POTASSIUM EFFECTS ON RHIZOSPHERE PROCESSES AND RESISTANCE TO DISEASES

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Overview

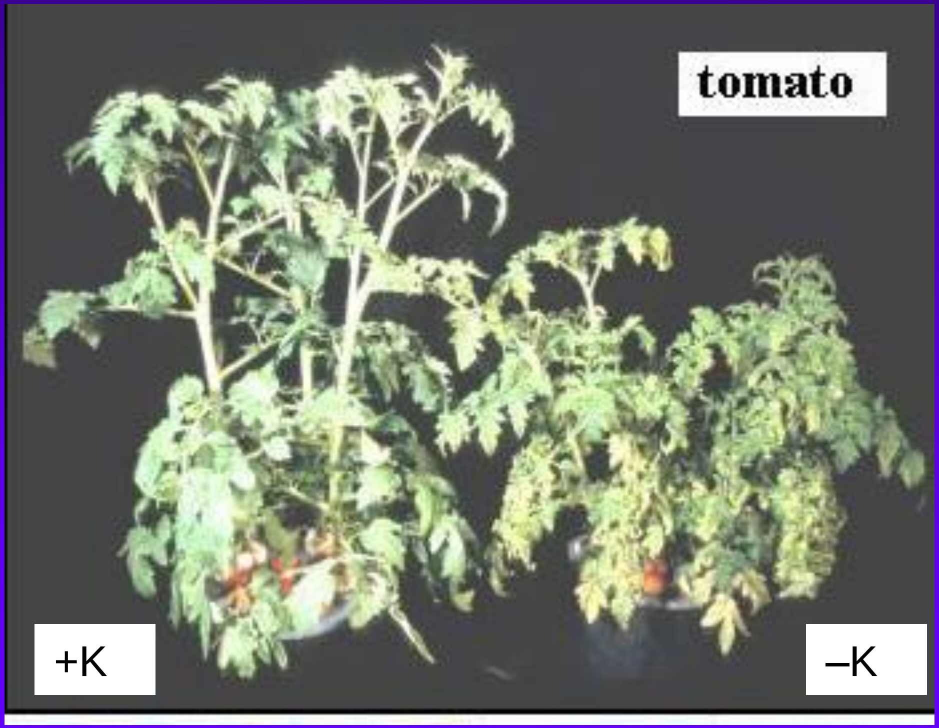
- Role of K in disease resistance
- Effects of K on rhizosphere processes
- Relationship between rhizosphere changes and disease resistance
- Case studies: adapted rhizosphere management for disease resistance
- Conclusion-Prospects

SIMPÓSIO SOBRE POTÁSSIO NA AGRICULTURA BRASILEIRA

SÃO PEDRO-SP, 22 a 24 de Setembro de 2004

■ Introduction

- K as an essential mineral has numerous effects on crop growth and quality



Tomato in nutrient solution (+ / - K supply) (Bremer, 2002)

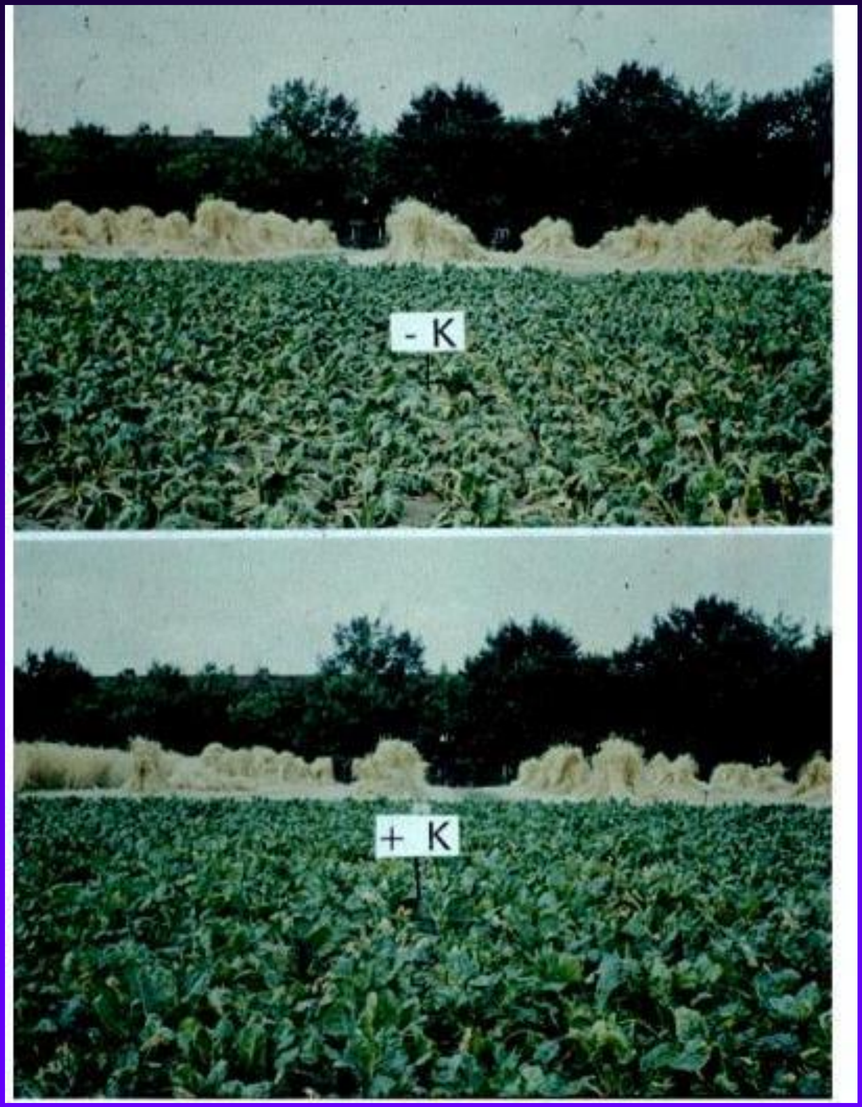
Quality of pommes frites depending on K/N ratio (Gerendas and Sattelmacher, 2004)

■ Introduction

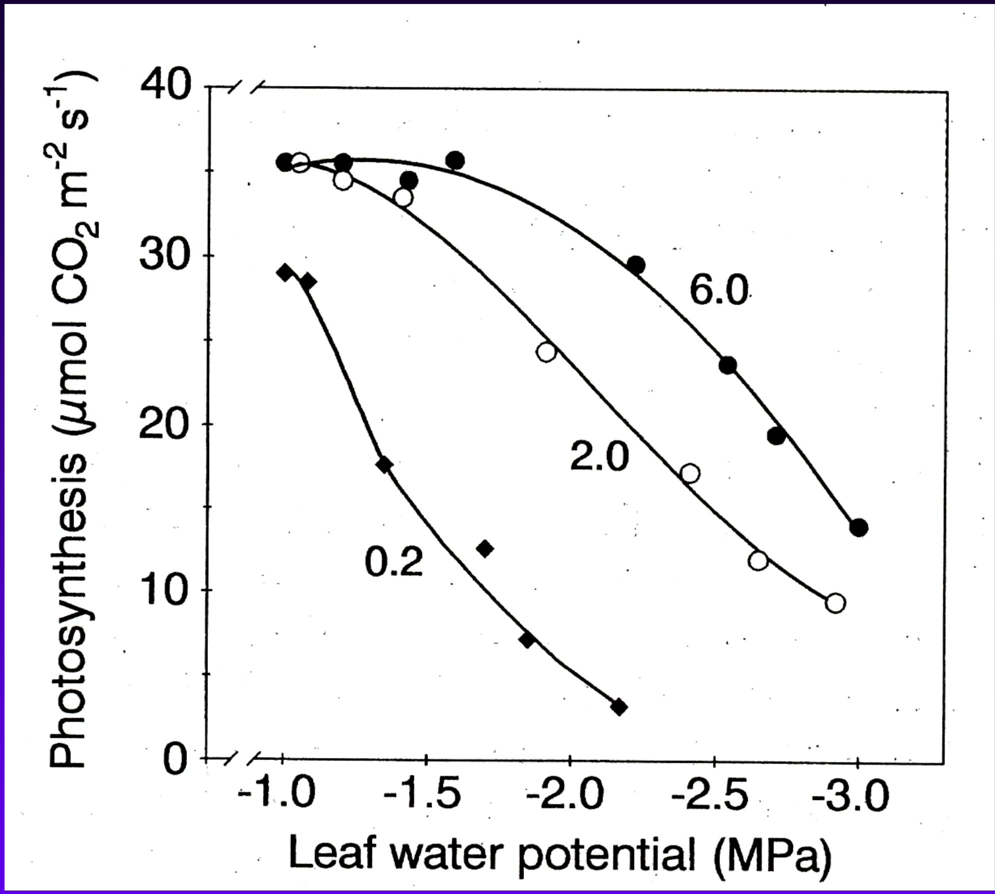
- K as an essential mineral has numerous effects on crop growth and quality such as:

- □ regulating the water household of a plant (cell extension, stomata opening, phloem transport, charge compensation) and
- □ many main enzyme activities (ATPase, starch synthesis, protein synthesis)
- □ general stress resistance (drought, salt, low temperature) and thus also disease resistance

Effect of K on stress resistance (e.g. drought stress)



Sugar beet on a sandy soil: wilting at low K during noon



Increasing photosynthesis at higher K supply, particularly at low leaf water potential (Marschner, 1995)

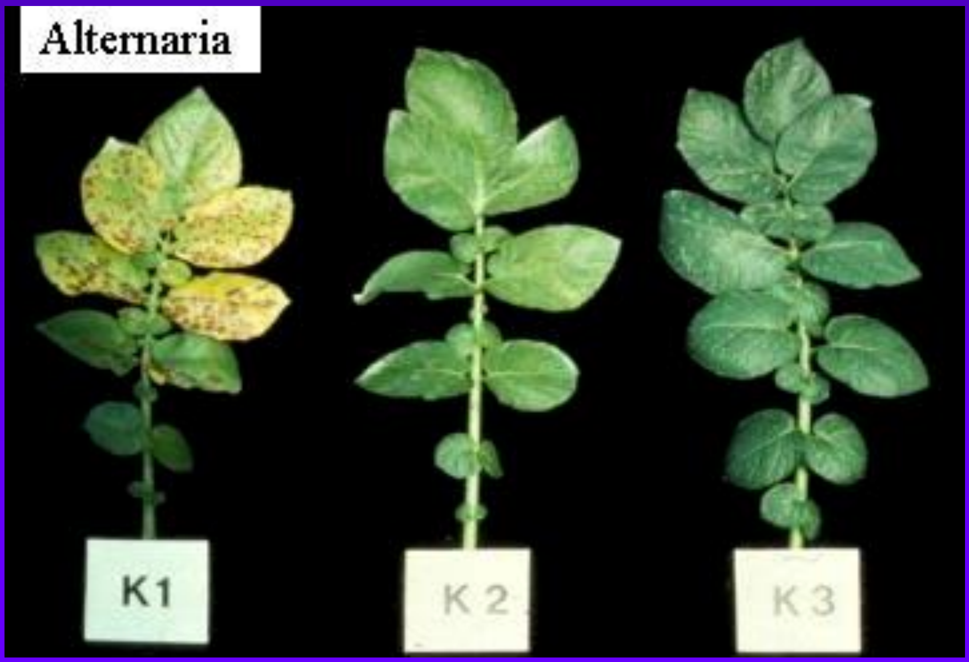
■ Role of K in disease resistance

Effect of N and K supply on disease susceptibility

(Kiraly, 1976; Porrenoud, 1977)

Pathogen/disease	N-level		K-level	
	low	high	low	high
Obligate parasite *Puccinia sp* *Erysiphe graminis*	 + +	 +++ +++	 ++++ ++++	 + +
Facultative parasite *Alternaria sp* *Fusarium oxisporum* *Xanthomonas sp*	+++ +++ +++	+ + +	++++ ++++ ++++	+ + +

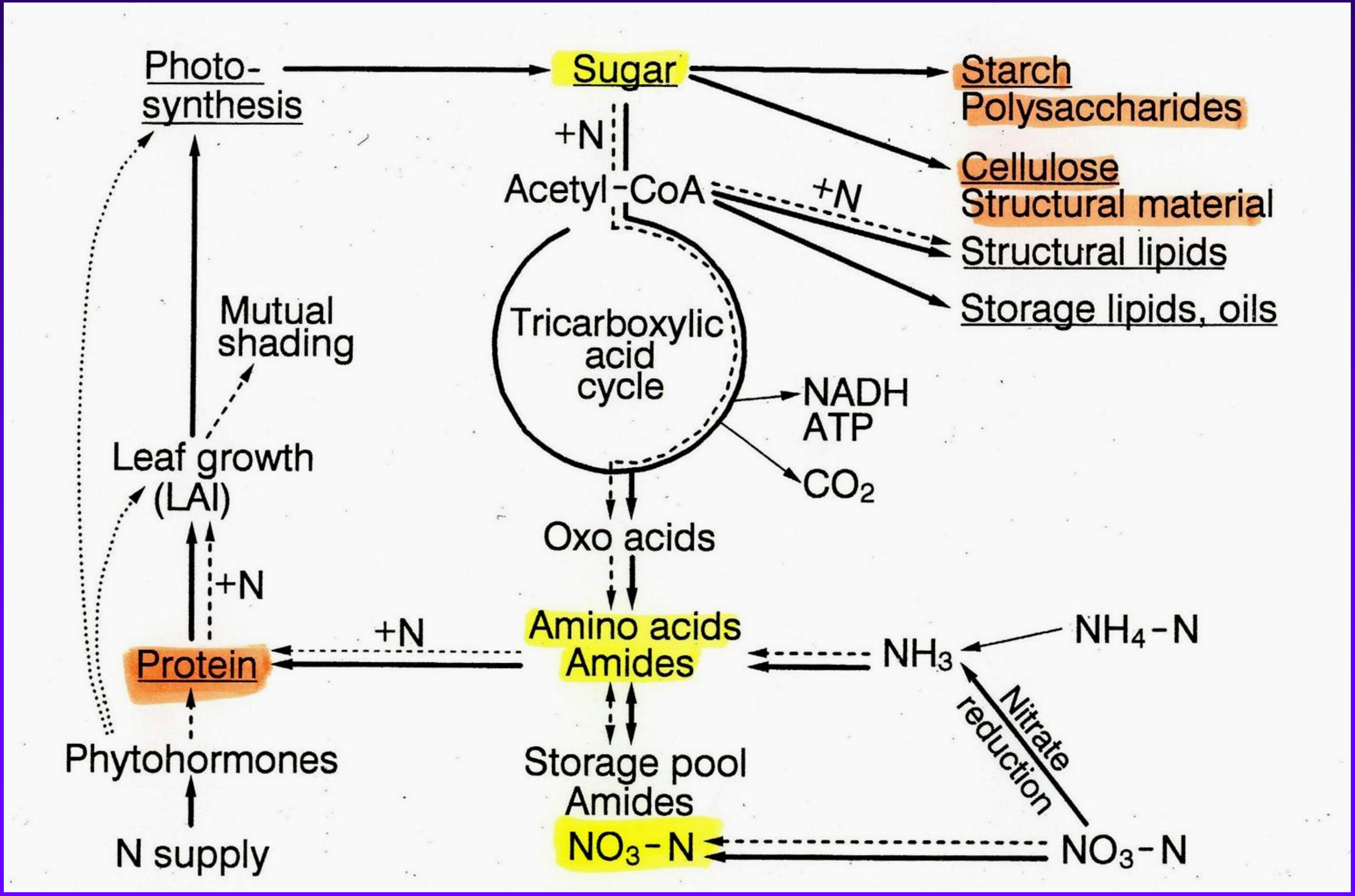
+ → ++++ increase in disease susceptibility

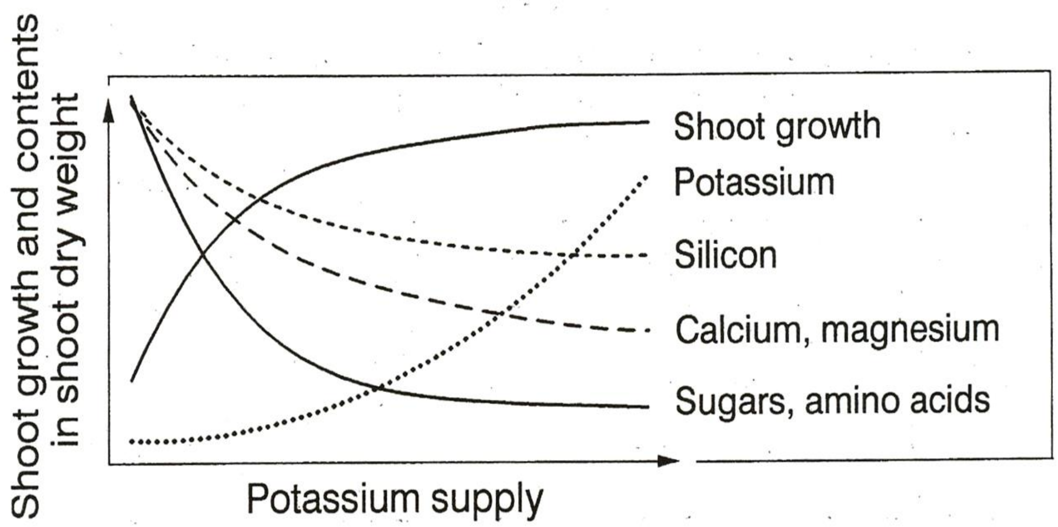


→ enhanced K supply can counteract negative effects of a high N supply on stress resistance e.g. disease resistance!

Potatol leaves

Effect of supply of a high or a low K / N ratio on soluble (low molecular weight) constituents (amino acids, sugars) and high molecular weight proteins, starch and cellulose (Marschner,1995)





Tentative scheme of growth response and major changes in plant composition with increasing potassium supply.

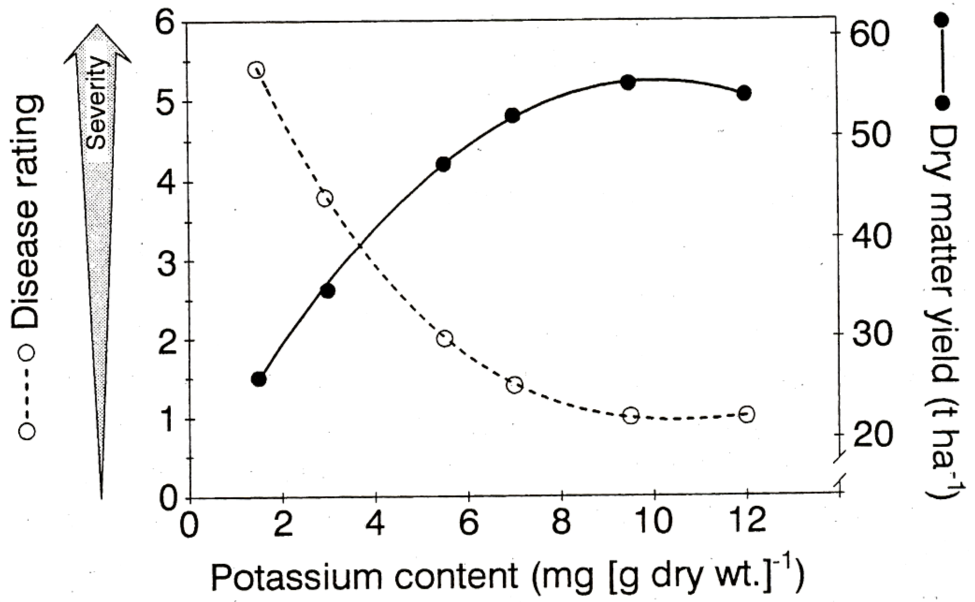
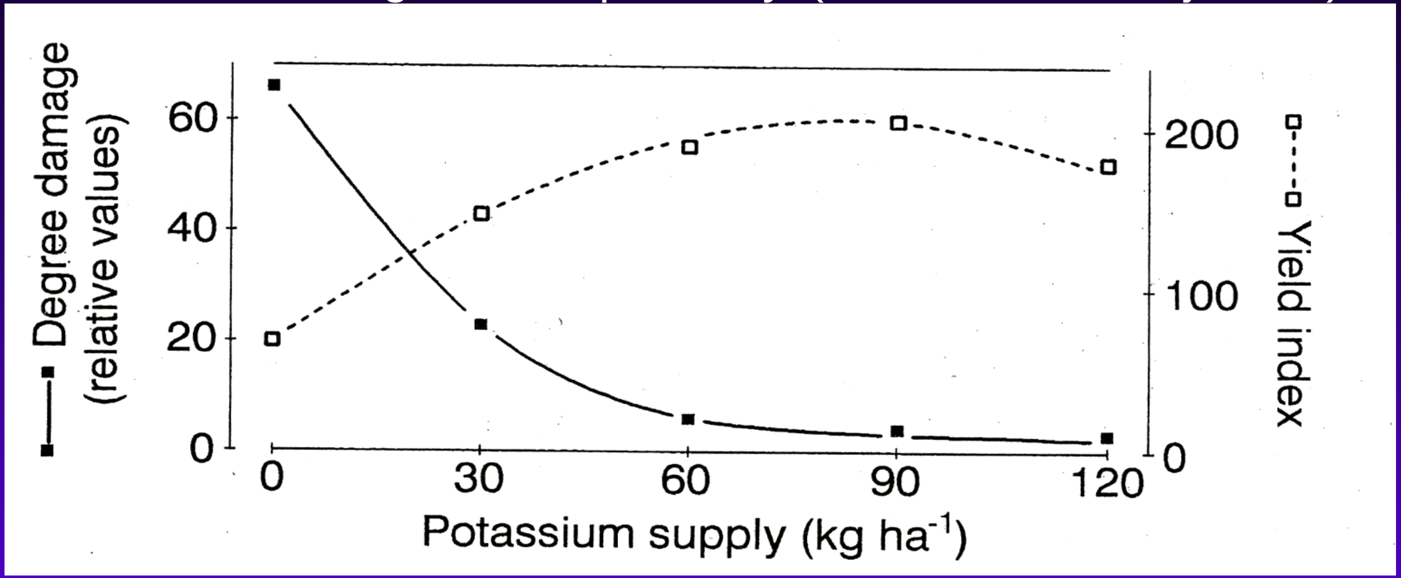


Fig. 11.8 Severity of leaf spot disease (*Helminthosporium cynodontis*) and dry matter yield in 'Coastal' bermudagrass (*Cynodon dactylon* L. Pers.) versus leaf potassium content. (Reproduced from Matocha and Smith, 1980, by permission of the American Society of Agronomy.)

Marschner,1995

Effect of potassium supply on grain yield of wetland rice and incidence of stem rot (*Helminthosporium sigmoideum*). Basal dressing of nitrogen and phosphorus constant at 120 and 60 kg ha^{-1}, respectively. (Based on Isunadji,1976)



Effects of Fertilizers Applied on a Soil Low in Available on Infestation of Oak Trees (*Quercus pendula*) by Cup-Shield Lice (*Eulecanium refulum* Ck11.)

	Fertilizer			
	K + Mg	N + P + K + Mg	Mg	N + P + Mg
No. of lice per 10-cm stem section	0.72	0.82	4.32	8.78

Based on Brüning (1967)

A better K supply might also increase mycorrhizae infection rate and thus disease resistance.

(Marschner,1995)

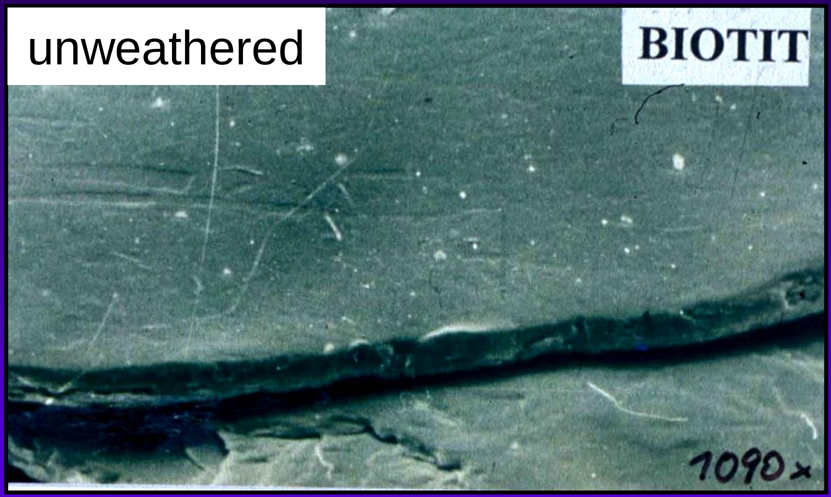
■ Effects of K on rhizosphere processes

- Better partitioning of carbohydrates between shoots and roots by an improved phloem loading of sugars
- Improved water use efficiency (WUE); higher photosynthesis
- Improved exudation of roots into the rhizosphere
- Decrease of rhizosphere pH

Beside possible effects of K or rhizosphere processes, K mobilization in the rhizosphere by root exudates in distinct plant species (e.g. sugar beet) has also to be considered (Steingrobe and Claassen, 2000; Samal, 2004)

Enhanced weathering of K minerals in the rhizosphere by root exudates

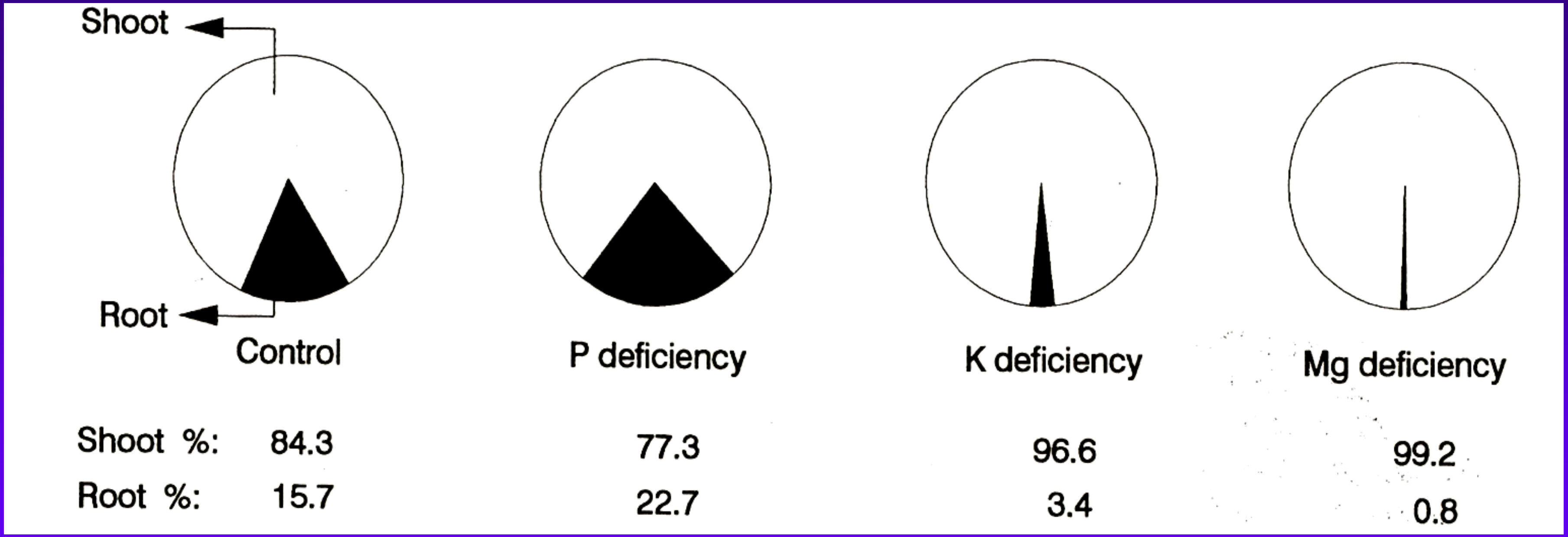
Biotite: naturally and chemically weathered



See: Hinsinger and Jailard, 1993

■ Effects of K on rhizosphere processes

- Better partitioning of carbohydrates between shoots and roots by an improved phloem loading due to a stabilized membrane potential / better membrane transport processes

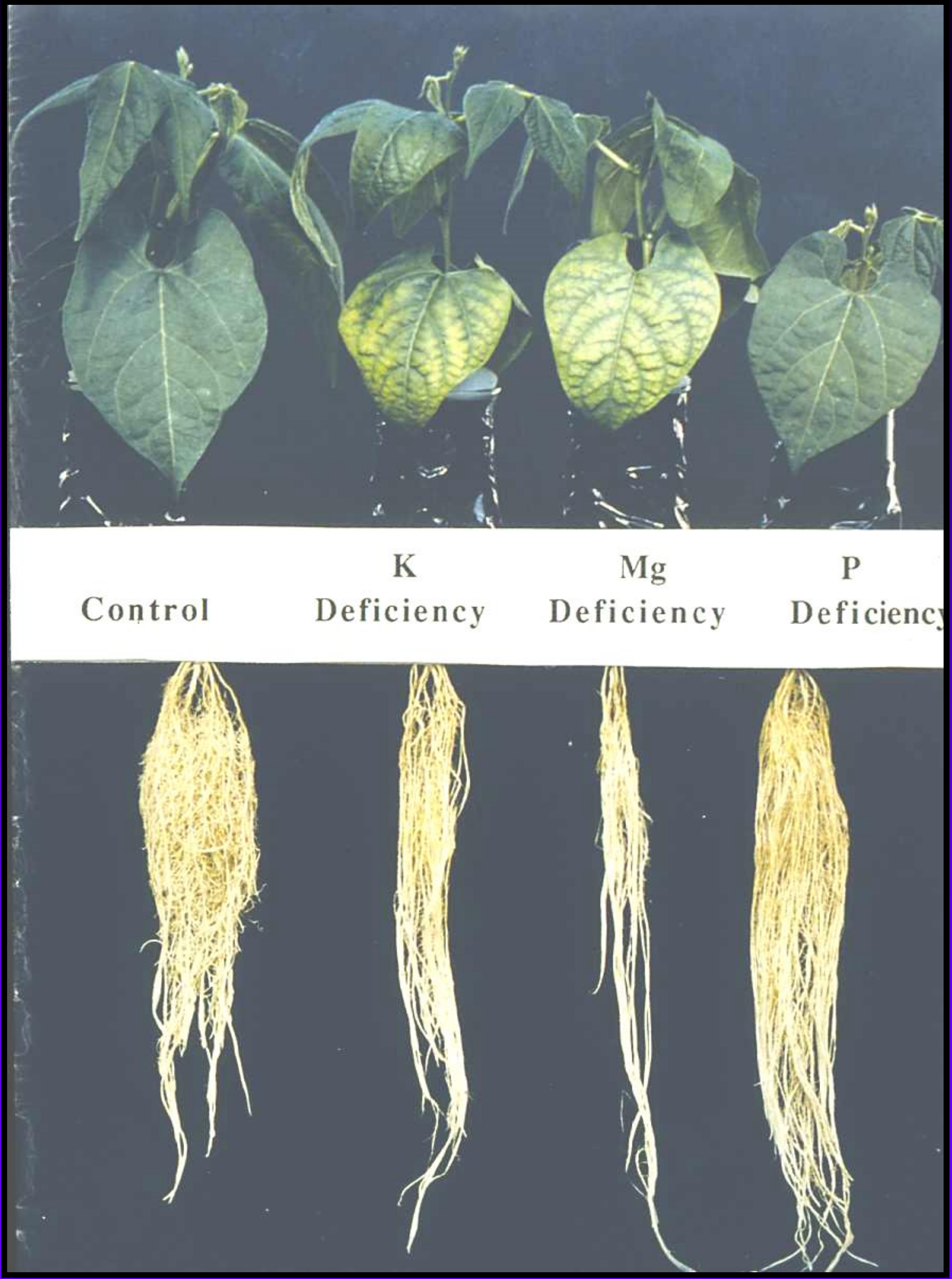


Relative distribution of carbohydrates (sum of reducing sugars, sucrose and starch) between shoot and roots of 12-d-old bean plants grown in nutrient solution with deficient supply of P, K and Mg. (Cakmak et al.)

Effect of K deficiency on root / shoot ratio

→ better root growth, more mycorrhizae and higher microbial activity in the rhizosphere by an adequate K supply!

Photo: Cakmak

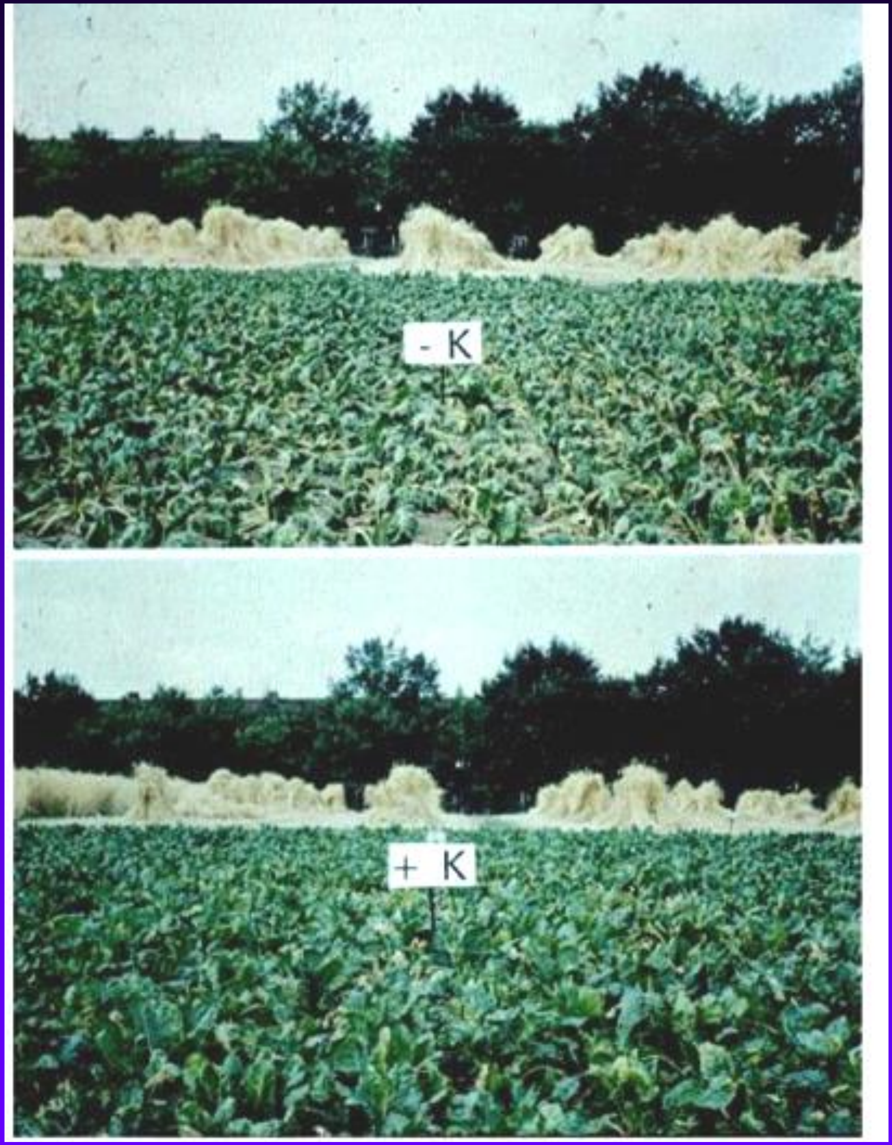


■ Effects of K on rhizosphere processes

- Better partitioning of carbohydrates between shoots and roots by an improved phloem loading

- Improved water use efficiency / higher photosynthesis

Salt stress after soil salinization (Cotton)



Sugar beet on a sandy soil: wilting at low K during noon

Effect of substrates salinization on growth, mineral element concentration and protein synthesis in barley at different NaCl and KCl supply

Treatment	Shoot DM (mg/plant)	Concentration (mmol/g DM)		^{15}N content (% of total ^{15}N)*	
		K	Na	Protein N	Inorganic N
Control	371	1.3	0.14	44	3
80 mM NaCl	286	0.8	2.1	29	20
80 mM NaCl + 10 mM KCl	323	1.4	1.6	49	1

* after supply of $^{15}NH_4\,^{15}NO_3$ for 24h (Marschner, 1995)

The adverse effect of elevated NaCl concentration on both K concentration and protein synthesis can be counterbalanced by KCl, despite the further decrease in the osmotic potential; thus better adaptation and better root growth and rhizosphere processes.

■ Effects of K on rhizosphere processes

- Better partitioning of carbohydrates between shoots and roots by an improved phloem loading

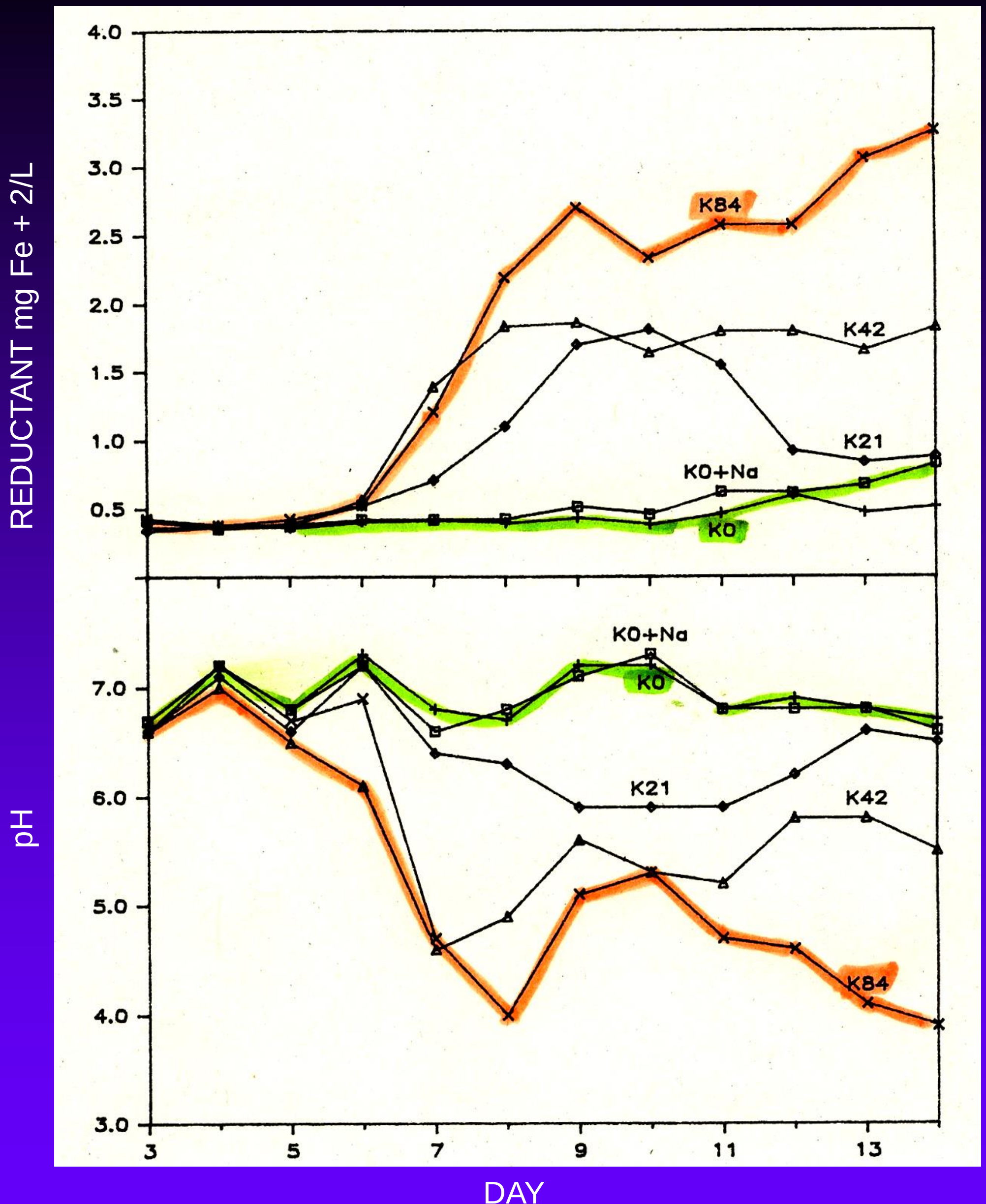
- Improved water use efficiency / higher photosynthesis

- Improved exudation of roots into the rhizosphere due to a stabilization of the membrane potential

  K stimulates release of nutrient mobilizing root exudates and sugars

→ better acquisition of micronutrients and phosphate (Mori et al., 1992; Denton and Lambers et al., 2004)

Presence of K is required for the function of the Fe-response mechanisms of Strategy I-plant species (Wallace, 1991; Plant Soil 130)



Effect of K supply on pH lowering and release of reductants (Jolley and Brown 1985)

(Römheld, 1985)

■ Effects of K on rhizosphere processes

- Better partitioning of carbohydrates between shoots and roots by an improved phloem loading
- Improved water use efficiency / higher photosynthesis
- Improved exudation of roots into the rhizosphere due to a stabilization of the membrane potential
- Decrease of rhizosphere pH

Effect of KCl and K_2SO_4 on bulk soil pH and chlorophyll of peanut growth on a calcareous soil

Treatment	Bulk soil pH		Chlorphyll (mg/g FM)	
	KCl	K_2SO_4	KCl	K_2SO_4
Control	8.34		0.42	
FeEDDHA	8.41		2.80	
K_1	8.41	8.19	0.89	1.16
K_2	8.35	8.22	0.88	0.34
K_3	8.26	8.20	0.77	1.24

Barak and Chen, 1984; J.Plant Nutrition 7, 125-133

Dry matter production and chlorophyll content of peanuts as affected by K and Fe source

Treatment	yield (g/pot)	Chlorophyll (mg/cm^2)
Control	3.3	0.64
K_2SO_4 I	4.3	0.85
II	5.4	0.97
III	4.4	0.97
K_2SO_4 I	10.3	3.15
(+$FeSO_4$)II	10.2	3.33
III	14.3	5.93
KCl I	4.2	1.38
(+$FeSO_4$) II	8.3	2.59
III	8.8	3.89
FeEDDHA	11.8	5.73

(Mortvedt, Plant Soil 130, 1991)

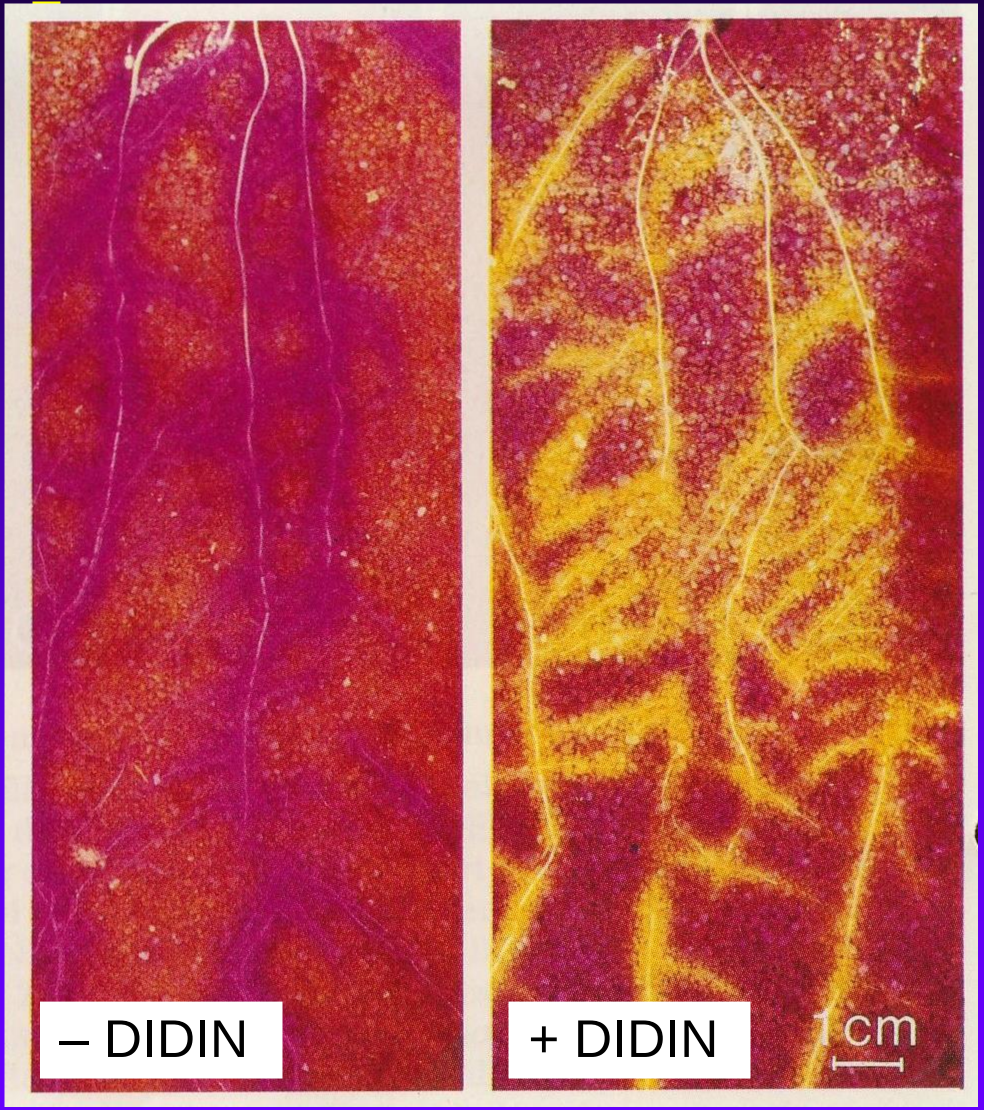
The higher effectiveness of K_2SO_4 compared with KCl in rhizosphere pH lowering is attributed to the different cation-anion balance of ion uptake.
(Barak and Chen, 1984; Mortvedt, 1991)

It can be assumed that this K_2SO_4 effect on rhizosphere pH will also promote the uptake of Mn, Zn or even Si beside of Fe.

(Römheld, 1986)

Effect of nitrification inhibitors together with NH_4-N (stabilized NH_4) on rhizosphere pH

„Stabilized NH_4“
results in rhizosphere
acidification

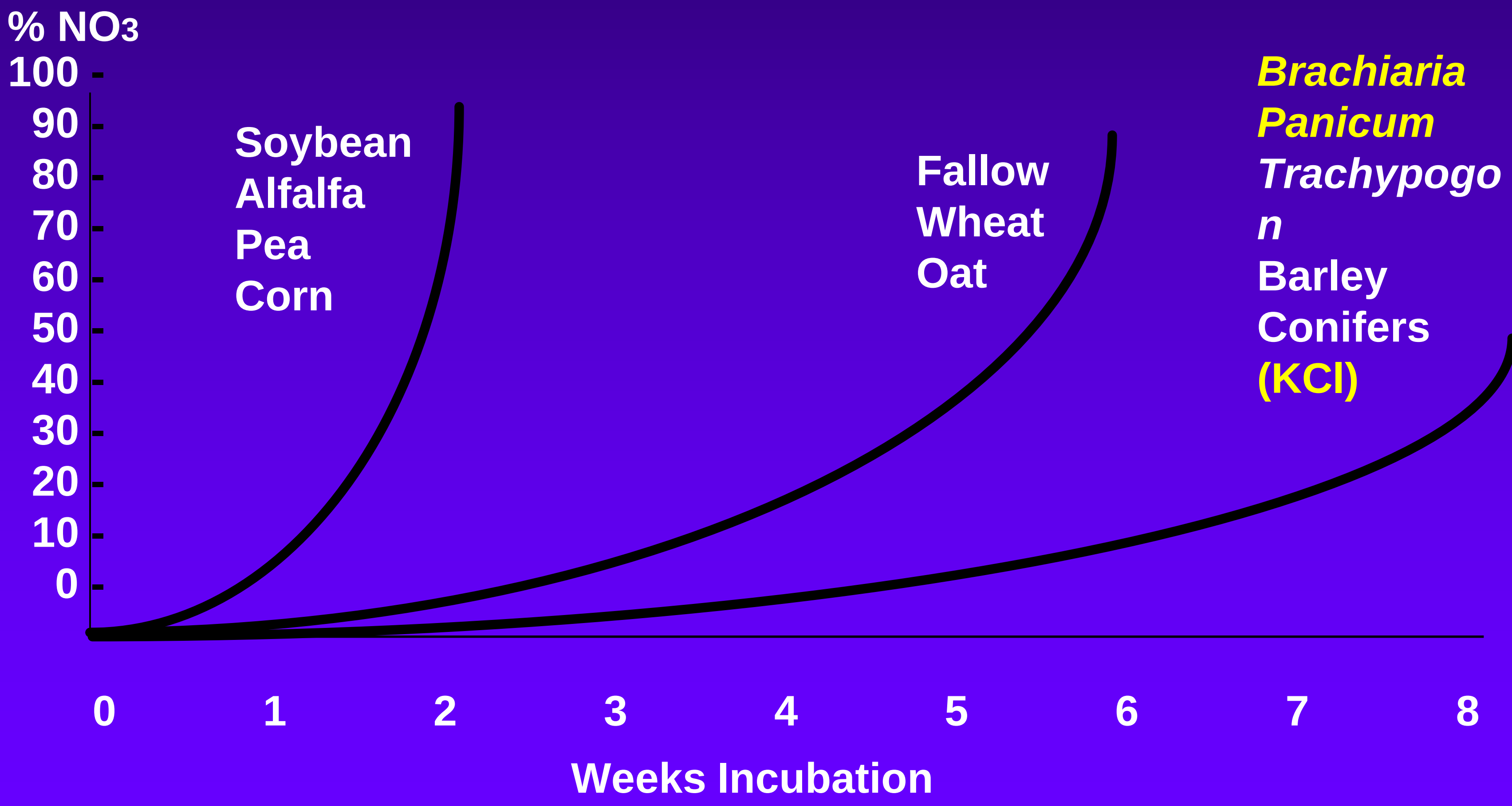


+/– Nitrification inhibitor

(Römheld, 1986)

Distinct plant residues and KCl inhibit nitrification of NH_4-N and thus result in rhizosphere acidification

Effect of different crop residues on inhibition of nitrification in a soil (D. Huber, 2002)



■ Relationship between rhizosphere changes and disease resistance

- Lowering rhizosphere pH due to K_2SO_4 or stabilized NH_4-N by KCl

  → improves Mn, Zn and Si acquisition, which can enhance disease resistance.

Effect of NH_4-N + nitrification inhibitor (ENTEC) on growth and uptake of Mn, Zn and Si by cucumber (C. Zhang, 2004)

Treatment	Growth (g DW/pot)	Mineral concentration (mg/kg DW) Mn	Zn	Si
Nitrate	0.46	20	30	1500
Ammonium + ENTEC	0.46	33	51	3200

Effect of chloride as (KCl as NaCl) on incidence of take-all in wheat applied with ammonium-N

Cl treatment (kg/ha) Autumn	Spring	% infected roots	Grain yield (t/ha)
0	0	45	5.3
56	0	34	5.7
56	185	11	6.5

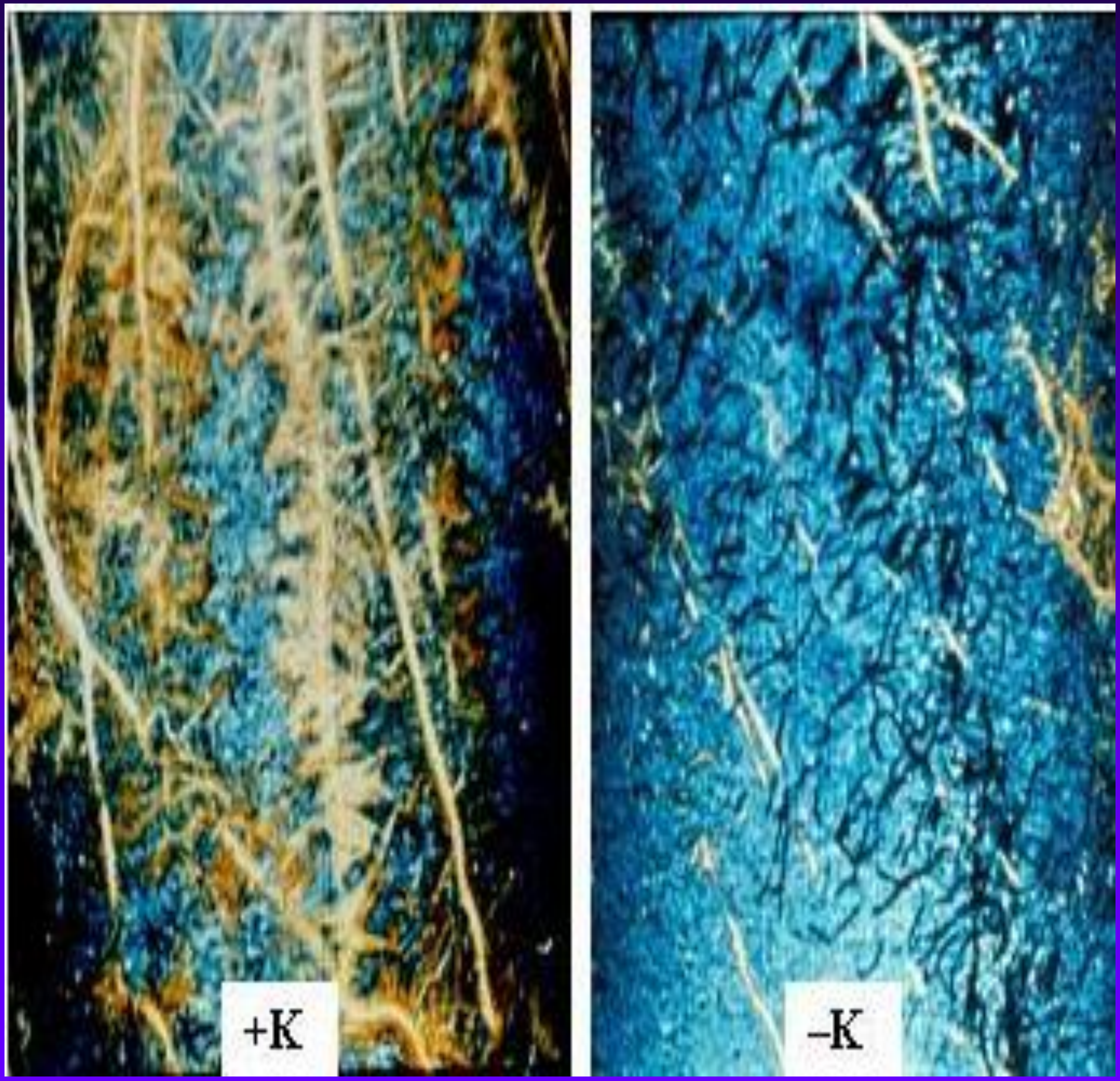
Christensen et al.,
Agron, J. 73, 1053-1058; 1981

Lowering rhizosphere pH inhibits the fungus of take-all

(D. Huber, USA)

– N serve + N serve

- K supply to lowland rice as prerequisite for adequate aerenchyma formation



Inadequate formation of aerenchyma under low K supply will result in a low root growth, and inhibited root functions (e.g. low nutrient uptake and enhanced disease susceptibility)

- Improved assimilate export to roots via phloem and secretion of nutrient mobilizing root exudates at adequate K supply

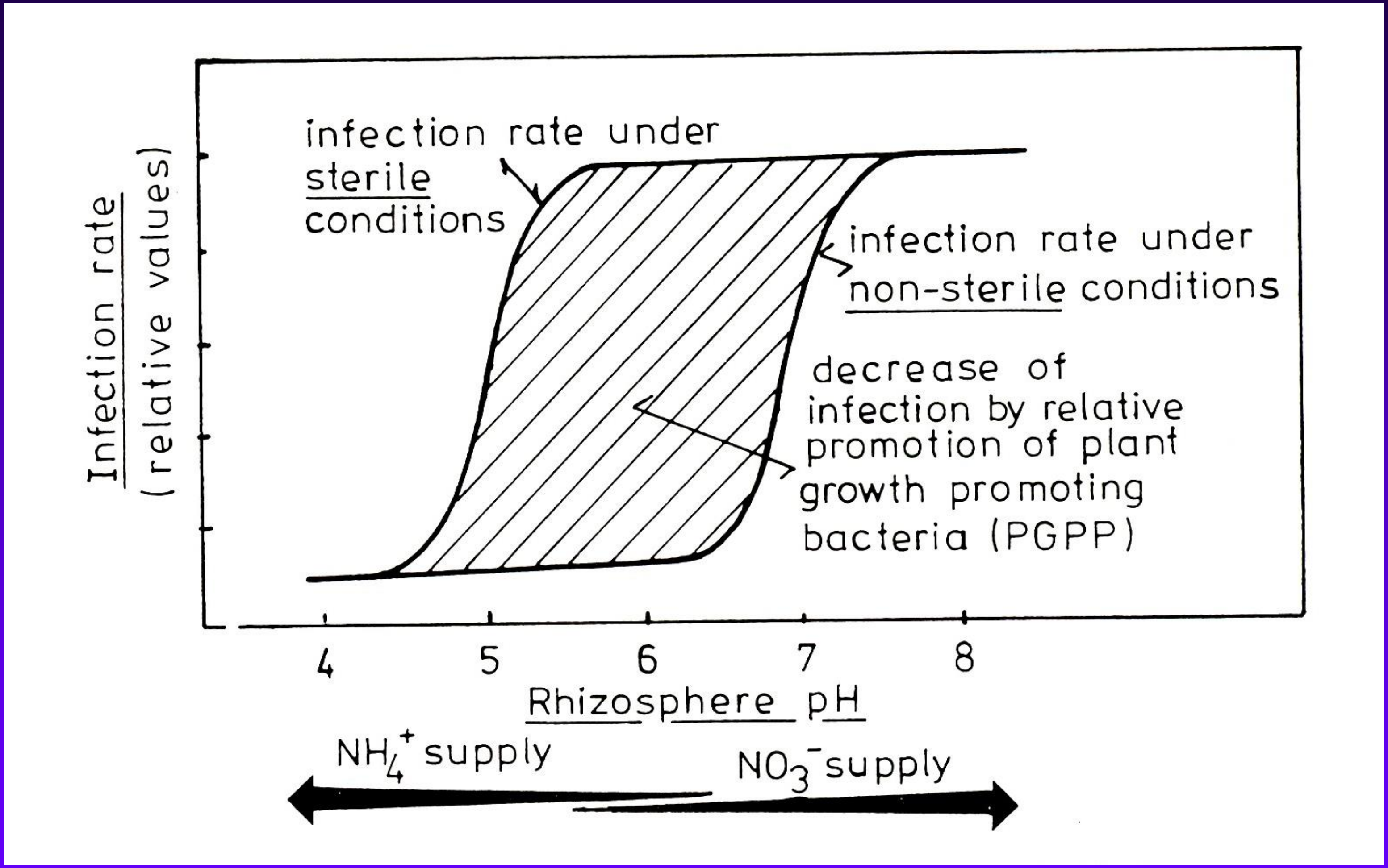
→ improved root growth for a better spatial availability and an enhanced exudation for a better chemical availability of nutrients (such as Mn, Zn or also Si), which can enhance disease resistance

→ higher infection rate with mycorrhizae which enhances disease resistance

Suppression of replant disease in grapes by mycorrhiza (AM) promoted at adequate K supply or K/N ratio.

■ Case studies: Adapted rhizosphere management for disease resistance

Example: take-all



(Römheld, 1990; Symbiosis 9, 19-27)

Use of KCl-stabilized NH_4-N or K_2SO_4 induced lowering of rhizosphere pH or Mn-mobilizing biofertilizer (*Trichoderma* etc.)

Example:

Rice blast, powdery mildew etc.

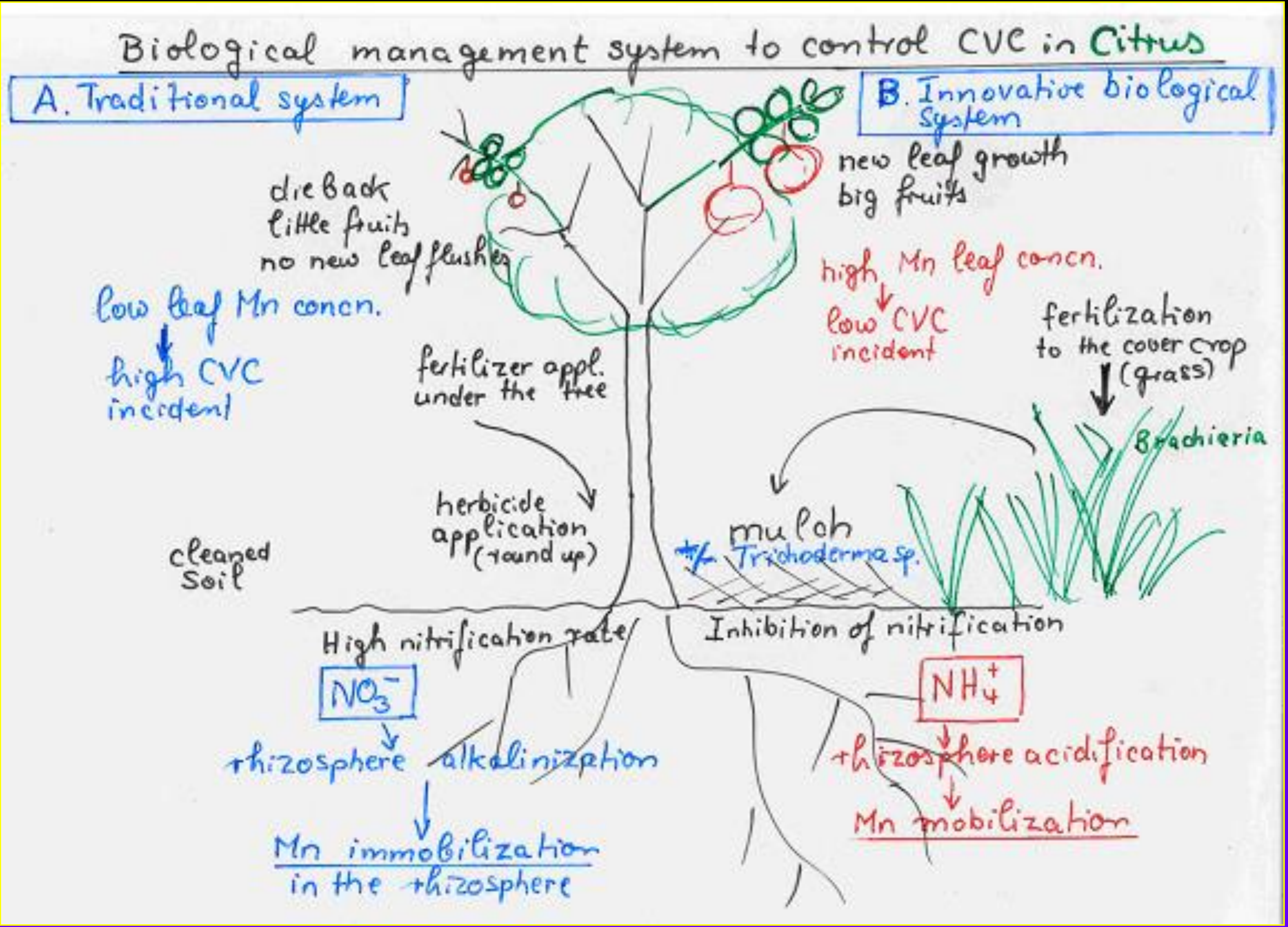
Suppression of both fungus by enhanced Mn and Si plant availability due to K-stimulated rhizosphere acidification

Example: C.V.C. (*Xylella fastidiosa*)

Case study: Biological management system to control C.V.C. disease of Citrus in Brazil

Traditional system (no mulching, use of herbicide)

Biological management system (mulching, no herbicides)



Suppression of C.V.C. by K-stimulated rhizosphere acidification or biofertilizer-promoted Mn mobilizing

■ Conclusions-Prospects

- K can affect rhizosphere processes by different mechanisms, which in turn can promote disease resistance.
- An adapted rhizosphere management, as indicated by various case studies can help to reduce plant disease problems in farmers fields within and integrated approach.
- For optimization of these strategies a better understanding of the various processes is still required.

Muito obrigado! Thanks for your attention!