RELATIONSHIP BETWEEN SOIL-ROOT INTERFACE (RHIZOSPHERE) AND MINERAL NUTRITION OF PLANT

Volker Römheld

Institute of Plant Nutrition

University Hohenheim, Stuttgart, Alemanha

Fone: 49-711459-2344

E-mail: roemheld@uni-hohenheim.de

OVERVIEW

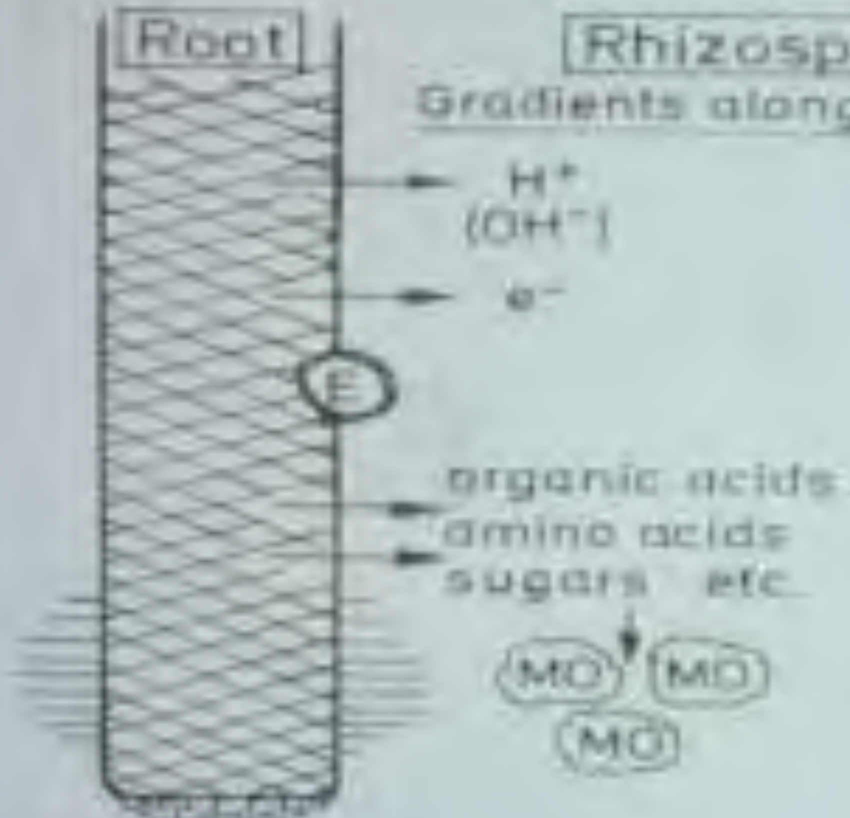
- Historical background
- Definition / characterization of the rhizosphere
- Importance of the rhizosphere for plants (in general)
- Rhizosphere effects on acquisition of mineral nutrients
- Role of rhizosphere processes in sustainable agricultural production systems
- Rhizosphere management for better plant growth
- Prospects

Lorenz Hiltner (1862-1923)
Techn. Universität München

The secrete world of roots

Rhizosphere

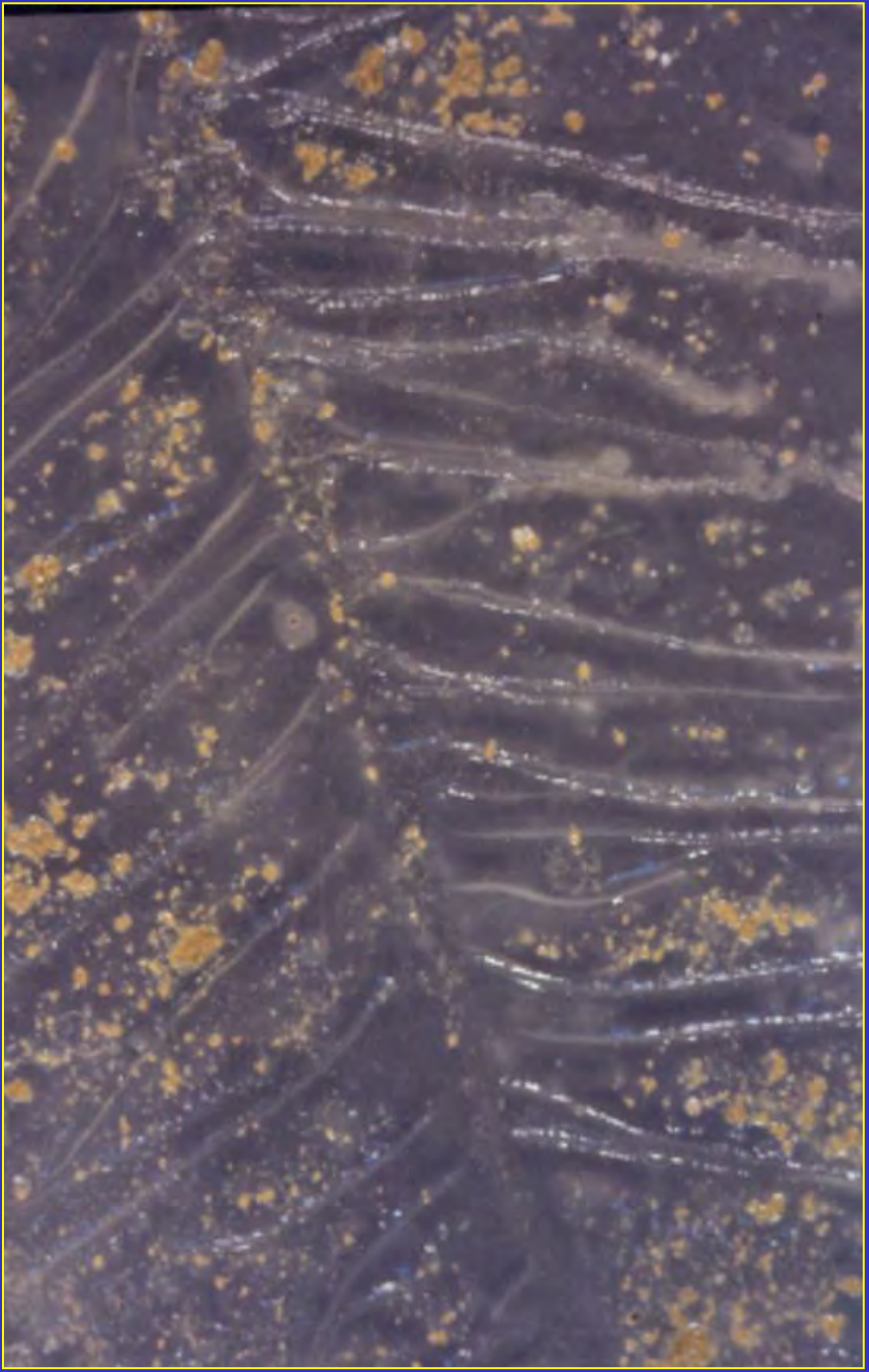
Gradients along the root axis in:



- pH
- redox potential
- ectoenzyme
- root exudates
- microorganisms

Root-induced changes in the rhizosphere

High microbial population density in the rhizosphere: finger print of the root/rhizosphere



■ Importance of the rhizosphere for plants

- Improved root growth
  - Detoxification of Al by root exudates
  - Biosynthesis of phytohormones by microorganisms
  - Suppression of pathogens
- Improved nutrient acquisition / nutrient efficiency
- Uptake of toxic substances

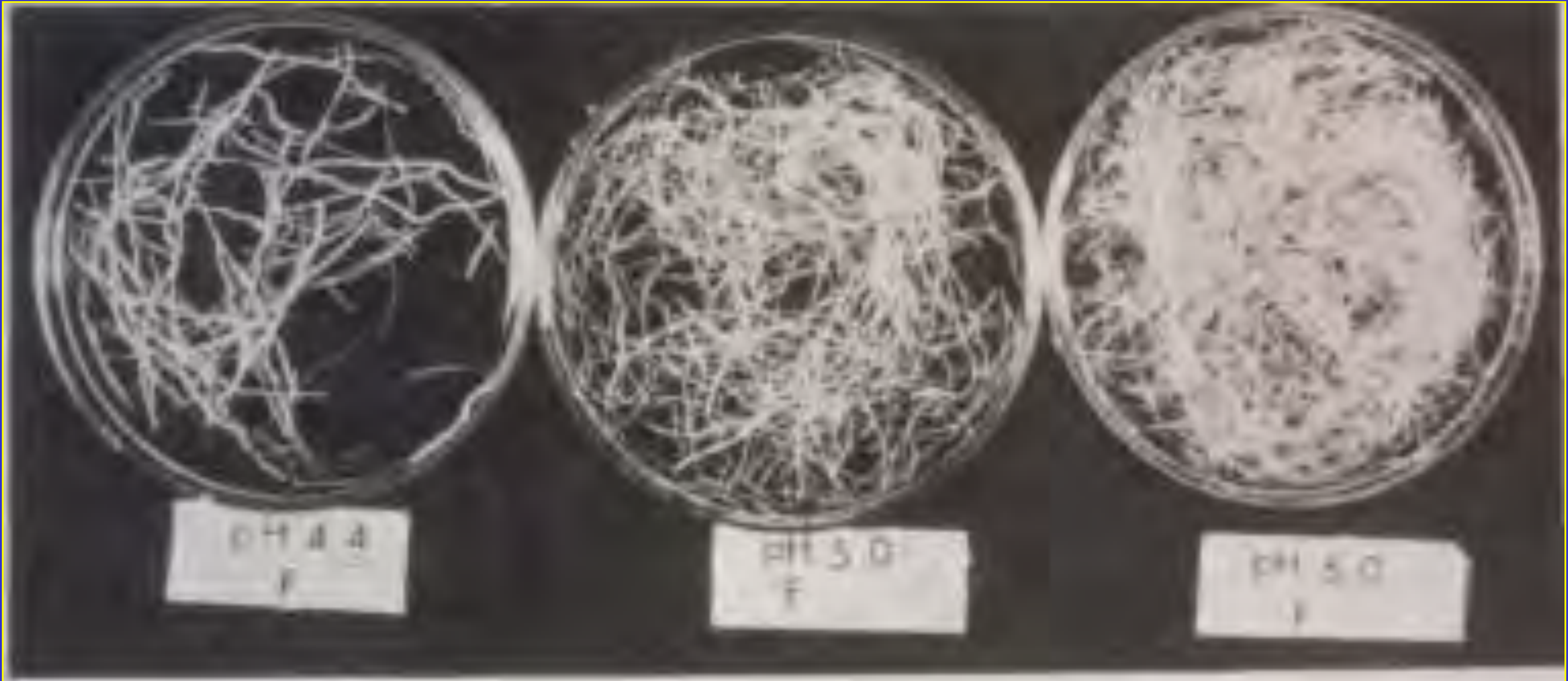
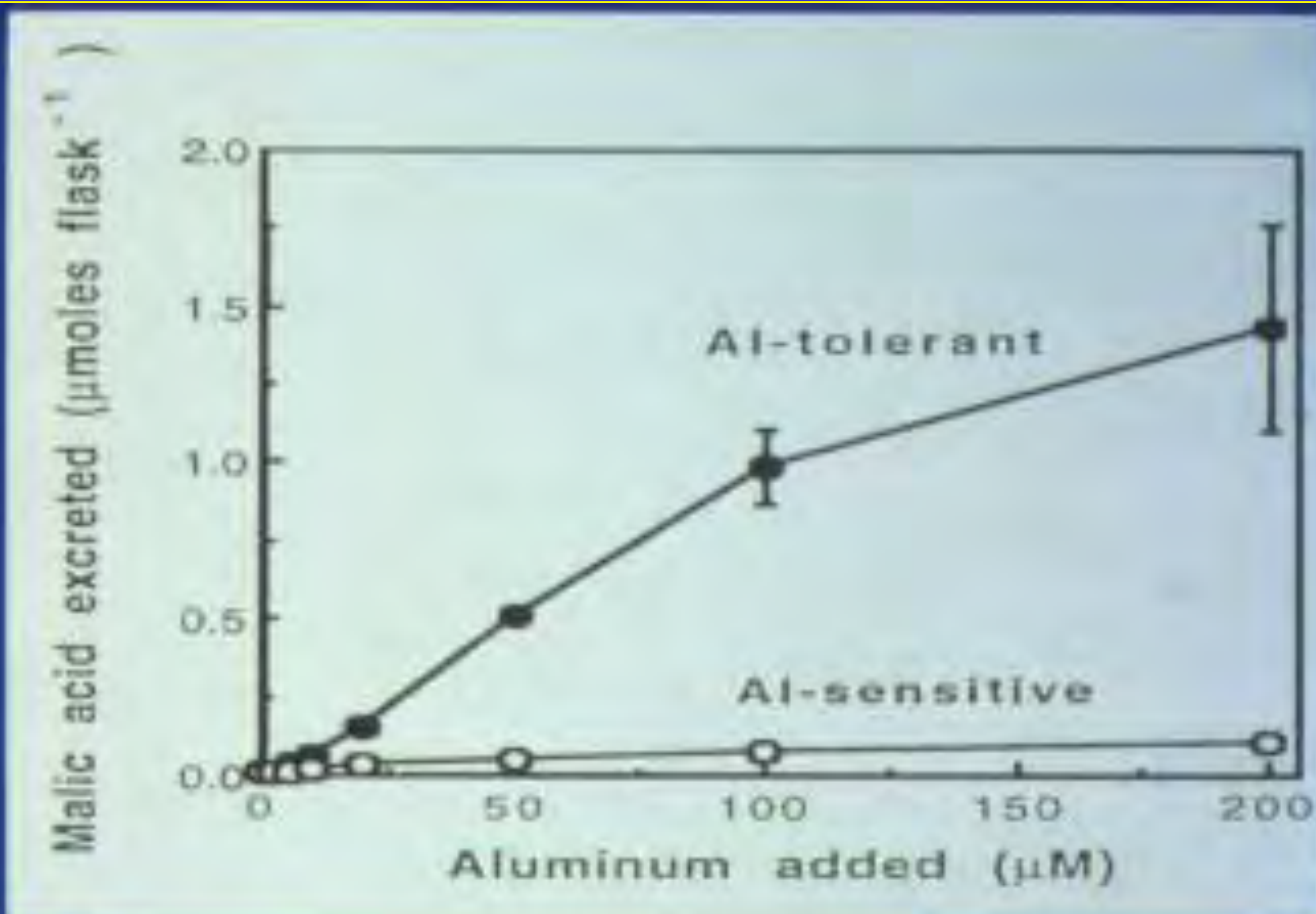


Fig. 10.3 Effect of pH in a Bladen subsoil on cotton root fineness

Roots of Kearney (left) and Dayton (right) barley varieties grown in acid, Al-toxic Bladen soil. Initial pH 4.6. (Foy, 1974)



Effect of Al concentration on excretion of malic acid by Al-tolerant (●) and Al-sensitive (○) wheat seedlings

Delhaize et al. (1993). Plant Physiol.


Topfreben
Riesling/125 AA
- AM
+ AM


-M
10 PPM B
+M

TEXAS, USA

bread

wheat

Zn efficient

durum

wheat

Zn inefficient


-P
+HYPERPHOS
+Ca(H2PO4)2
-P
+HYPERPHOS
+Ca(H2PO4)2
Rock-P
Super-P

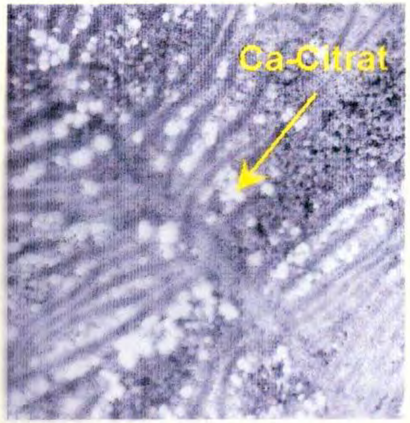
■ Rhizosphere effects on acquisition of mineral nutrients (improved nutrient efficiency)

Example

- Phosphate efficiency
- Iron efficiency (chlorosis resistence)
- Zinc efficiency

- Improved disease resistance due better Zn and Mn efficiency!

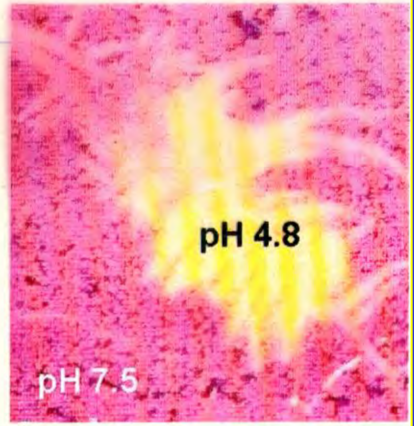
Root-induced changes in rhizosphere chemistry - Organic acids



P-deficiency induced changes in the rhizosphere of cluster roots in white lupin

(Dinkelaker et al. 1989, Pl. Cell Env. 12: 285-292).

	Bulk soil	Rhizosphere soil (cluster roots)
pH (H_2O)	7.5	4.8
Citrate [µmol g^{-1} soil]	< 0.05	47.7
Phosphorus [µmol kg^{-1} soil]		
H_2O-extractable	178	61
CAL	904	581
Olsen	581	484
DTPA-extractable [µmol kg^{-1} soil]		
Fe	34	251
Mn	44	222
Zn	2.8	16.8



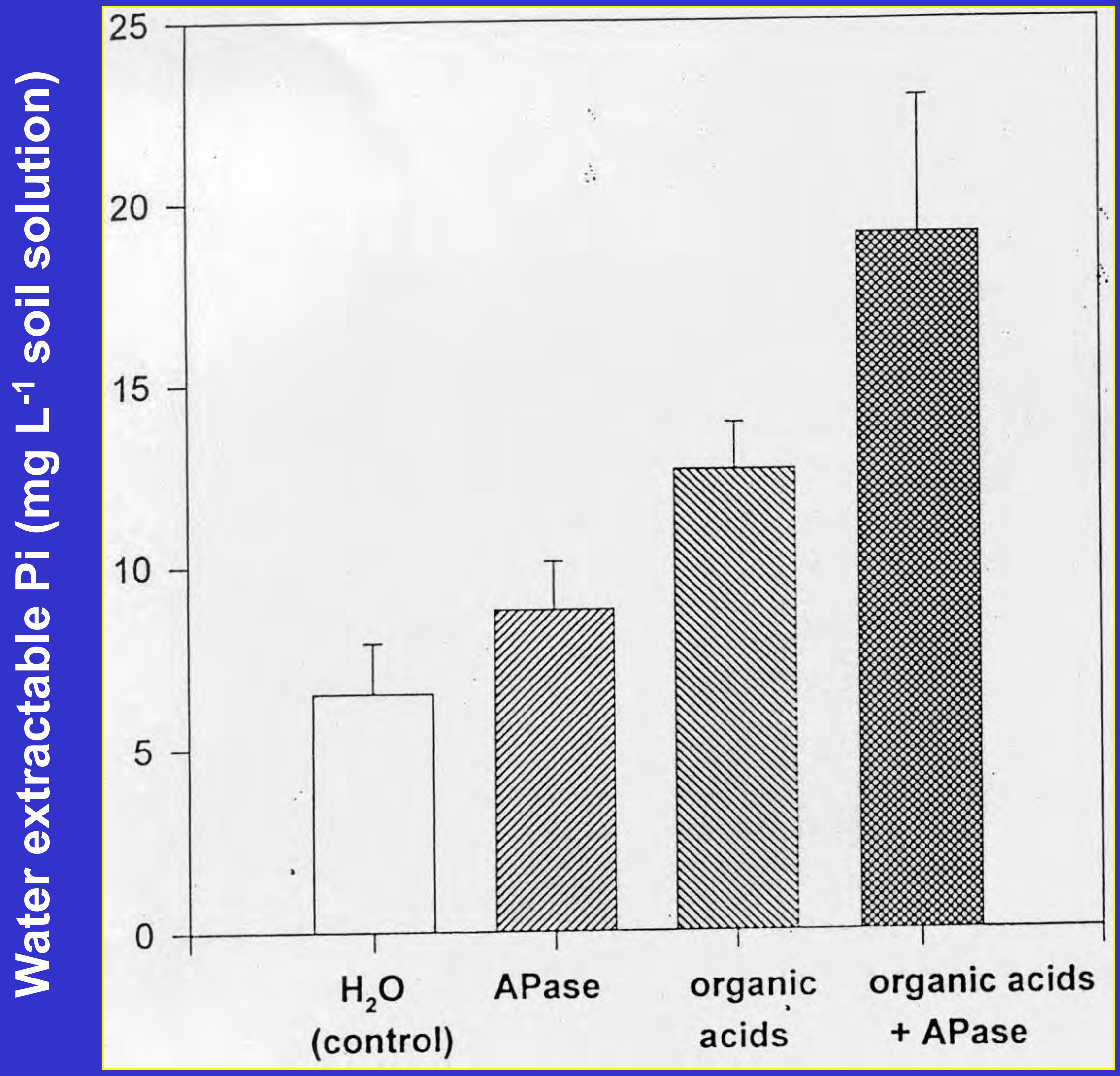
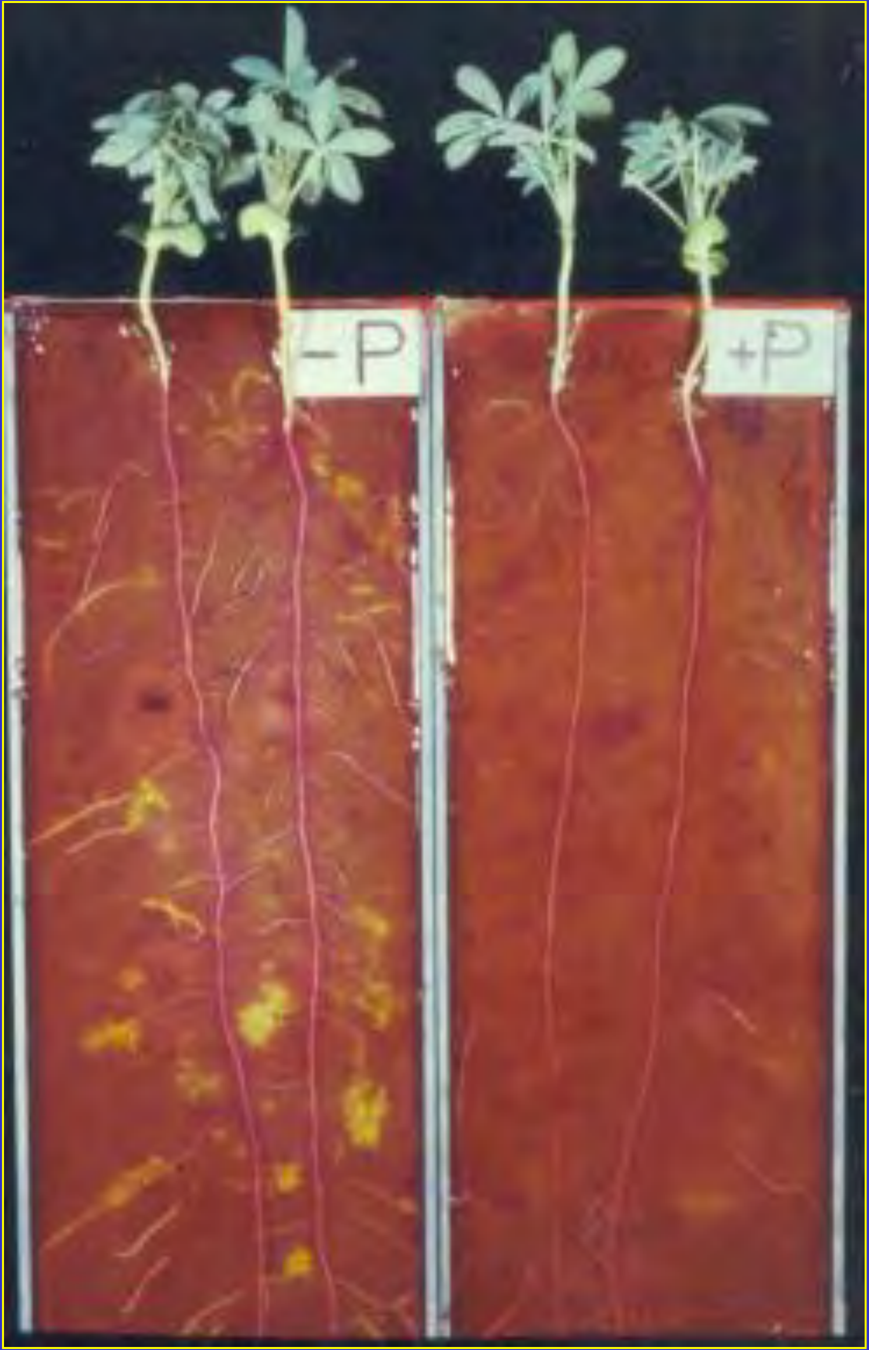
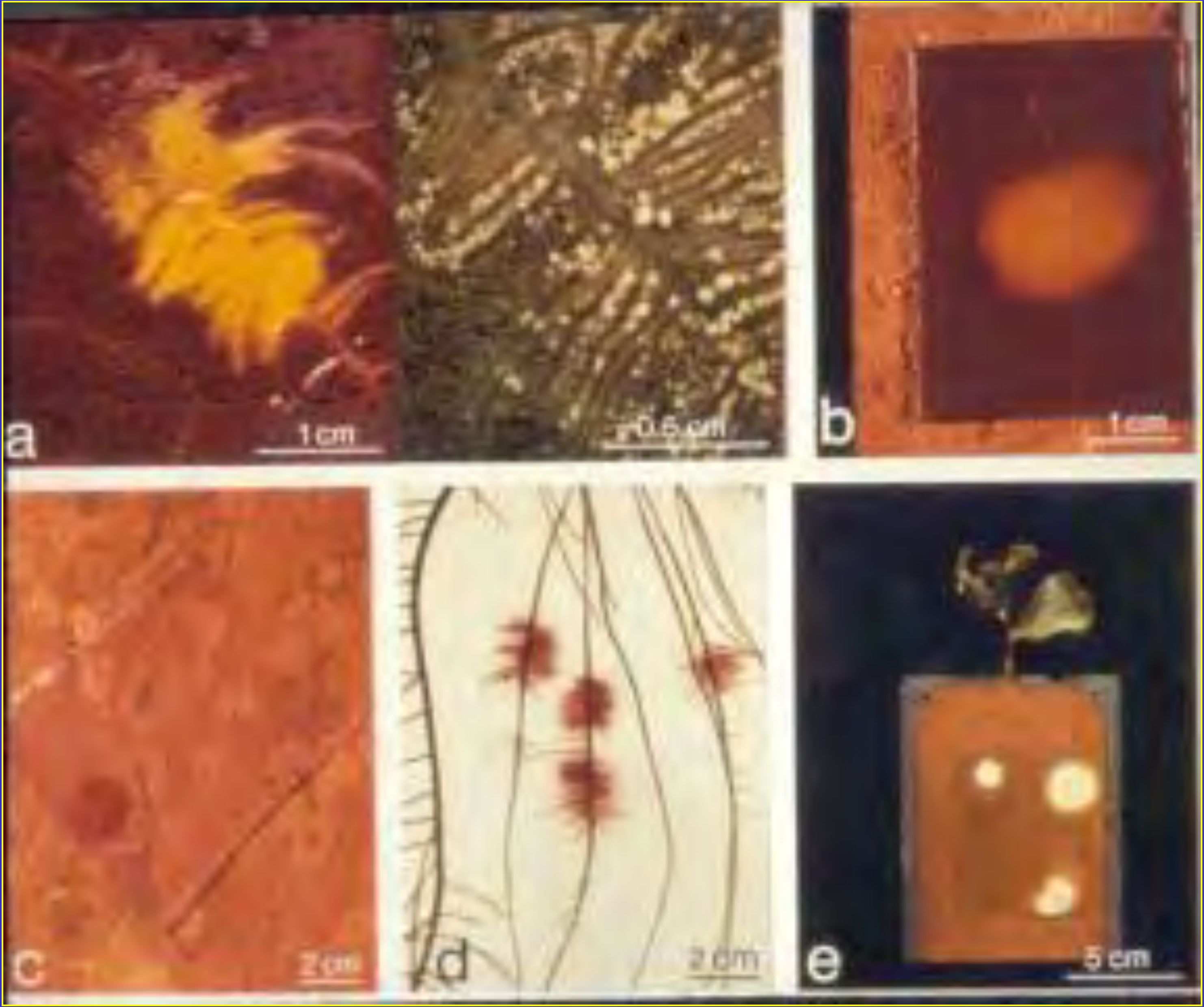


Figure 6. Water-extractable Pi in a phosphorus-deficient sandy soil from Niger (West Africa) after separate or simultaneous addtion of acid phosphatase and of organic acids detected in the proteoid-rhizosphere soil solution of *Hakea undulata*. Organic acids: malic 7.5 mM; citric 2 mM; fumaric 1 mM; t-aconitic 0.6 mM acid phosphatase: Wheat germ Apase according to enzyme activity in rhizosphere soil [0.7 U g soil $^{-1}$].

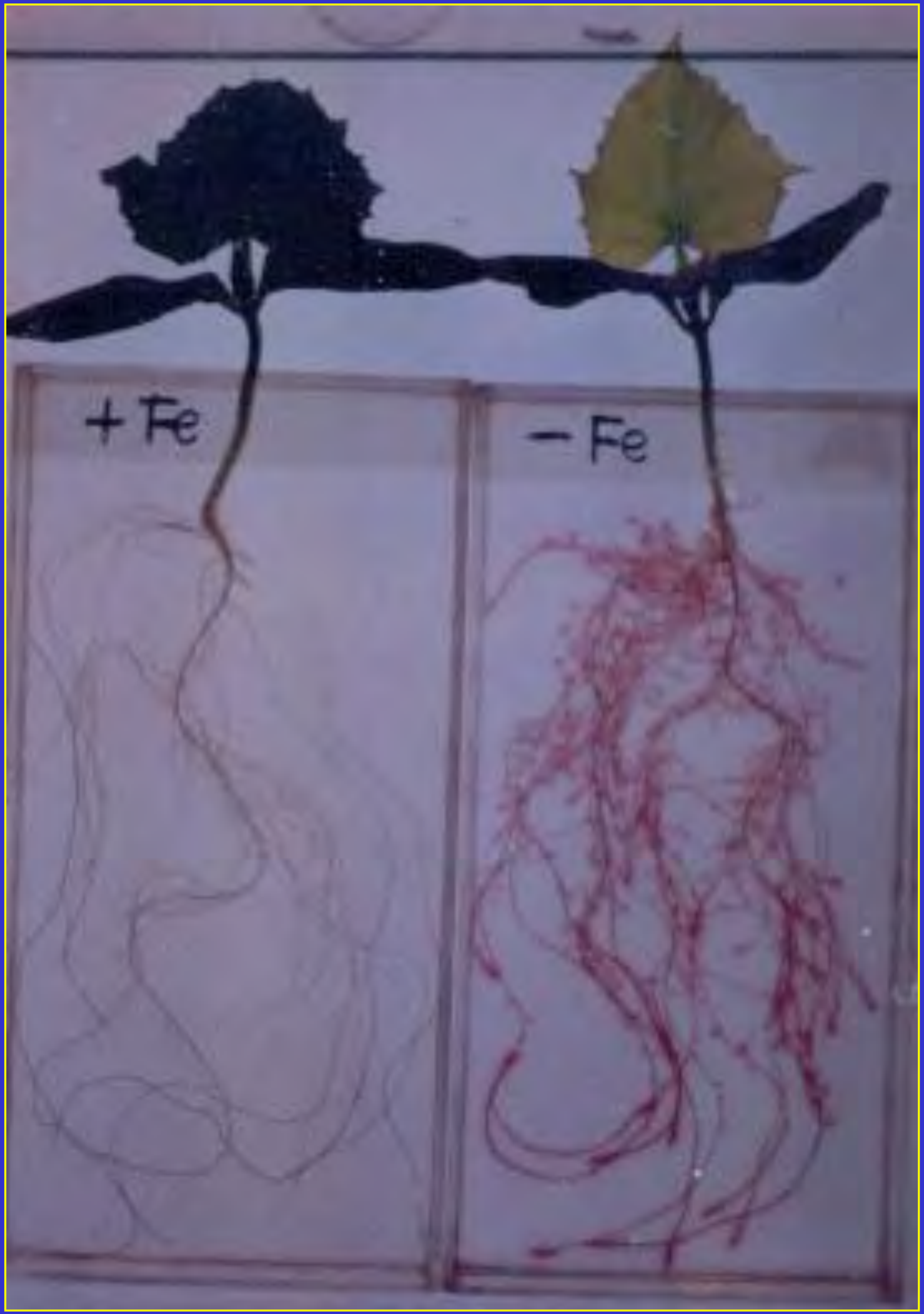

-P
+P

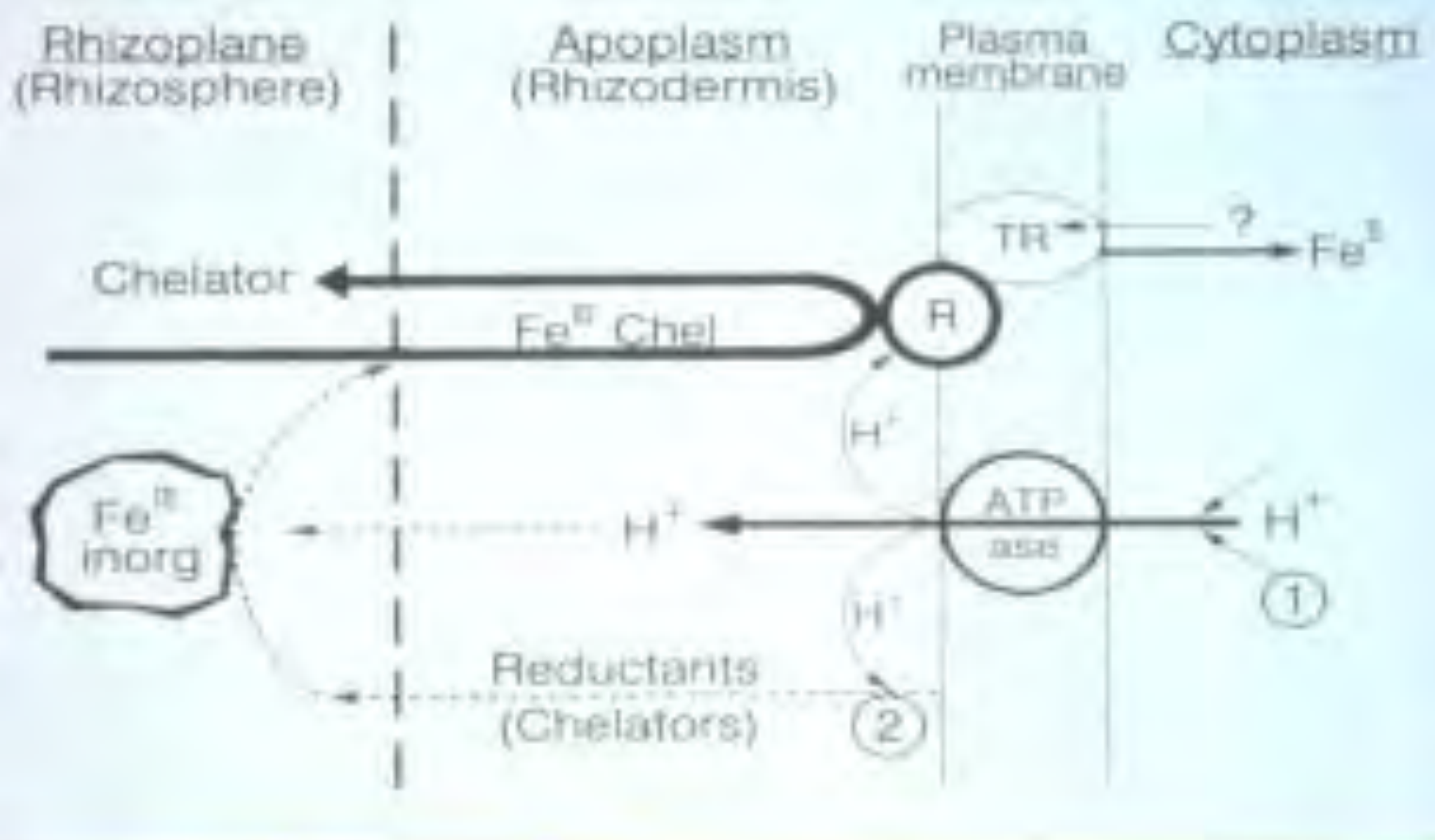

a
1 cm
0.5 cm
b
1 cm
c
2 cm
d
2 cm
e
5 cm


Valencia
71-234
Fe-anorg
2x10⁻⁵M

Severe Fe deficiency chlorosis in a new cultivar of lettuce on a calcareous soil in Italy

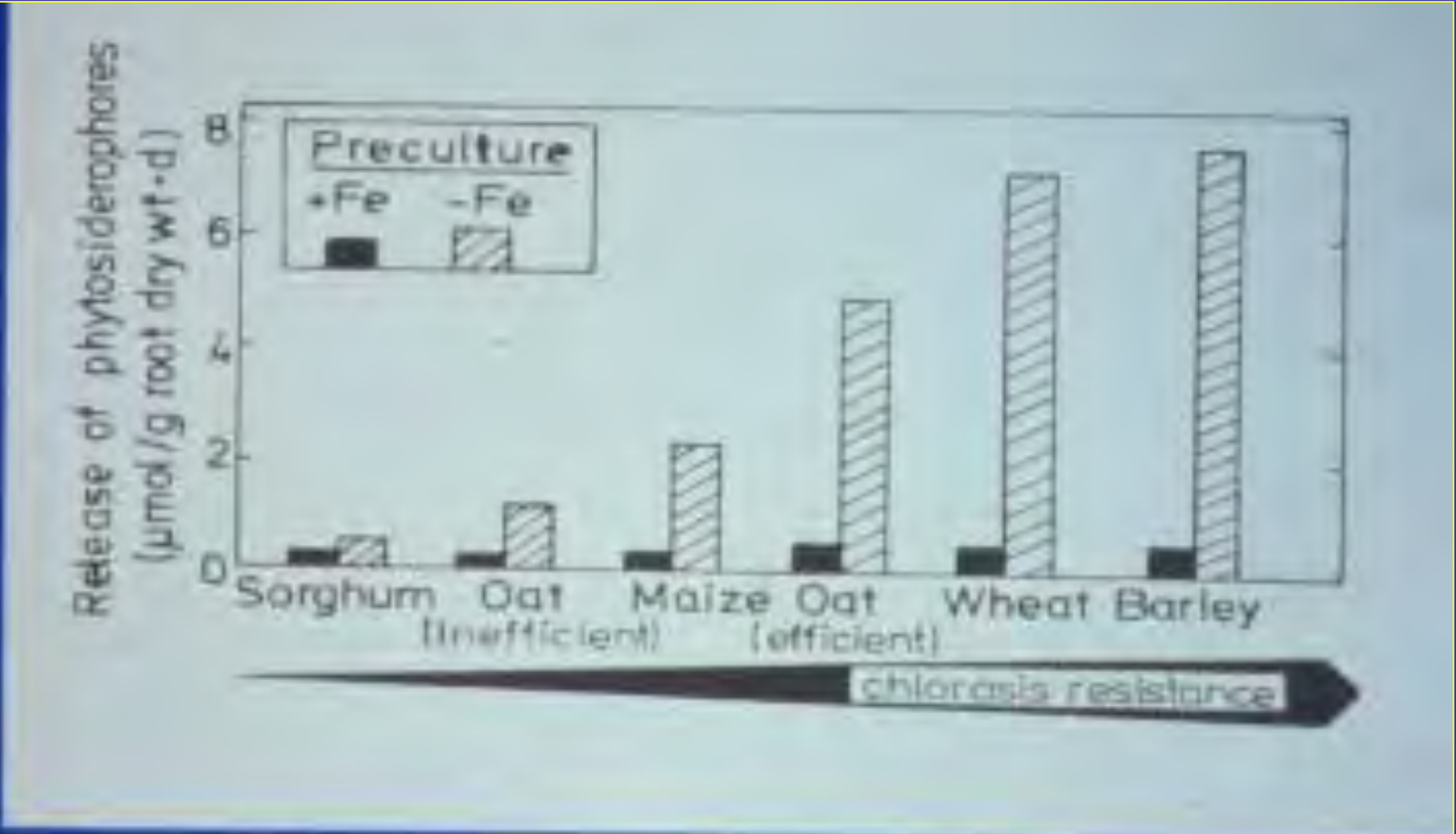

+Fe
– Fe


+ Fe
− Fe

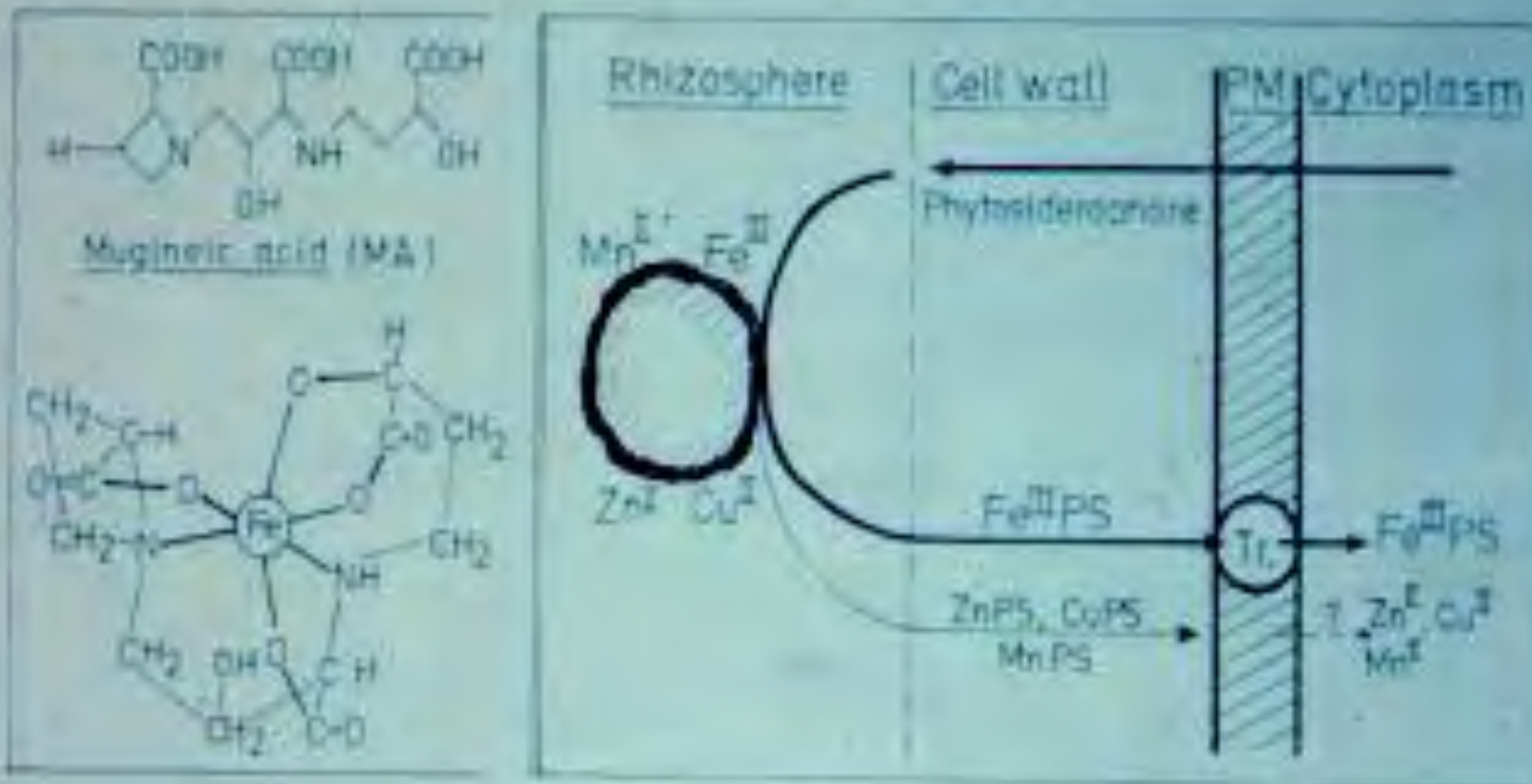


Model for root responses to Fe deficiency in graminaceous species (Strategy I)


Alice
ys1/ys1

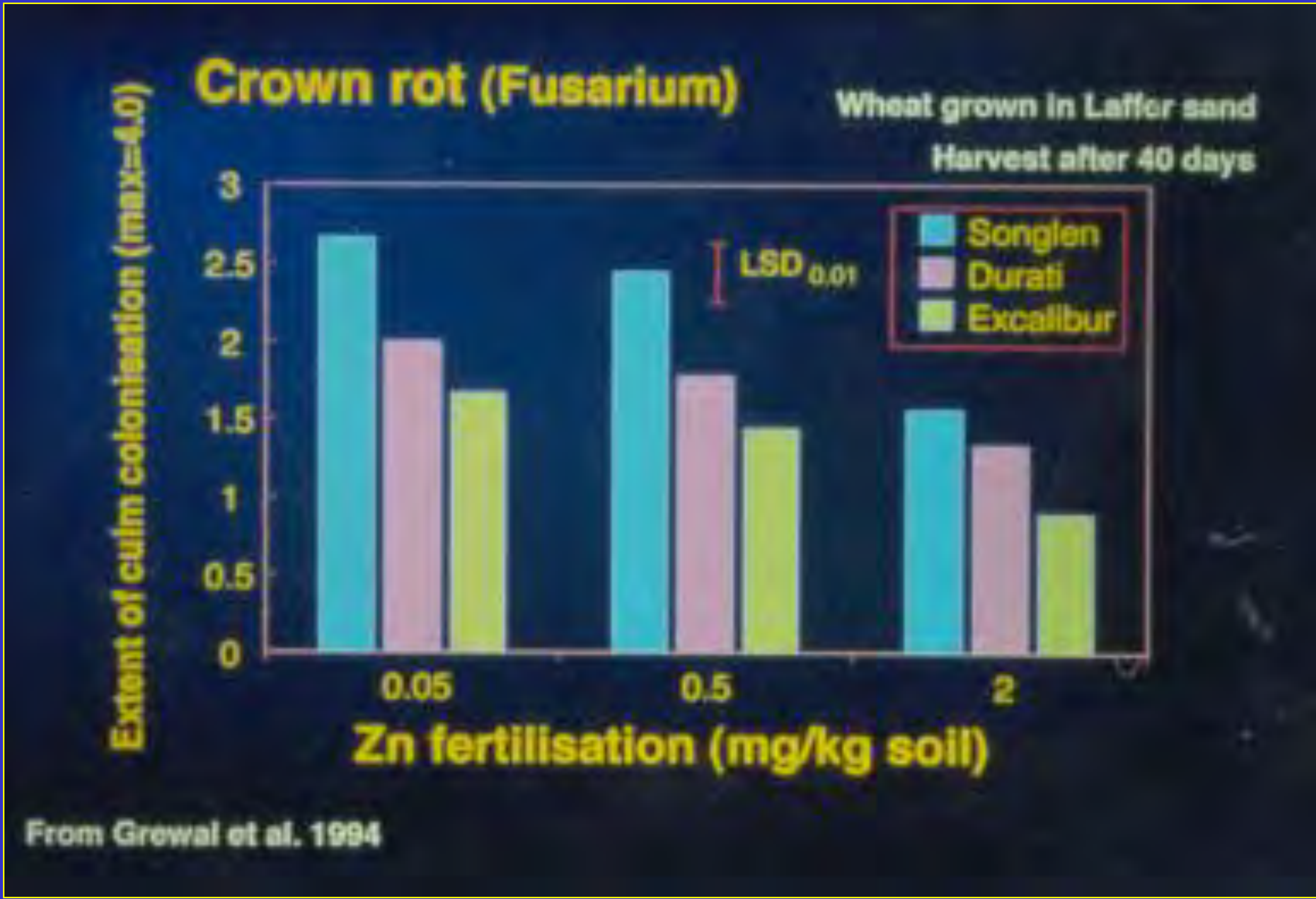


Relationship between release of Fe mobilizing root exudates (PS) and Fe chlorosis resistance in various graminaceous genotypes

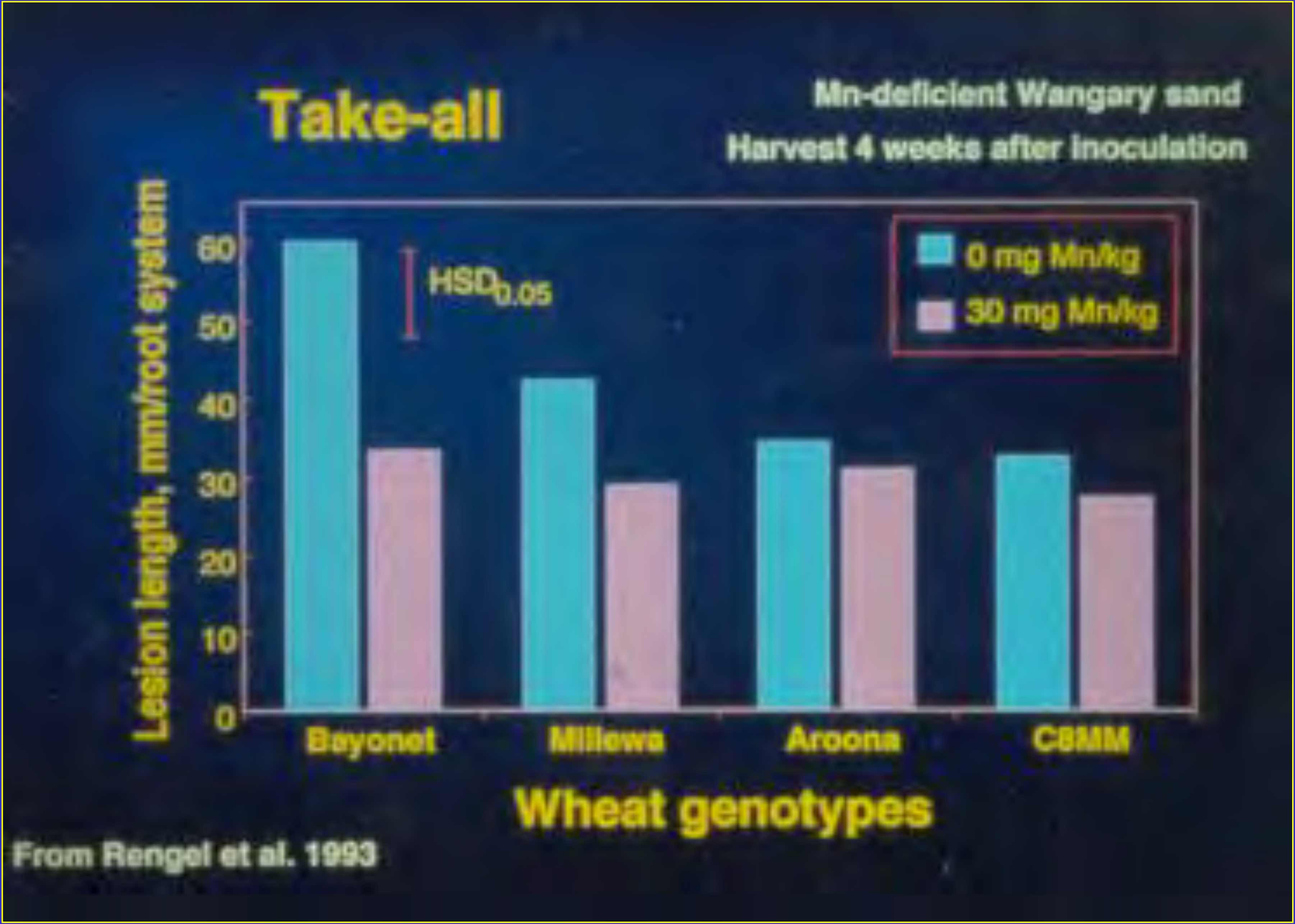


Model for root responses to Fe deficiency in graminaceous species (Strategy II)


+Zn
-Zn
durum wheat
bread wheat
rye



Crown rot (Fusarium)
Wheat grown in Laffer sand
Harvest after 40 days
Extent of culm colonisation (max=4.0)
3
2.5
2
1.5
1
0.5
0
LSD 0.01
Songlen
Durati
Excalibur
0.05
0.5
2
Zn fertilisation (mg/kg soil)
From Grewal et al. 1994



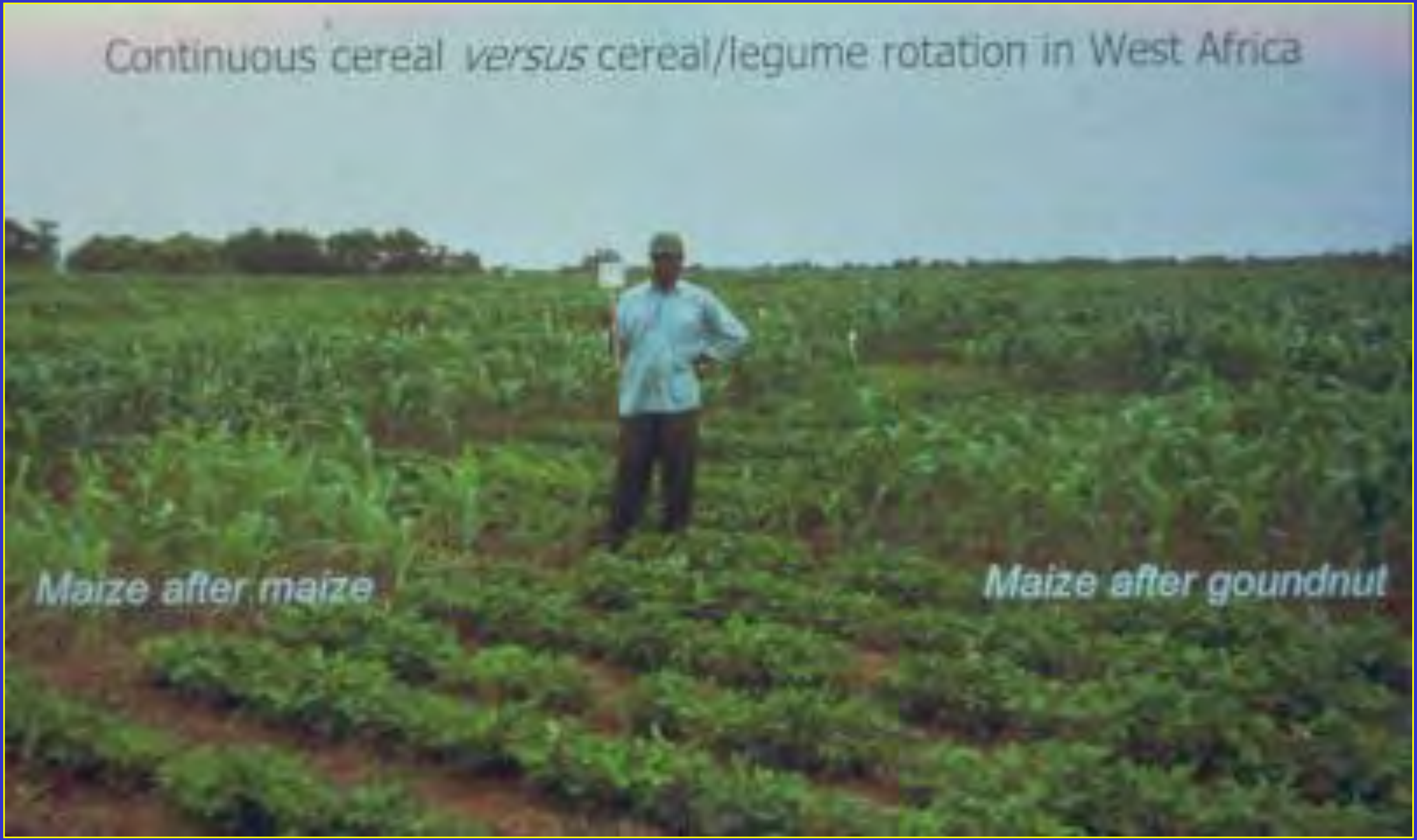
Take-all
Mn-deficient Wangary sand
Harvest 4 weeks after inoculation
Lesion length, mm/root system
0
10
20
30
40
50
60
HSD0.05
0 mg Mn/kg
30 mg Mn/kg
Bayonet
Millewa
Aroona
C8MM
Wheat genotypes
From Rengel et al. 1993

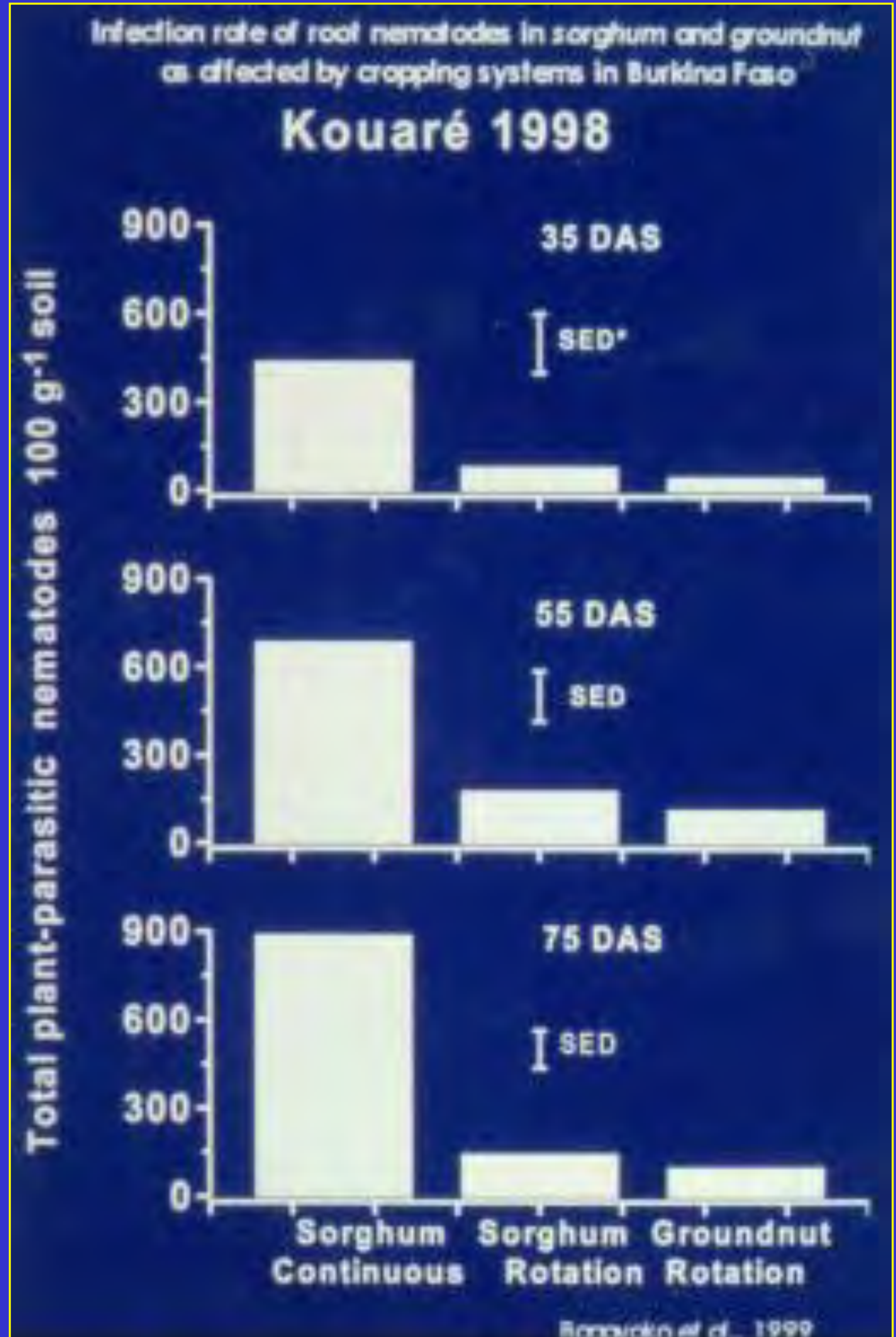
- Mn
- Gg.
+ Mn
+ Gg
- Mn
+ Gg
+ Mn
- Gg

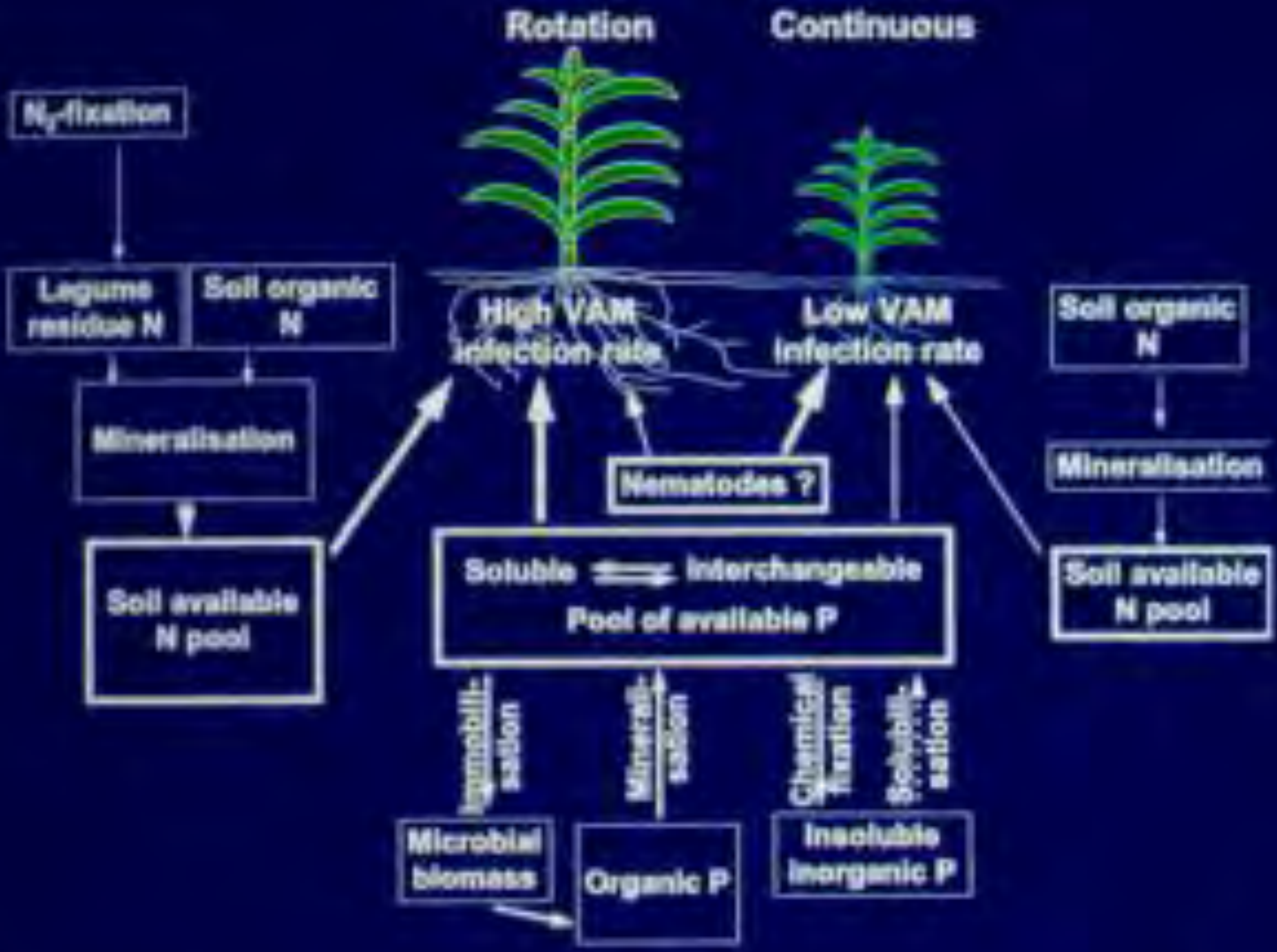
- **Role of rhizosphere processes in sustainable agricultural production systems**

Example:

- Cereal / legume rotation (West Africa)
- Improved growth by crop residues application


Continuous cereal versus cereal/legume rotation in West Africa
Maize after maize
Maize after goundnut

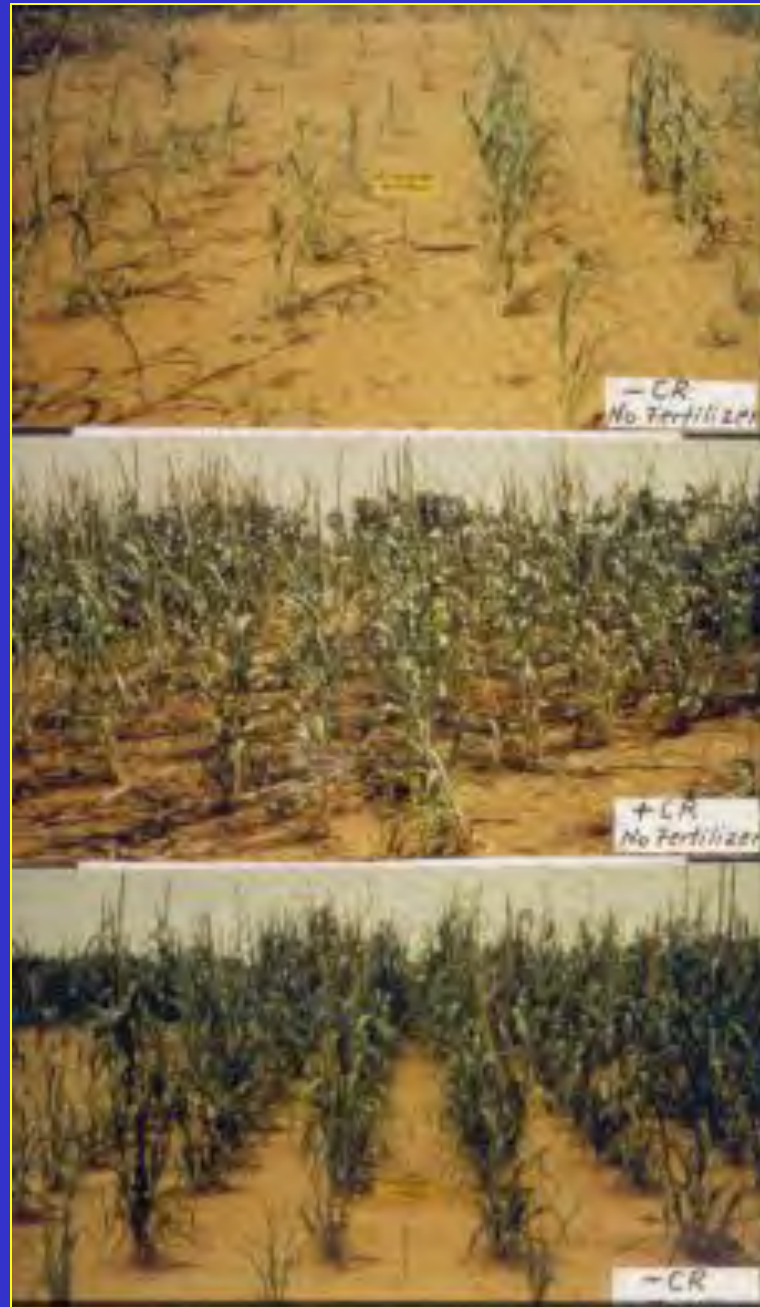

Infection rate of root nematodes in sorghum and groundnut
as affected by cropping systems in Burkina Faso
Kouaré 1998
Total plant-parasitic nematodes 100 g-1 soil
900
600
300
0
35 DAS
SED*
55 DAS
SED
75 DAS
SED
Sorghum Continuous
Sorghum Rotation
Groundnut Rotation



A conceptual model to explain rotation effects in the Sudano-Sahelian zone of West Africa

Bagayoko et al., 1999


Rotation effects in Sudano-Sahelian West Africa
Continuous
Rotation
Likely causes:
early increase in Nmin
early increase in AM
decrease in nematodes
increase in phosphatase


– CR
No Fertilizer
+ CR
No Fertilizer
– CR

On-farm trial (Niger)

Effects of crop residues on growth

- Protection of seedlings against wind erosion and high soil temperature
- Less soil crusting
- Return of nutrients
- Lower Al saturation
- Lower Al concentration in soil solution
- More Al complexation / detoxification
- Higher P concentration in soil solution
- Higher Mo concentration in soil solution
- Higher activity of diazotrophic bacteria

→ more N_2 fixation, more phytohormones!

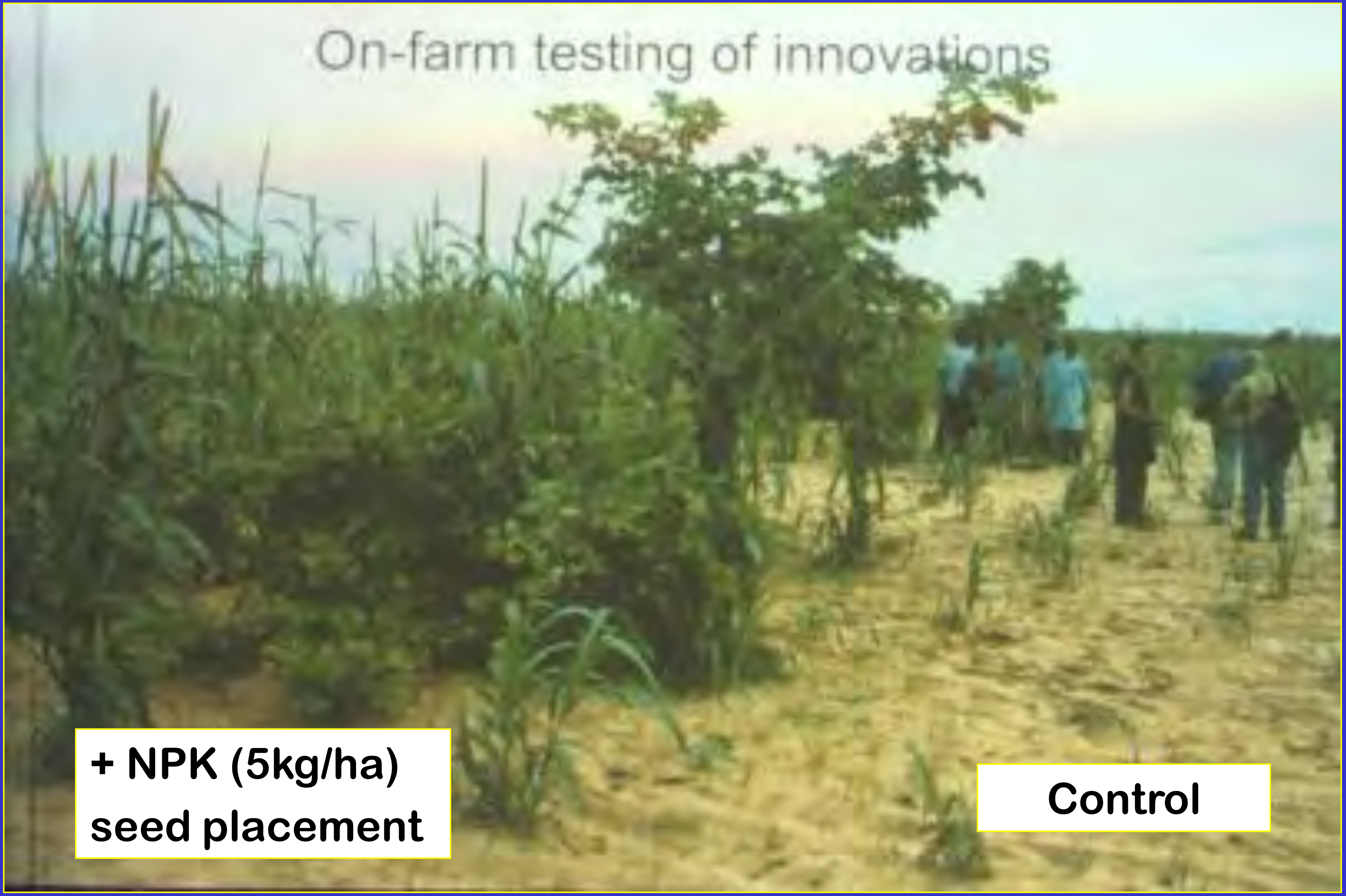
→ Better root growth

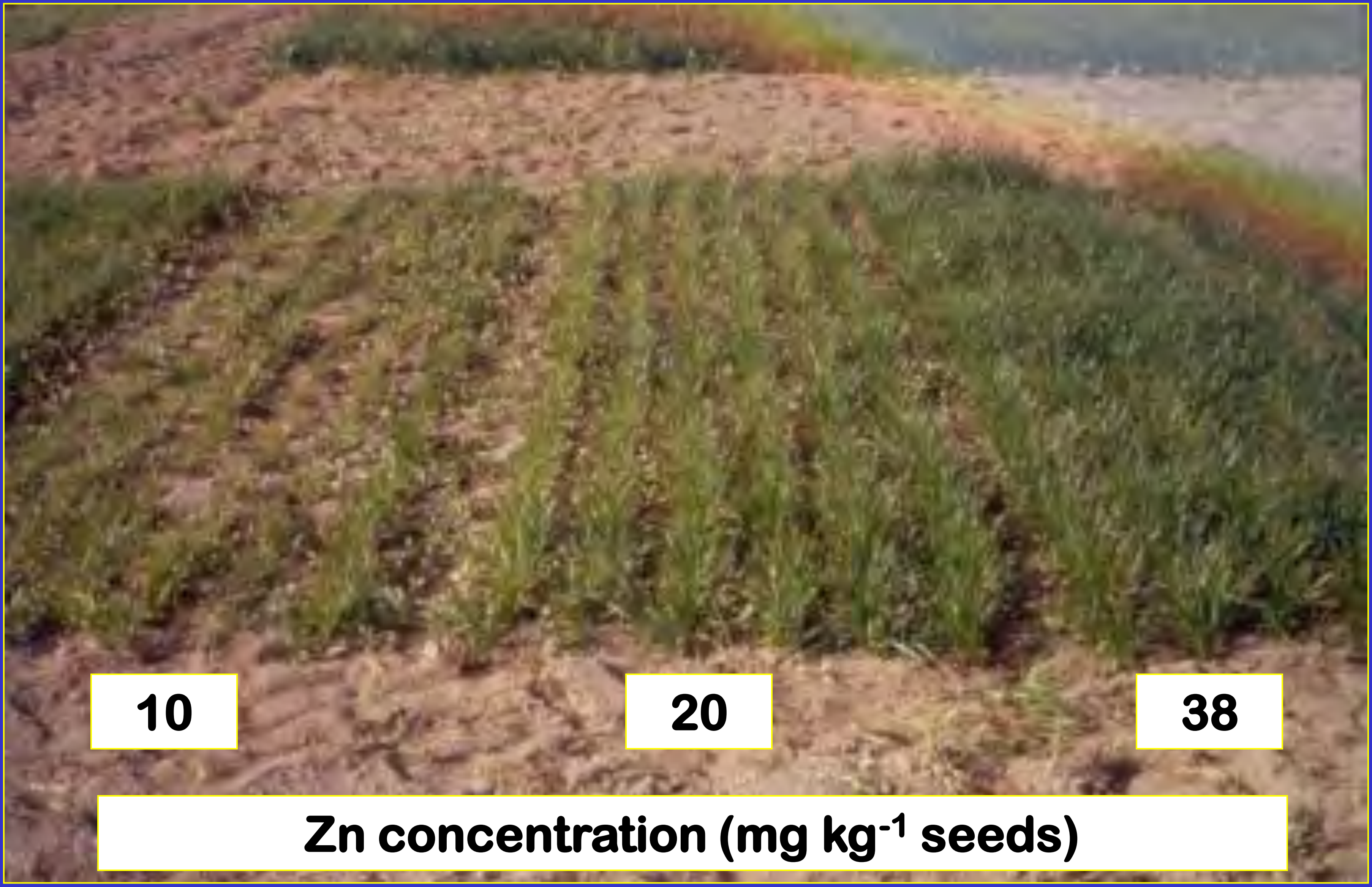
→ Better nutrient acquisition!

■ Rhizosphere management for better plant growth

- Fertilizer placement - homeopathic application rate
- Seed coating with Zn, Mn, Mo
- Use of NH_4^+ + nitrification inhibiton
- NH_4^+ placement / "cultan" technique
- Use of biofertilizer

  - P mobilizing bacteria
  - N_2 fixing bacteria
  - Phytohormone producing bacteria
  - Plant growth promoting bacteria
  - Pathogen suppressive bacteria
  - Mycorrhiza inoculum


On-farm testing of innovations
+ NPK (5kg/ha)
seed placement
Control


10
20
38
Zn concentration (mg kg-1 seeds)

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- Gleichmäßigerer Feldaufgang
- Positive Beeinflussung der Wurzelentwicklung
- Bessere Wasser- und Nährstoff-versorgung
- Greening-Effekt in den Blättern
- Bessere Kolbenfüllung
- Bessere Verträglichkeit von PS-Maßnahmen

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Positive Wurzelentwicklung durch Opticoat®-ZM Plus

Weitere Infos:
www.opticoat.de

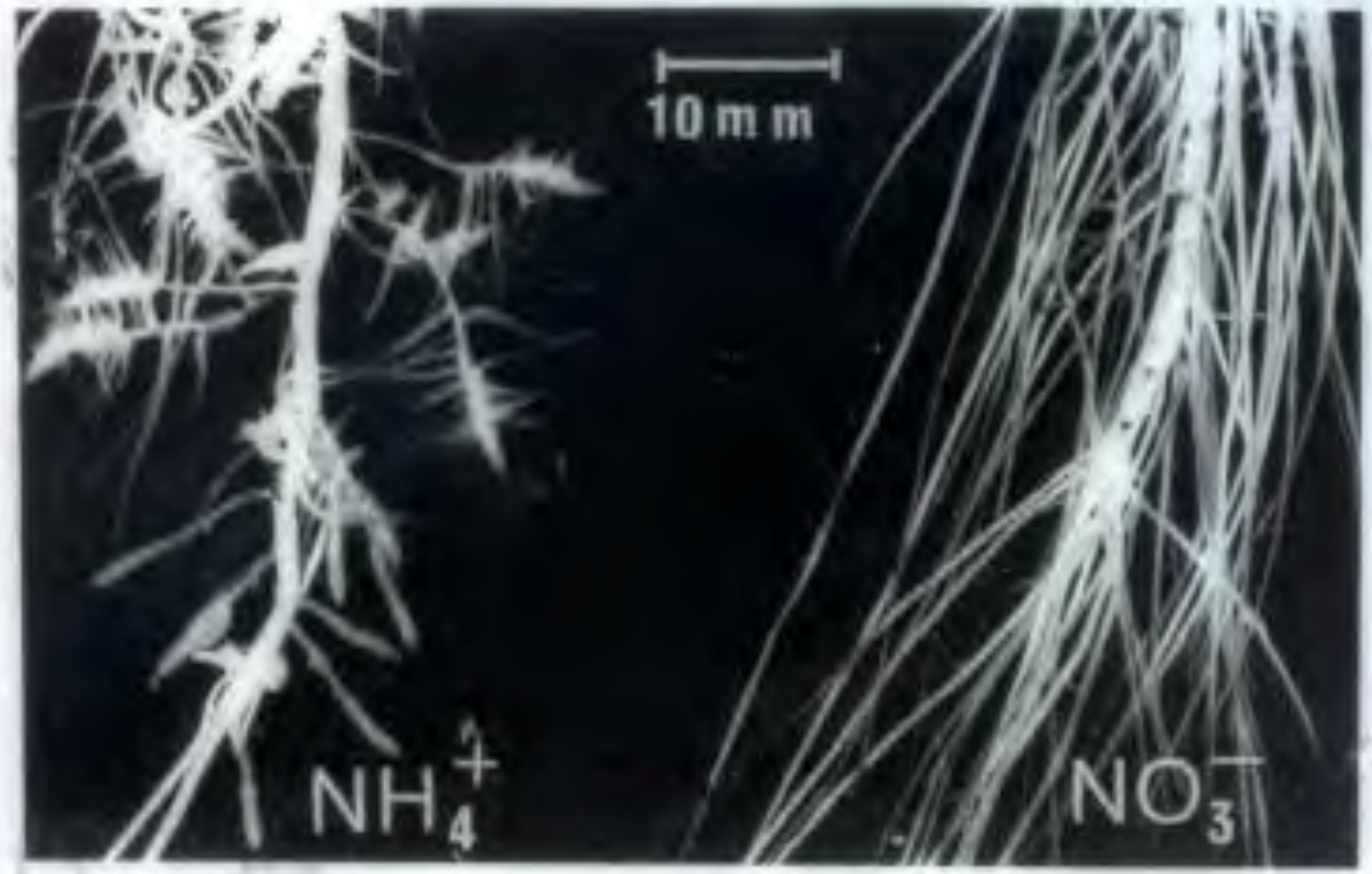
Faktoren, die die Verfügbarkeit von Mangan und Zink im Boden beeinflussen

Faktoren	Mn	Zn
Hoher pH-Wert	↓	↓
Niedriger pH-Wert	↑	↘
Hohe P-Bodengehalte	↘	↓
Mangel an O_2 im Boden	↗	
Organische Substanz (Huminsäuren/Fulvosäuren)	↑	↑
Hohe Temperaturen	↑	↑
Niedrige Temperaturen	↓	↓
Starker Lichteinfluß	↓	
Trockenheit	↓	↘

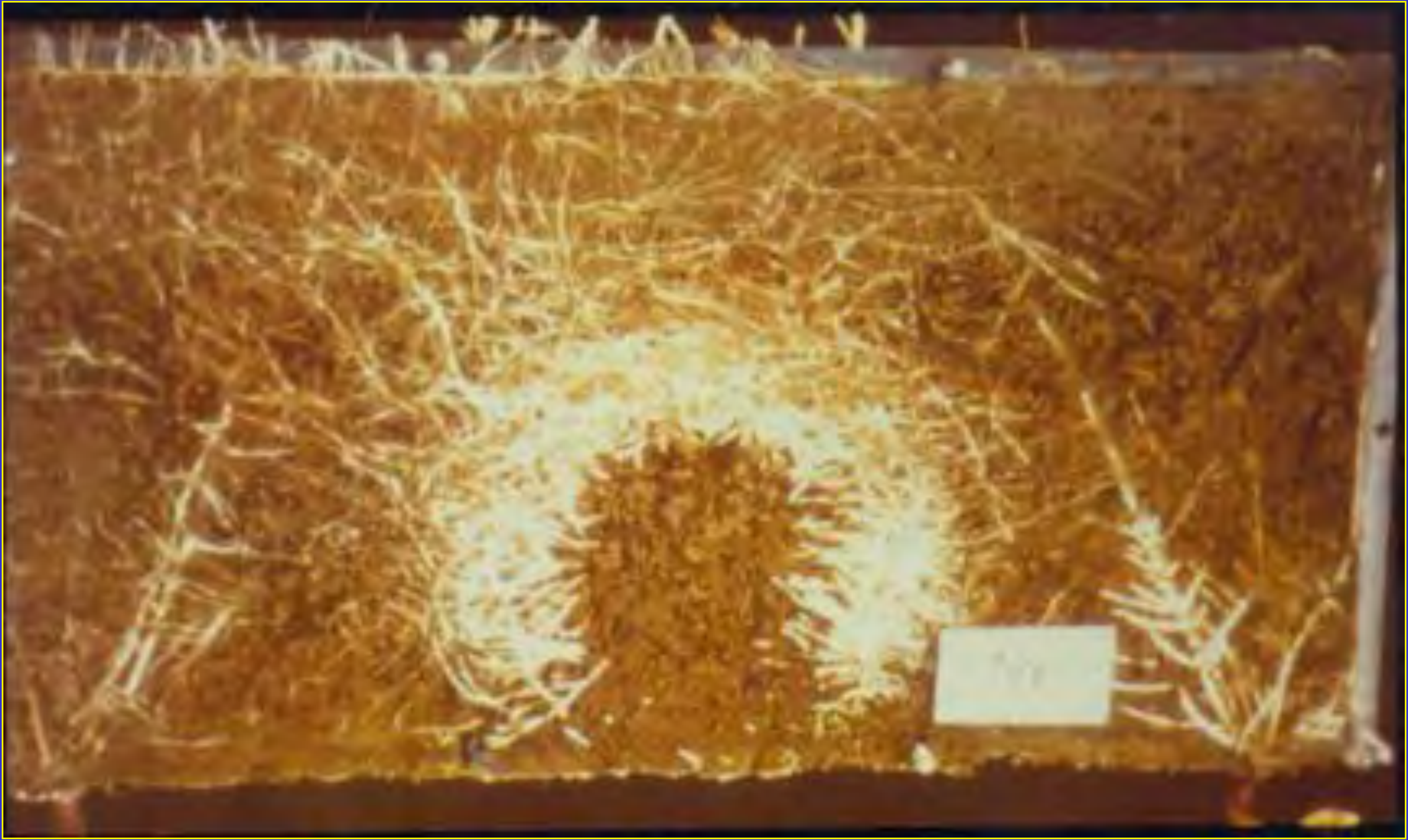
Inhibition of leaf expansion at sole NH_4^+ nutrition

27A
28

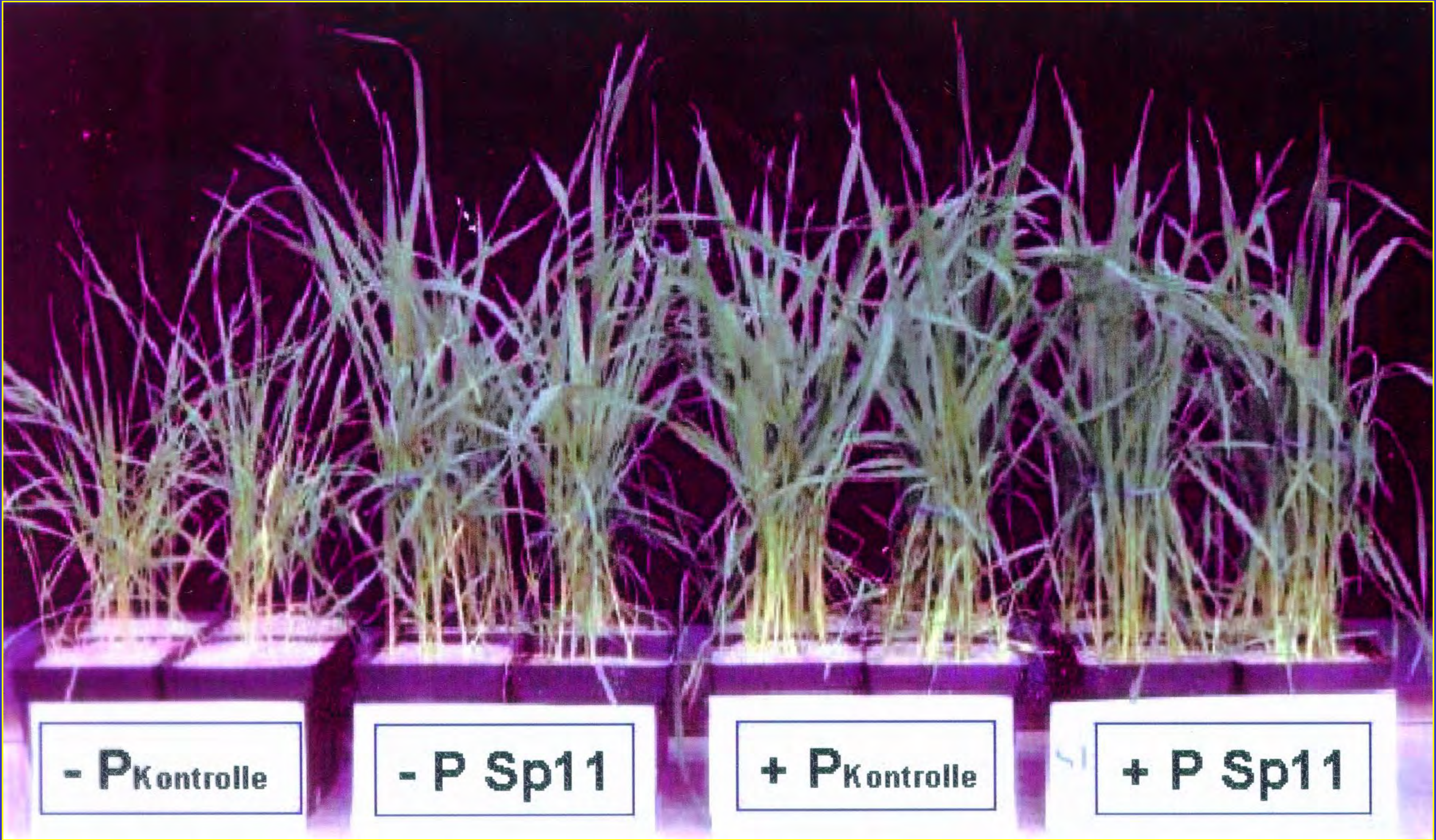
pH 4.5
5.5
6.0
6.5
7.5
NO_3^--N
NH_4^+-N

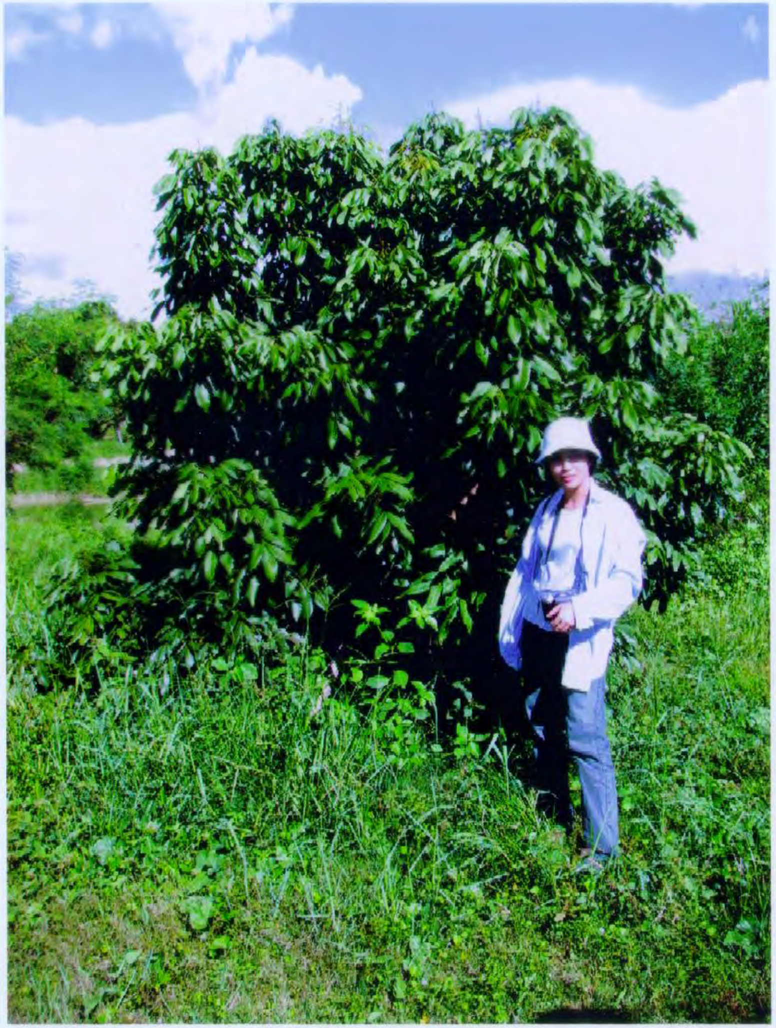


Bhat, Plant Soil 71 (1983)



AM inoculation


- P Kontrolle
- P Sp11
+ P Kontrolle
+ P Sp11



Three years old longan tree, regulary sprayed with "biofertilizer"

Five years old longan trees, conventionally raised and treated

■ Summary - Prospect

- Rhizosphere processes are important for growth improvement
- Our knowledge in rhizosphere processes is still incomplete, e.g. if microorganisms/pathogens involved
- A better understanding of rhizosphere processes will help to develop/establish new innovative fertilization techniques for integrated sustainable production systems.


Stimulated by
Tsuioshi Yamada's
ideas