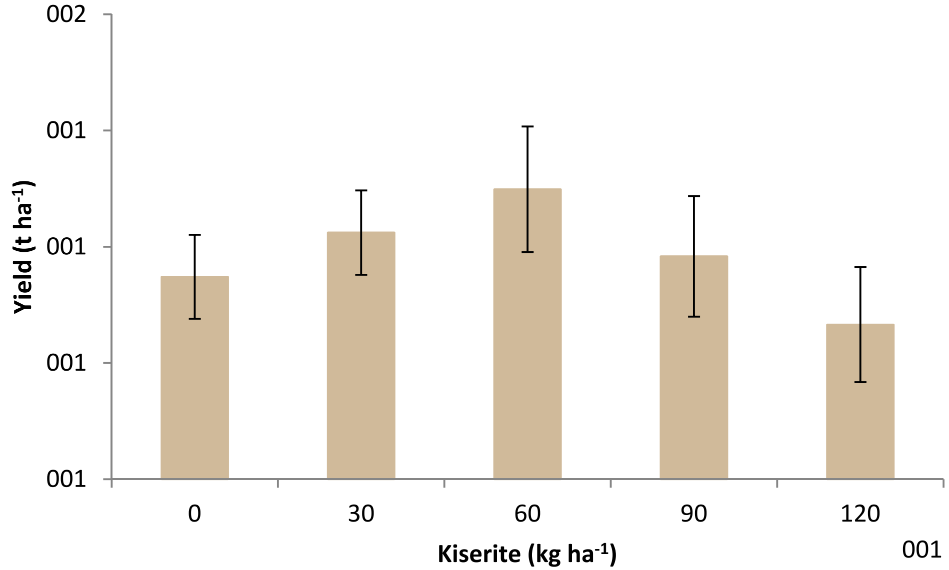
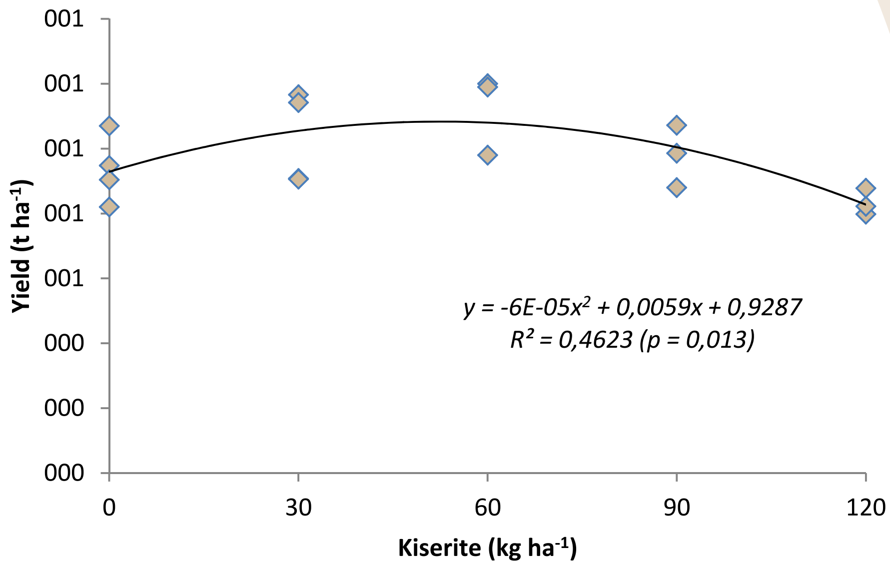


Fageria, 2009

Field trials with Kieserite in Soy beans – (2012/2013)





Summary

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- Mg is a key element to increase yield and quality of crops

- right amount in the soil depends on the need of the crops and the concentration of other cations

- Mg can increase the use efficiency of other nutrients

- crops can take up Mg only in a water soluble form

Questions?

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Thank you
for your attention