IPNI
INTERNATIONAL
PLANT NUTRITION
INSTITUTE

Fertilizer Efficiency with Drip and Microsprinklers

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Merced, CA

IPNI Mission

"To develop and promote scientific information about the responsible management of plant nutrition for the benefit of the human family."

Member Companies

- Agrium Inc.
- Arab Potash Company
- Belarusian Potash Company
- Bunge Fertilizantes S.A
- CF Industries Holdings, Inc.
- Incitec Pivot
- Intrepid Potash, Inc.
- K+S KALI GmbH
- The Mosaic Company
- OCP S.A.
- PotashCorp
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- Sinofert Holdings Limited
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- Terra Industries, Inc.
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- Arab Fertilizer Association (AFA)
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- International Fertilizer Industry Association (IFA)
- International Potash Institute (IPI)
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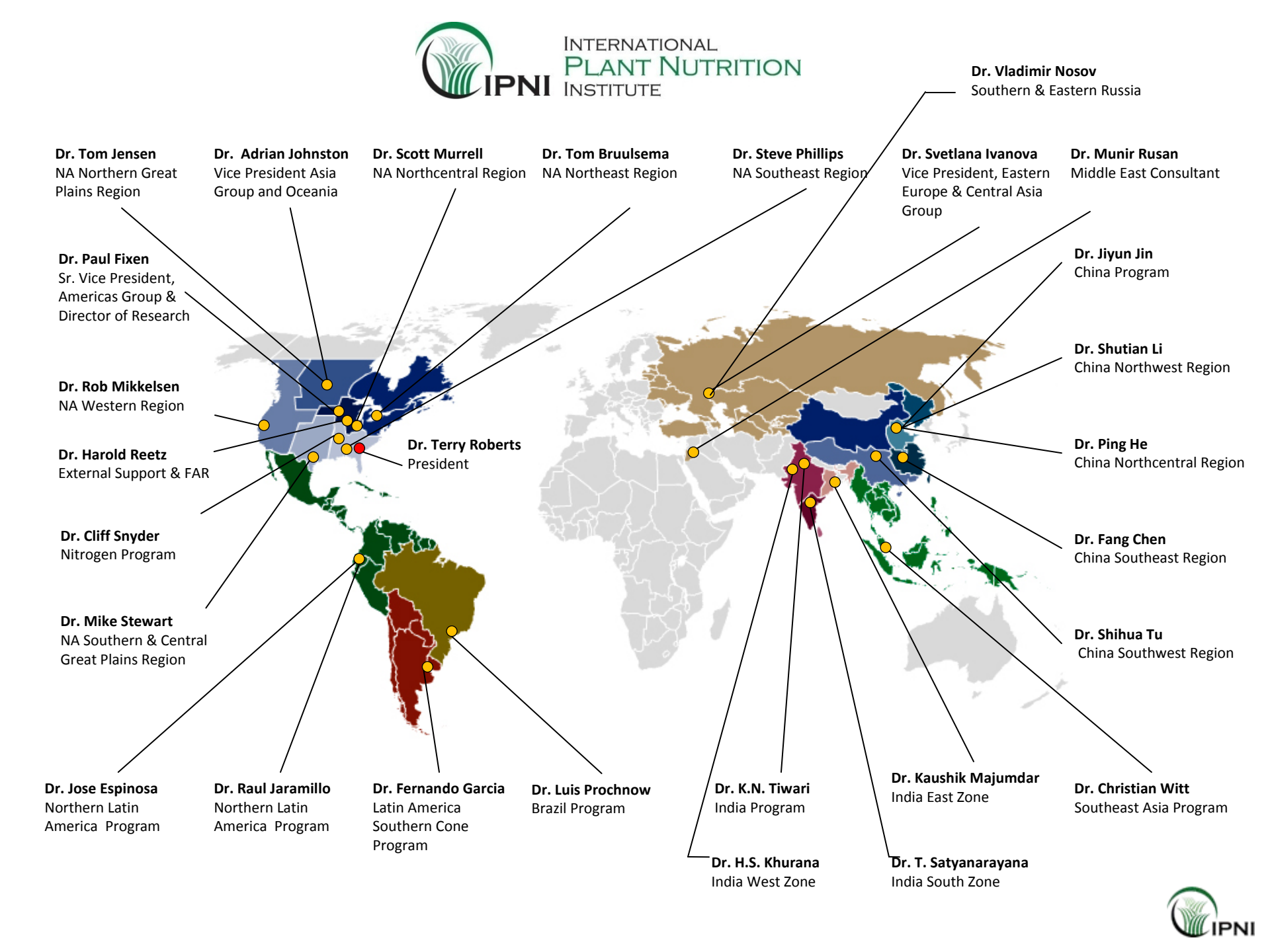

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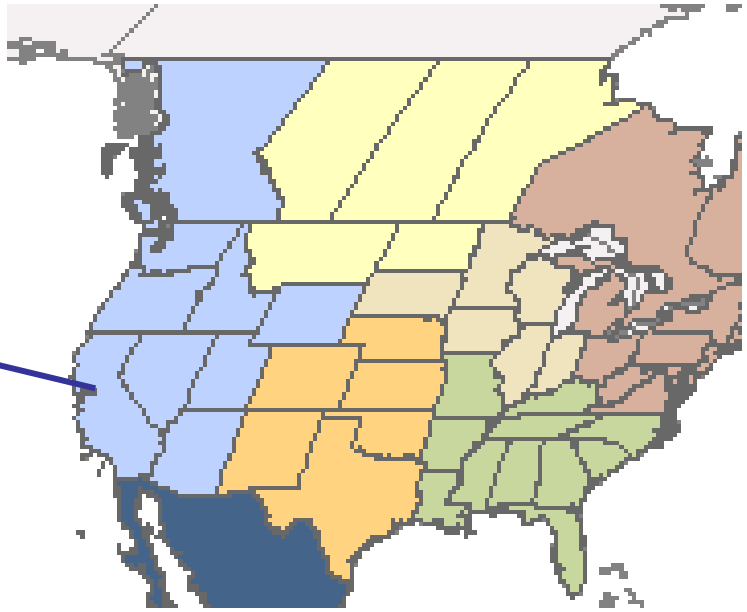
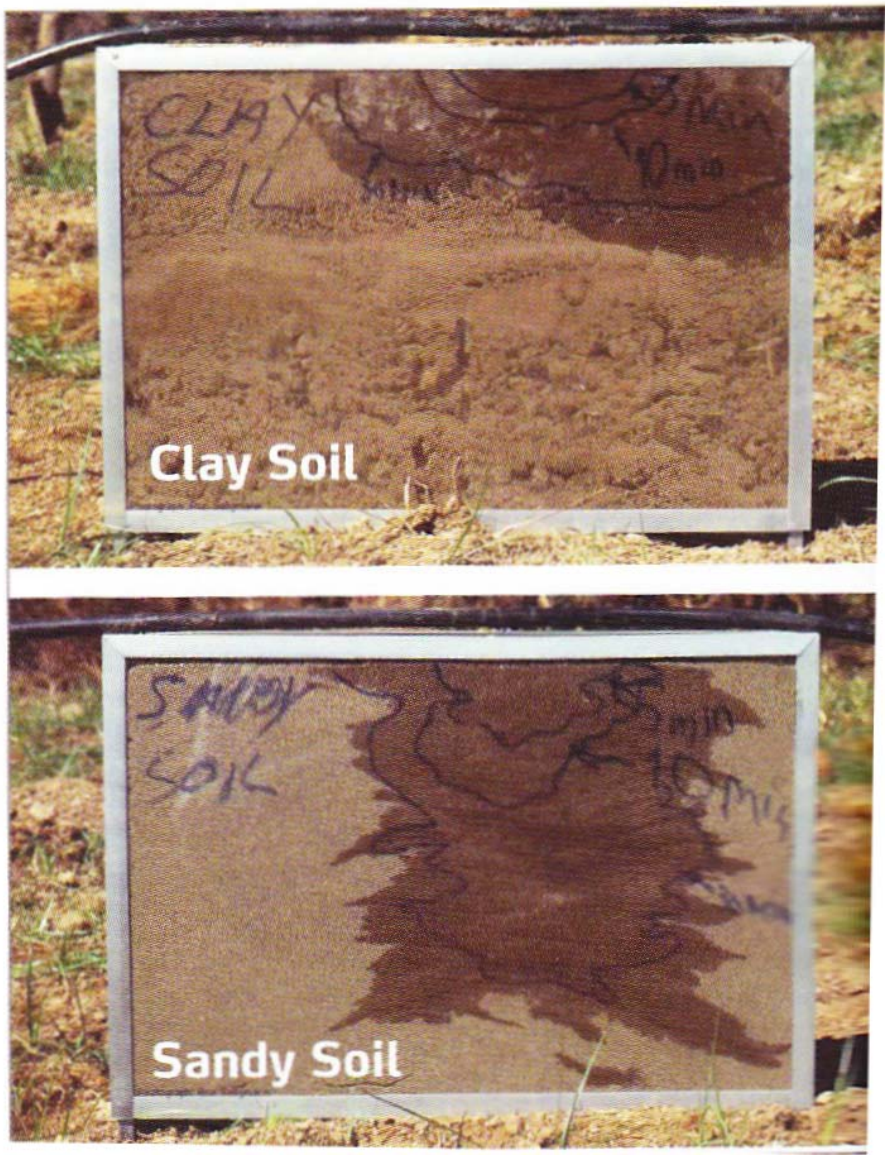
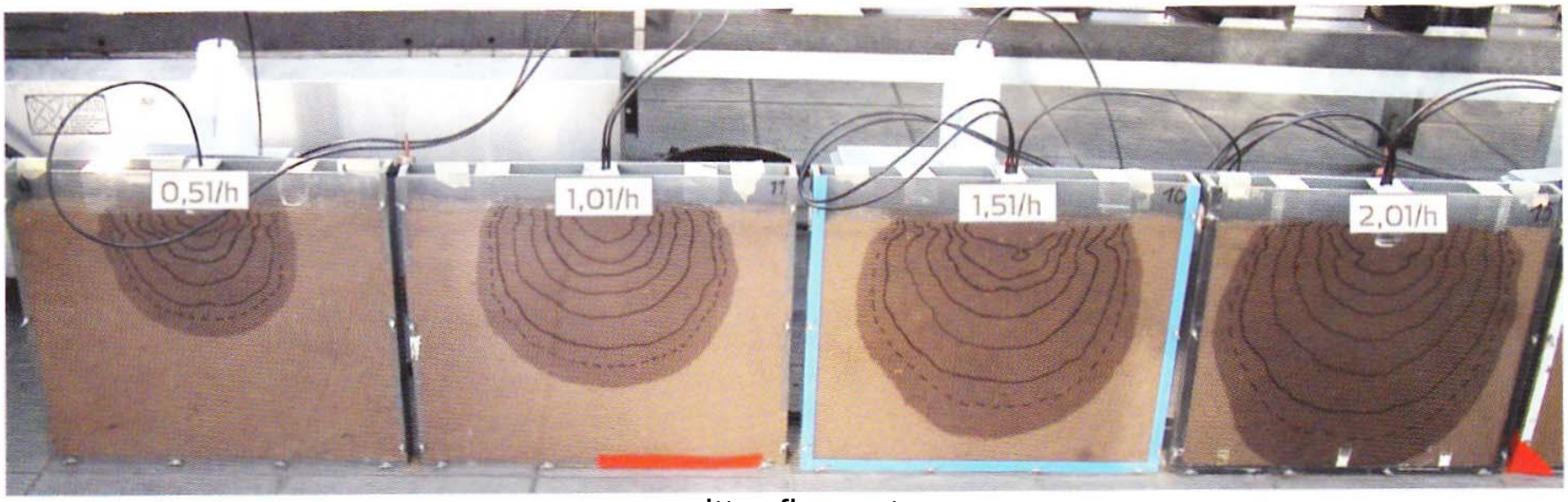


Water infiltration pattern
in a clay and a sandy-textured soil

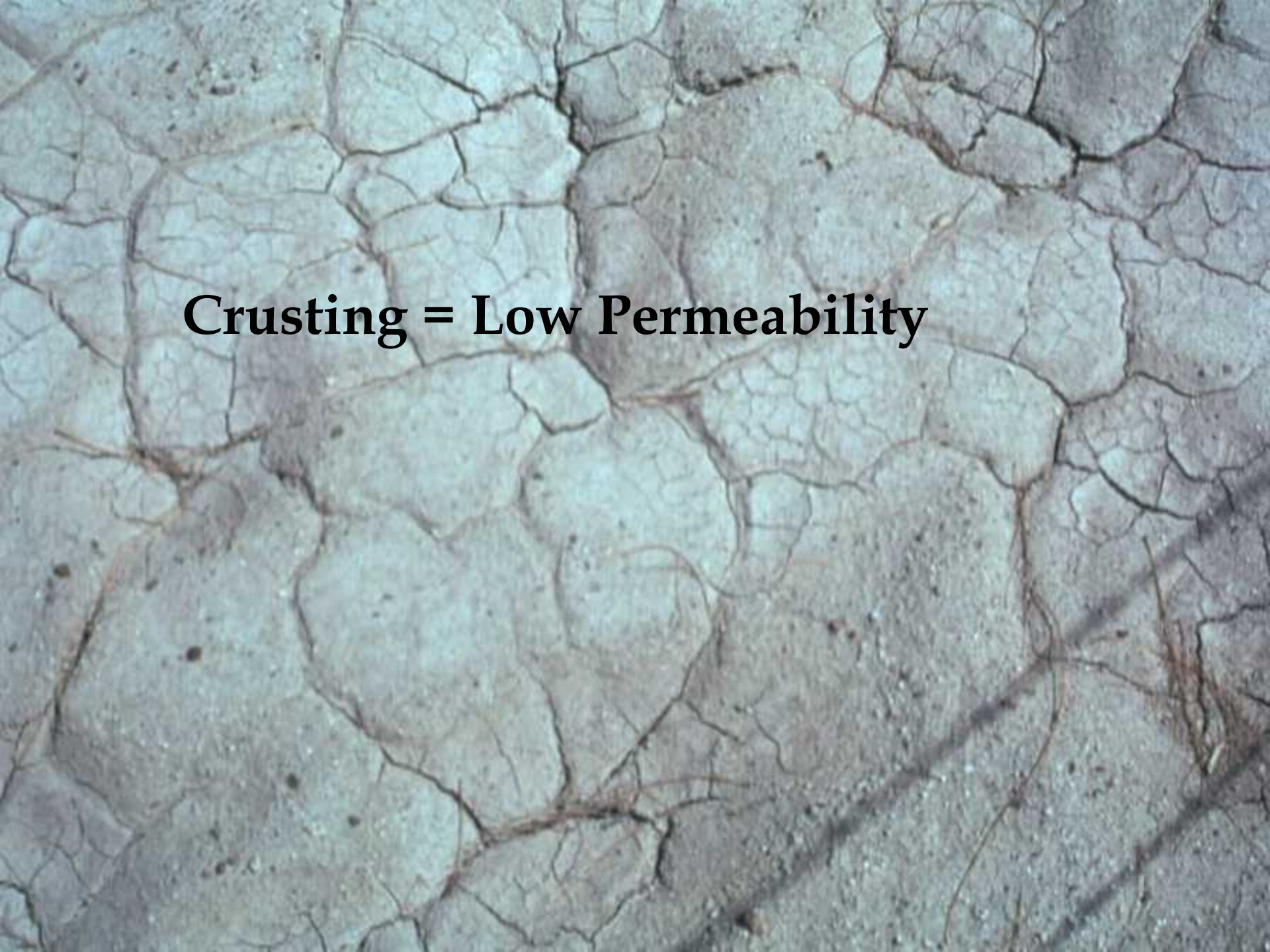


Rate of water delivery determines the volume of wetted soil

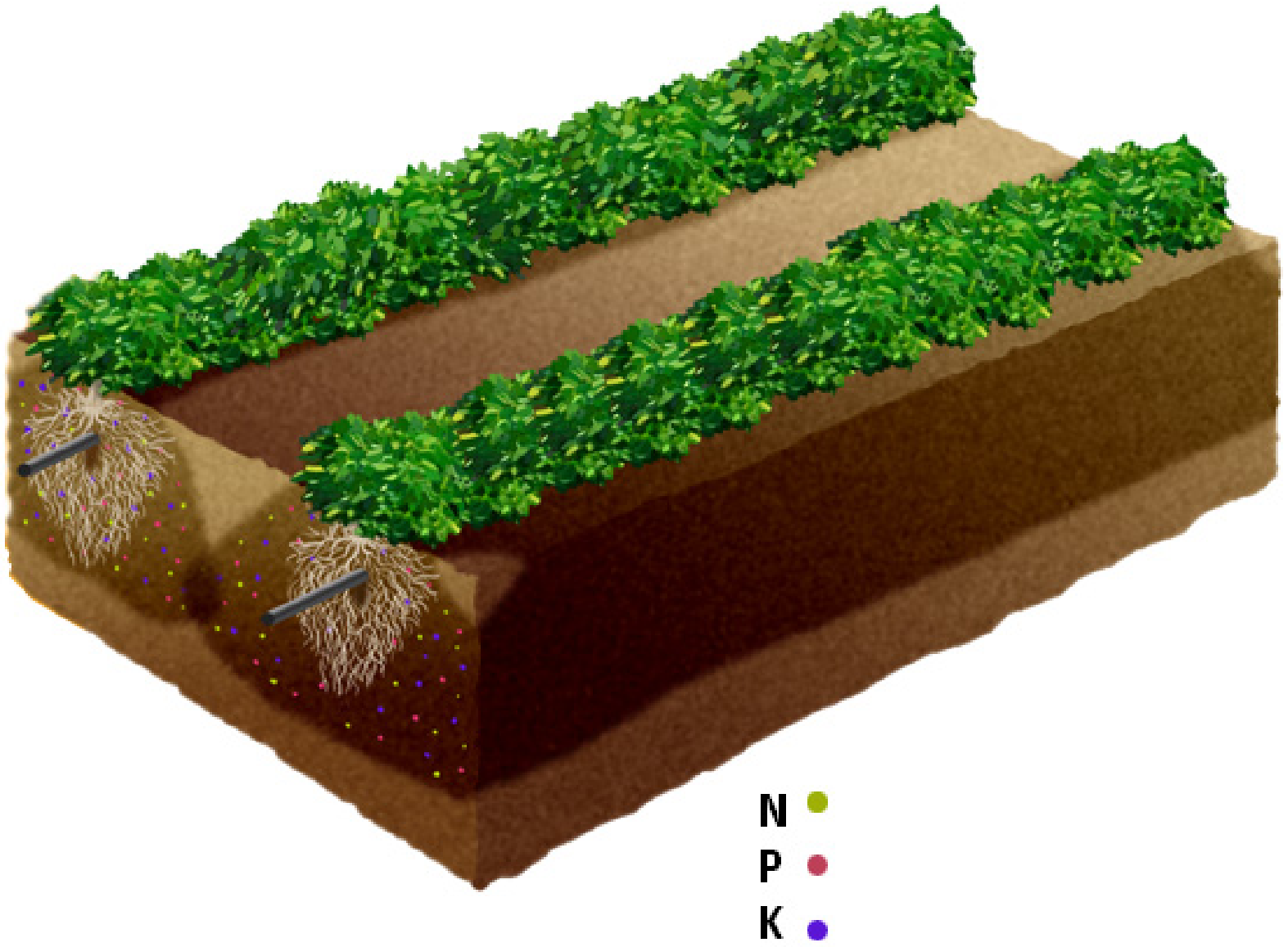


emitter flow rate

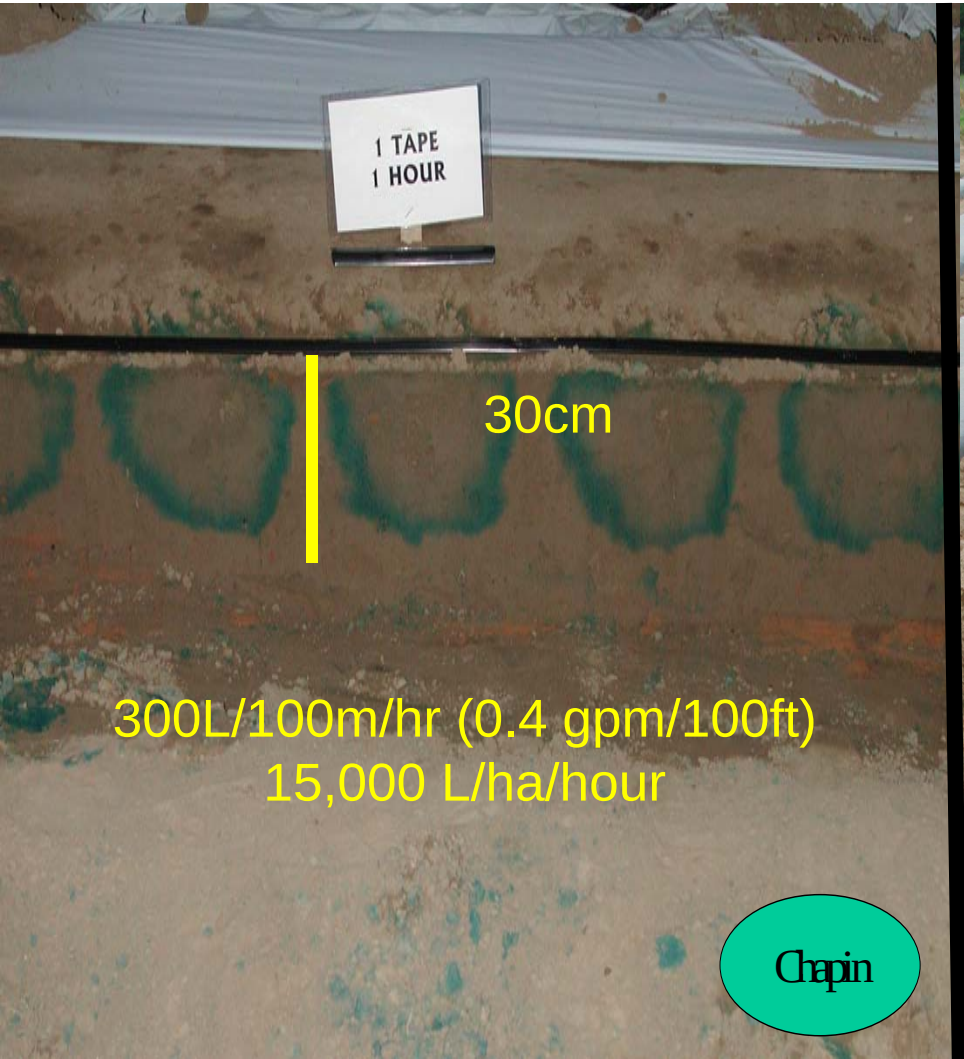
0.5 L/hr 1 L/hr 1.5 L/hr 2L/hr


Crusting = Low Permeability

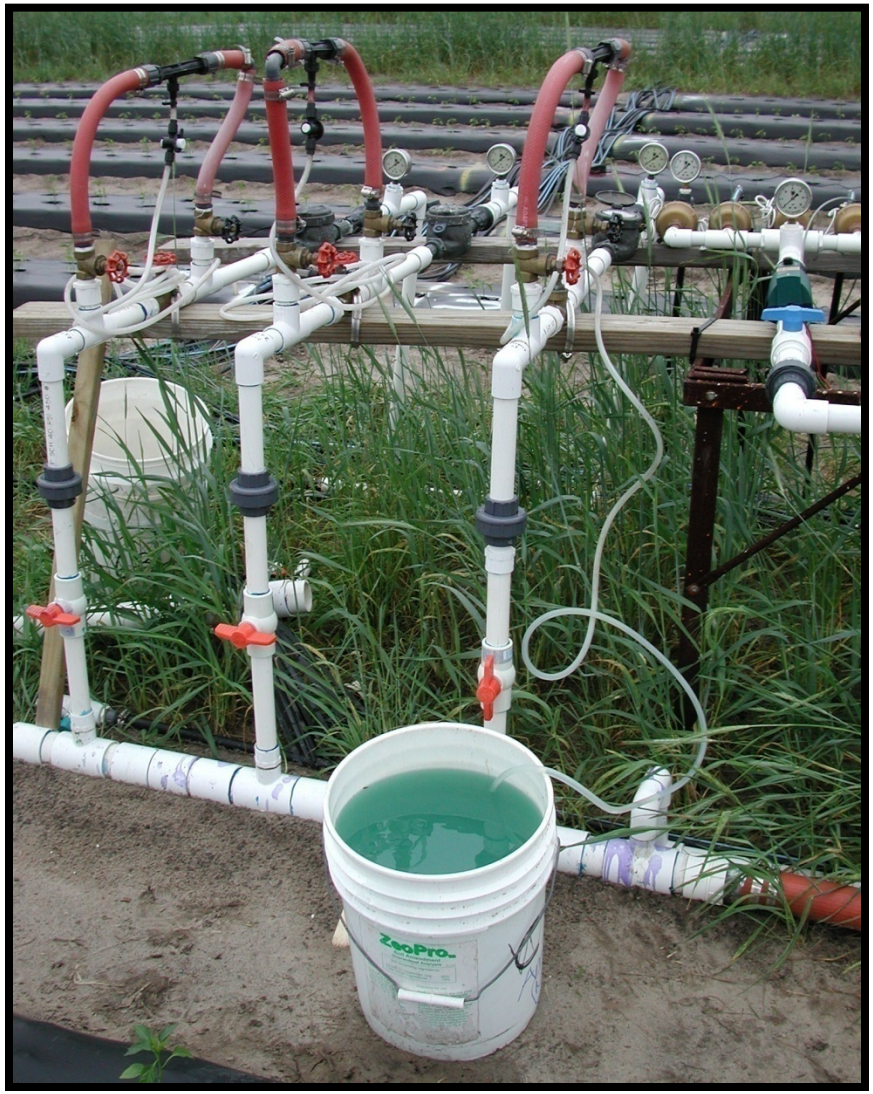
Low Water Permeability

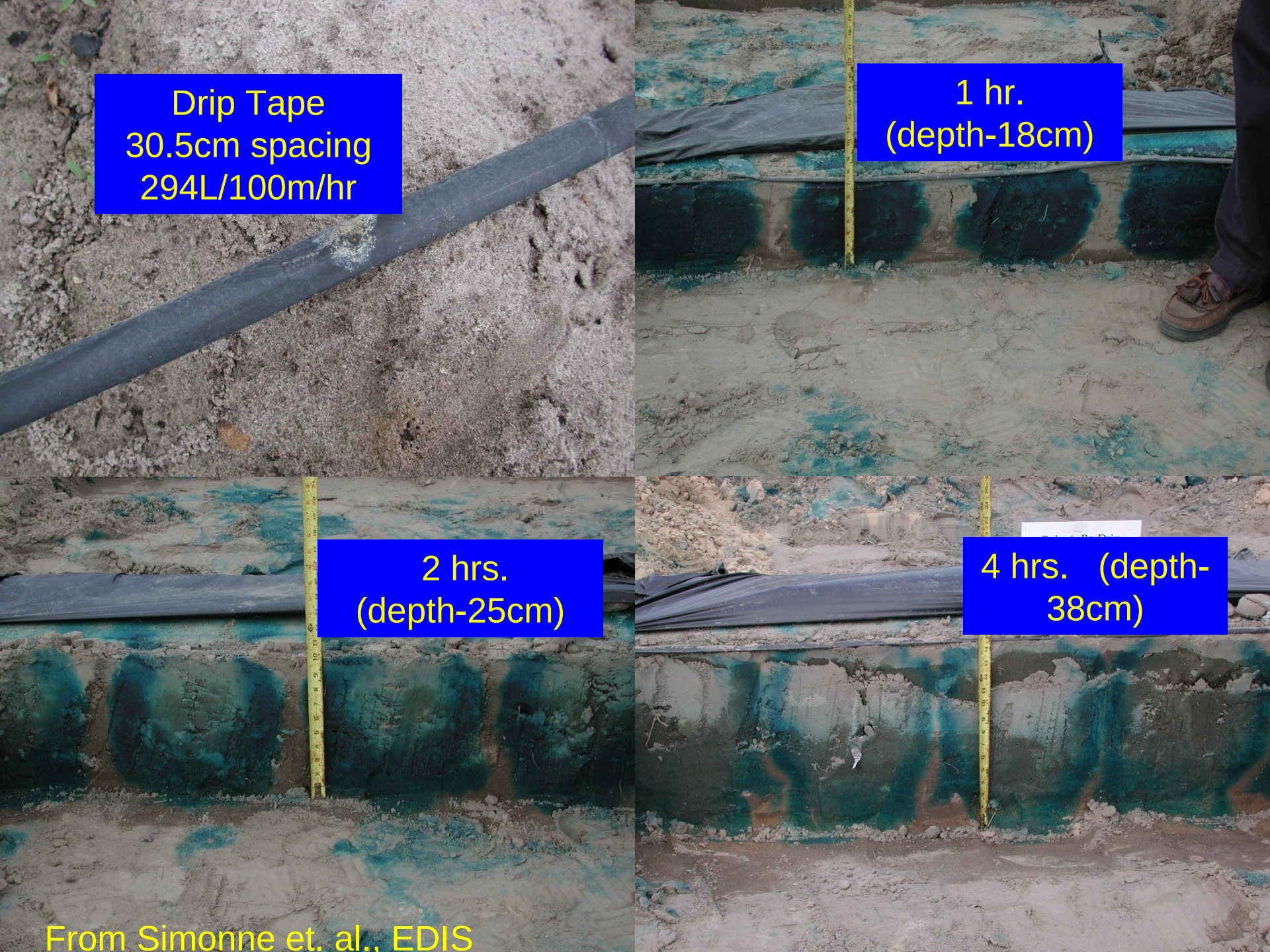

N
P
K

Water and nutrients must be carefully managed to avoid over-irrigation and poor nutrient application



Some advantages….
reduced water use, fertilizer application, and
precise water distribution

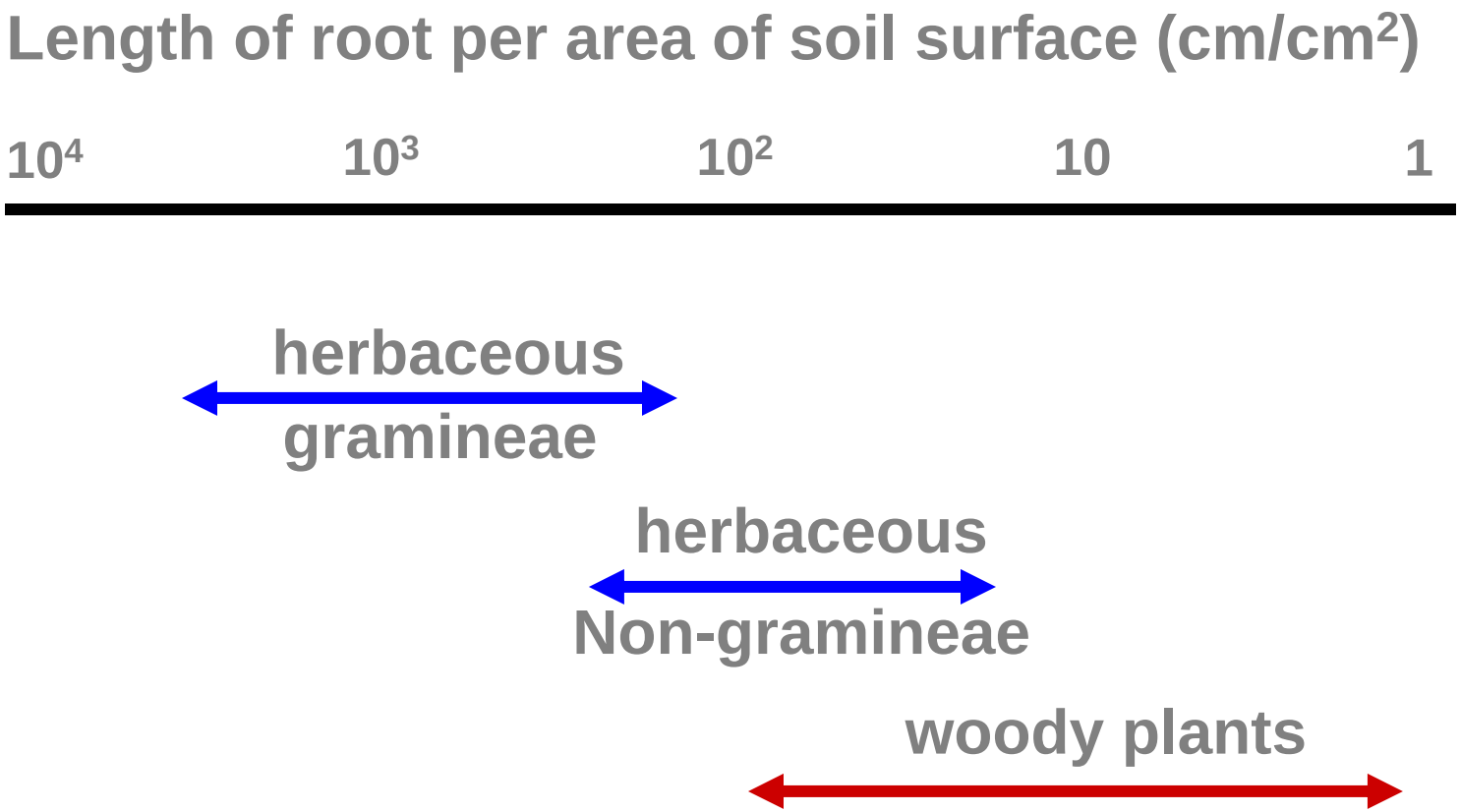




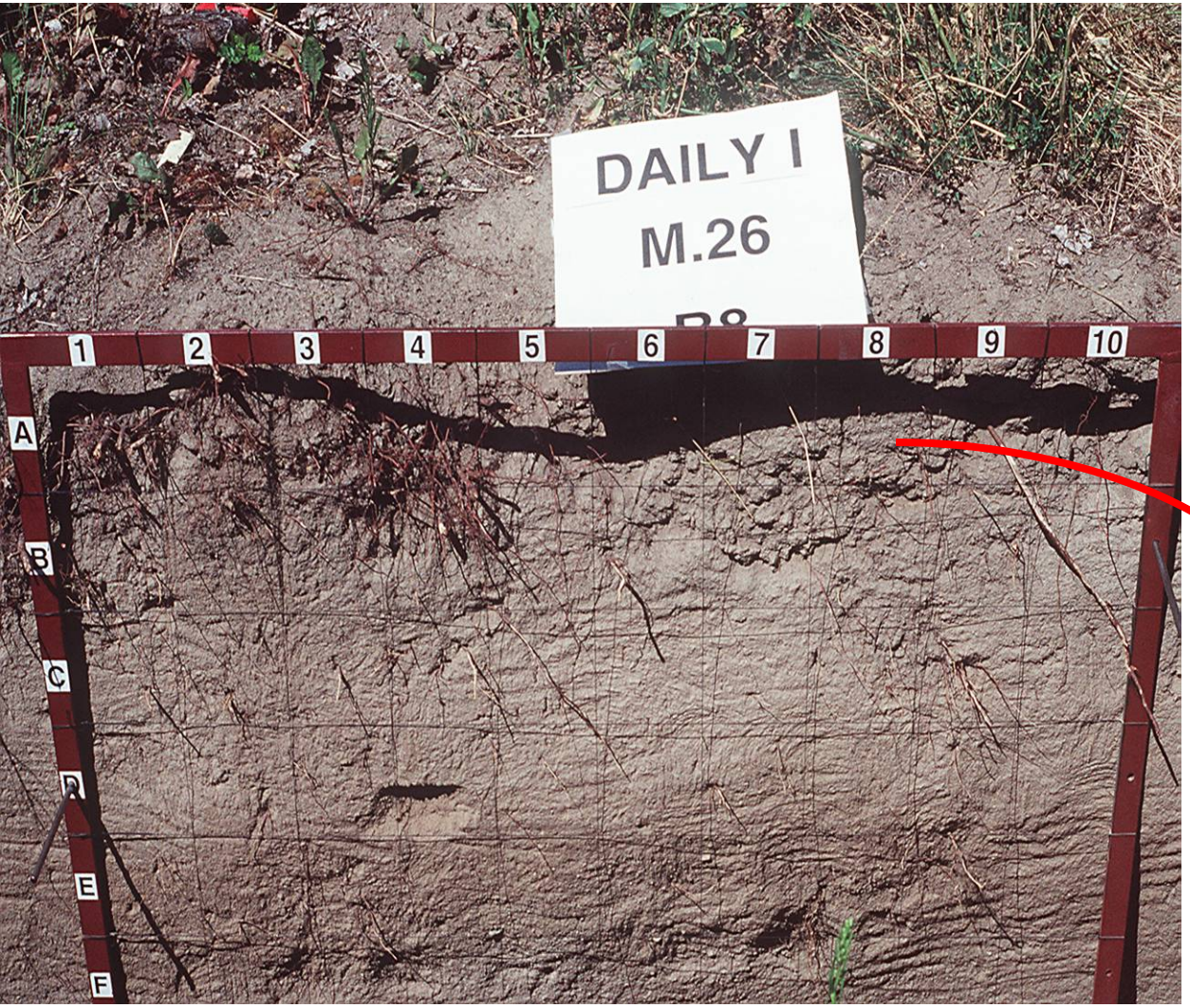
From Simonne et. al., EDIS

Where are the roots?

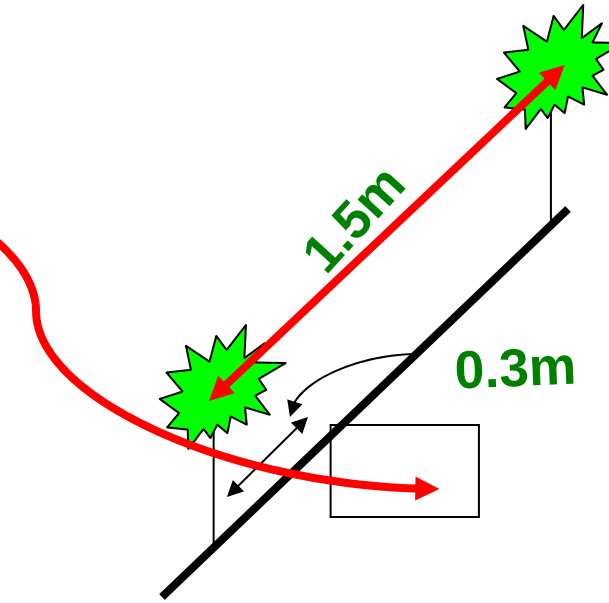
Relative size of plant root systems



Distribution of roots in apple trees

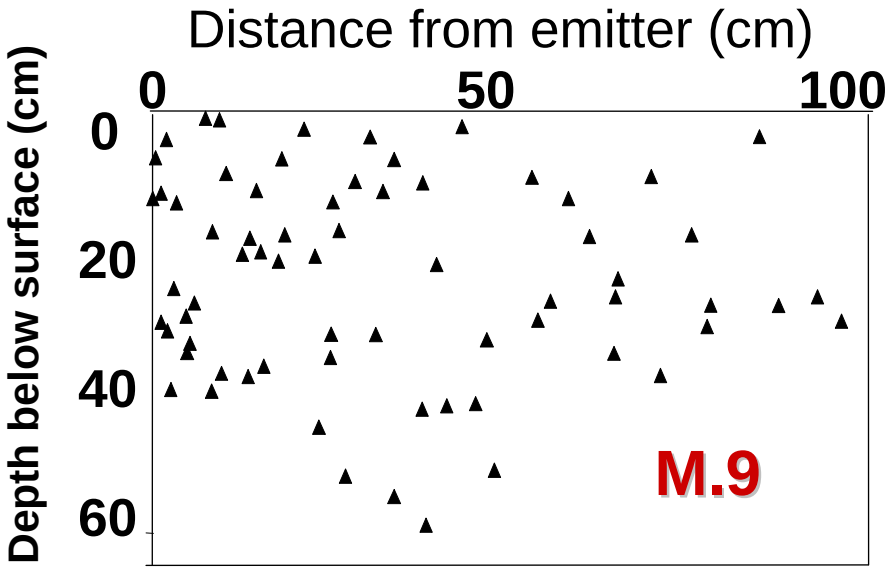


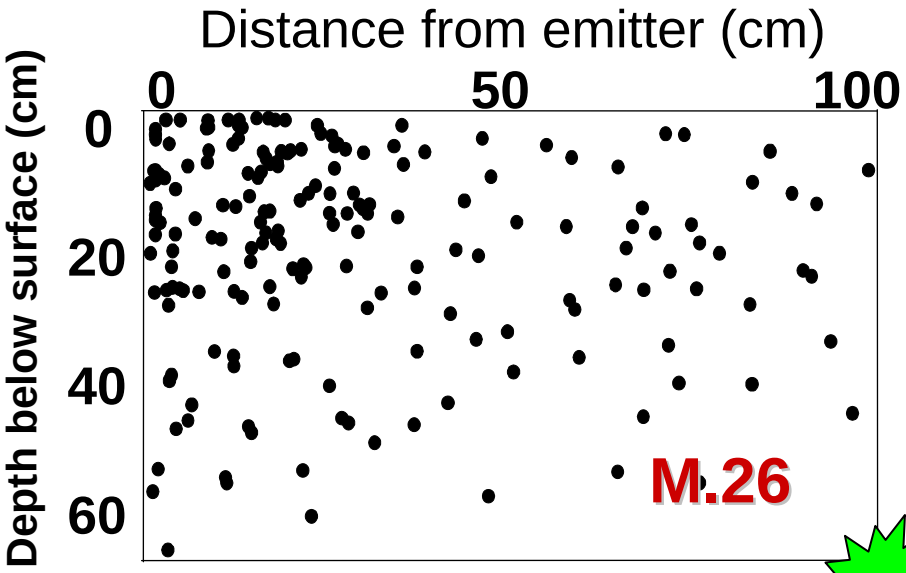
- McIntosh/M.9;M.26;M.7
- Fertigated for 5 years

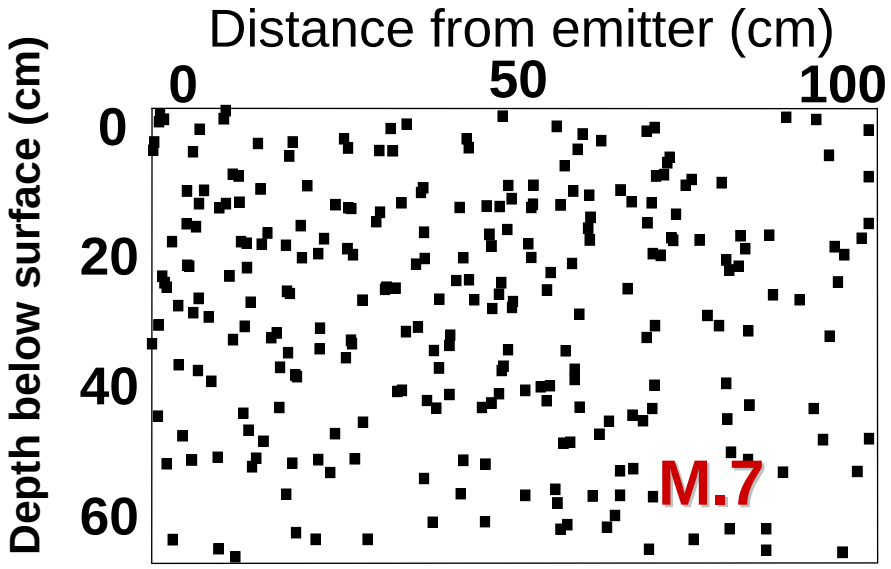


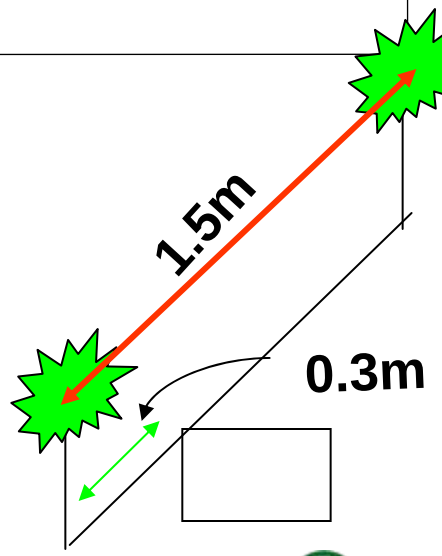
Neilsen et al. 1997
Can. J. Plant Sci. 77

The volume of soil accessed by roots depends on rootstock vigor









Water and nutrition are linked

water is

- **a solvent and transporting agent for nutrients in the soil and plant**
- **nutrient availability is affected by water movement through soil**
- **irrigation management is the key to nutrient placement and retention in root zone**

Nutrient solubility and mobility

Mobile nutrients – N, B

- **remain dissolved in the soil solution**
- **move by mass flow**

Moderately mobile nutrients – K, Ca, Mg, Na

- **remain dissolved in solution and are easily exchanged from soil particles**
- **move by mass flow**

Immobile nutrients – P, Zn, Mn

- **fixed by soil**
- **move by diffusion (occasionally mass flow)**

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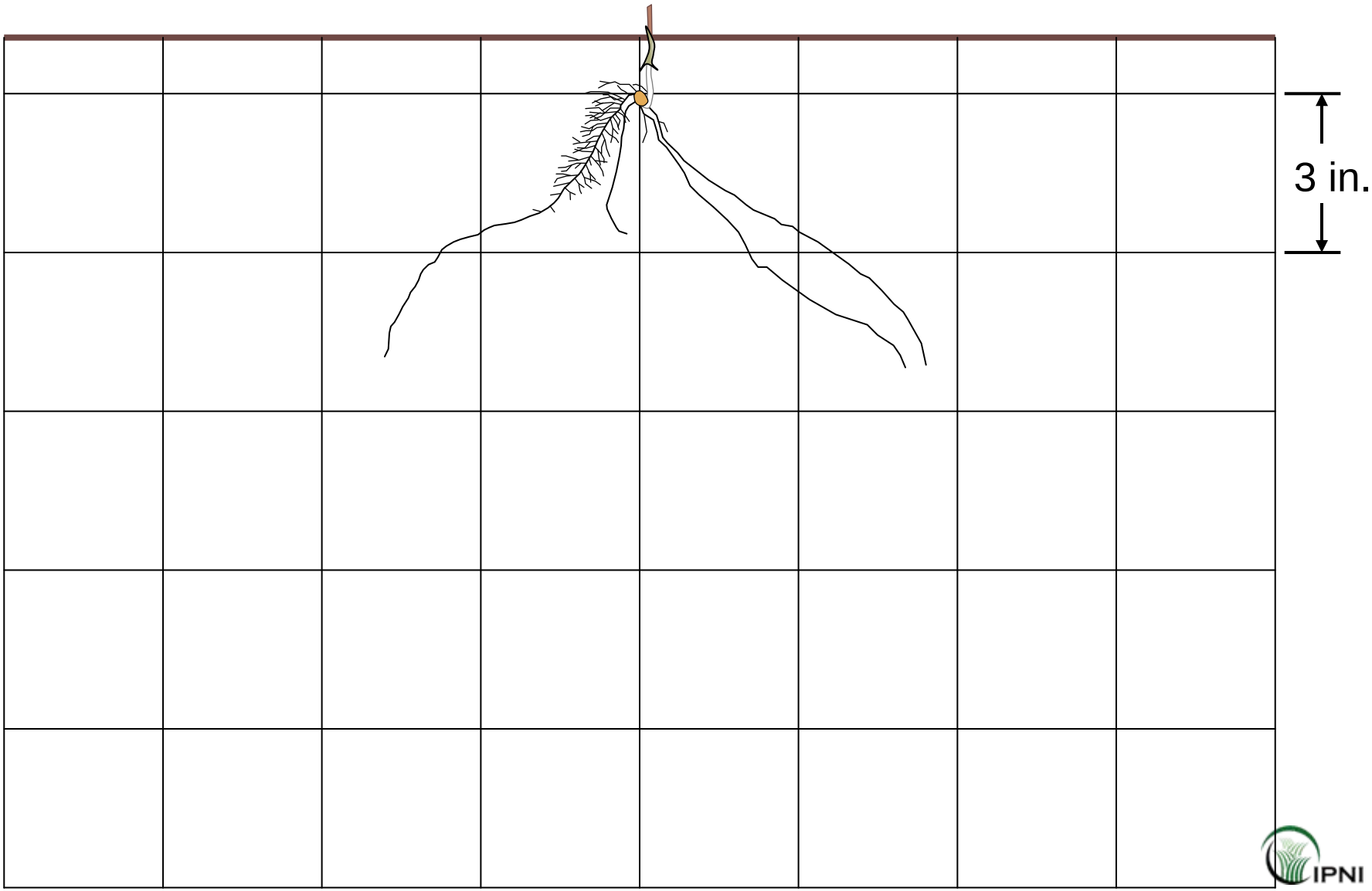
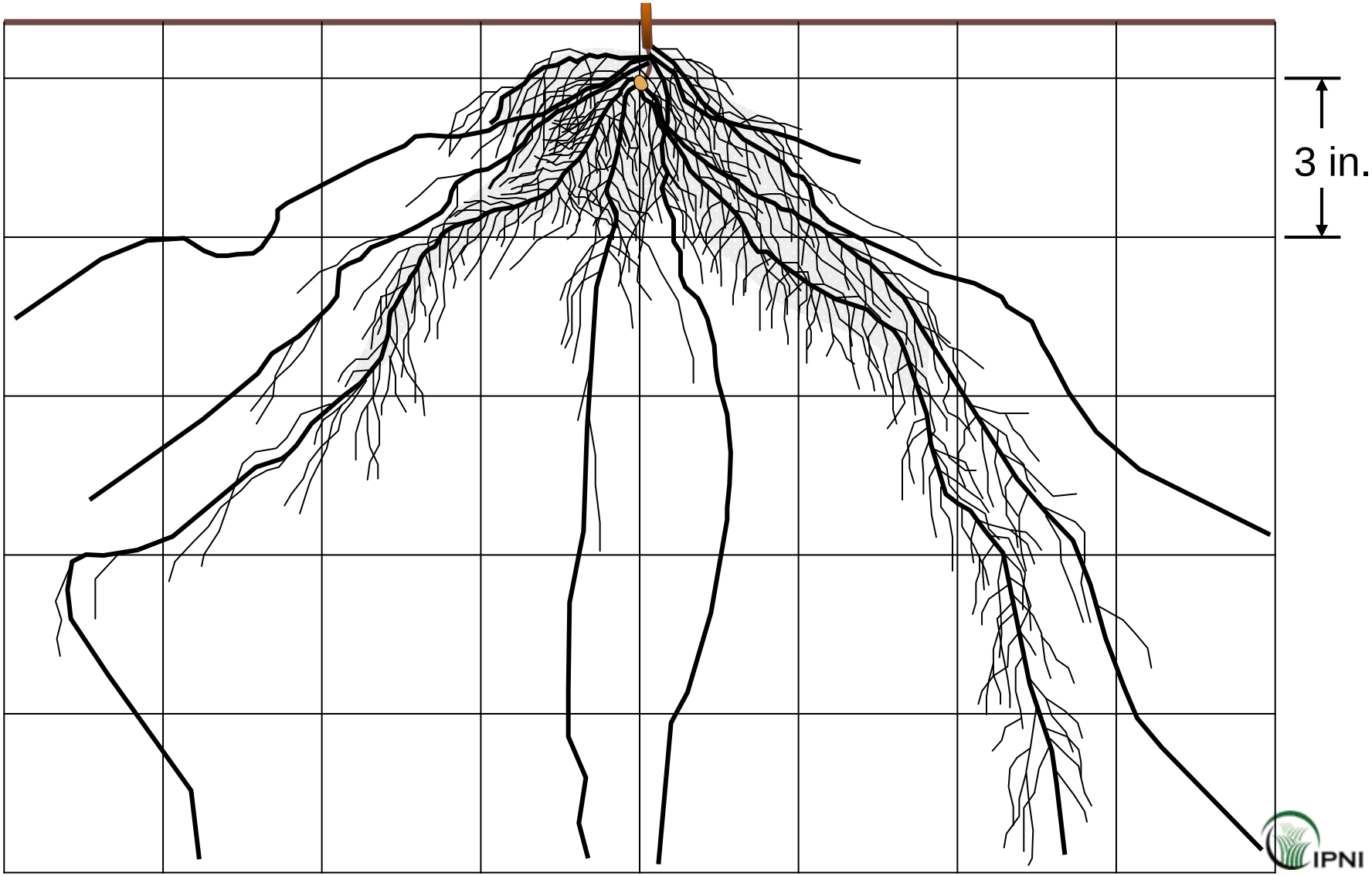
Corn roots: V1



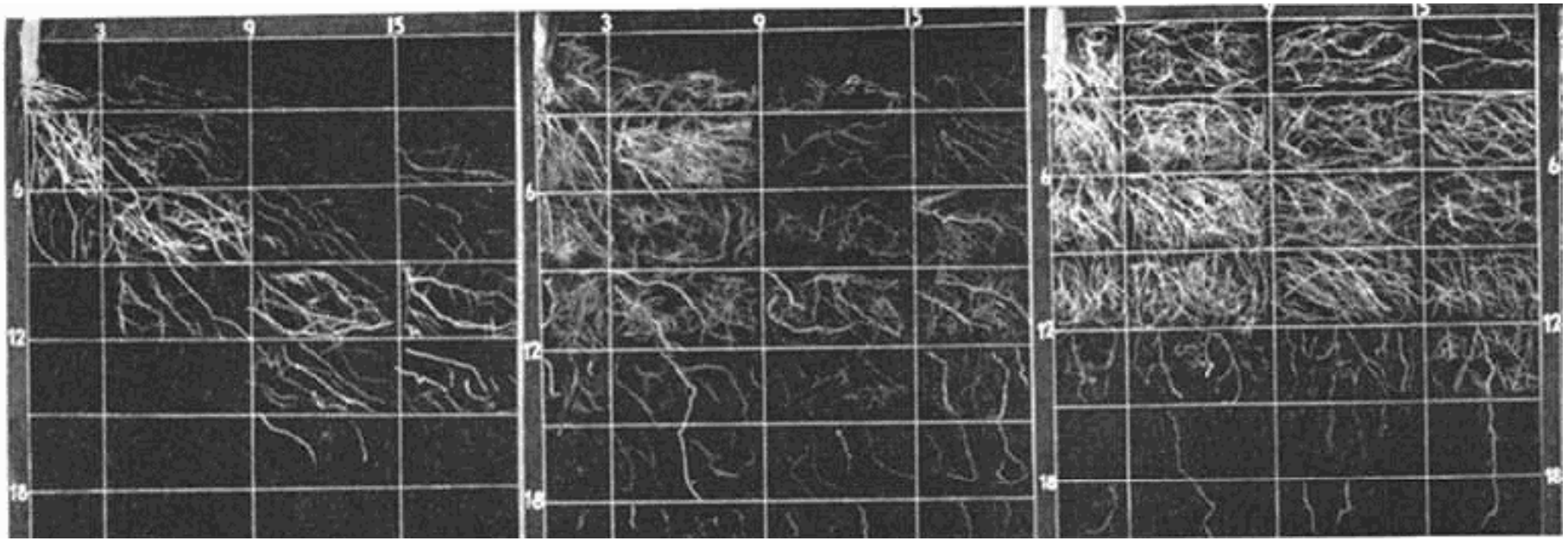
Corn roots: V3

Corn roots: V5



Corn root growth

Day 37 Day 41 Day 47



Foth, 1962

How does irrigation and application method affect nutrient and root distributions?

Management factors affecting root morphology

- Cultivar choice
  - Root angle
  - Root elongation rate
- Planting date
  - Soil temperature
  - Soil moisture
  - Photoperiod
  - Quantity of radiation
- Tillage
  - Soil moisture
  - Soil temperature
  - Soil bulk density
  - Soil aeration
- Soil fertility
  - Plant dry matter distribution
  - Root proliferation
- Irrigation
  - Soil moisture profile

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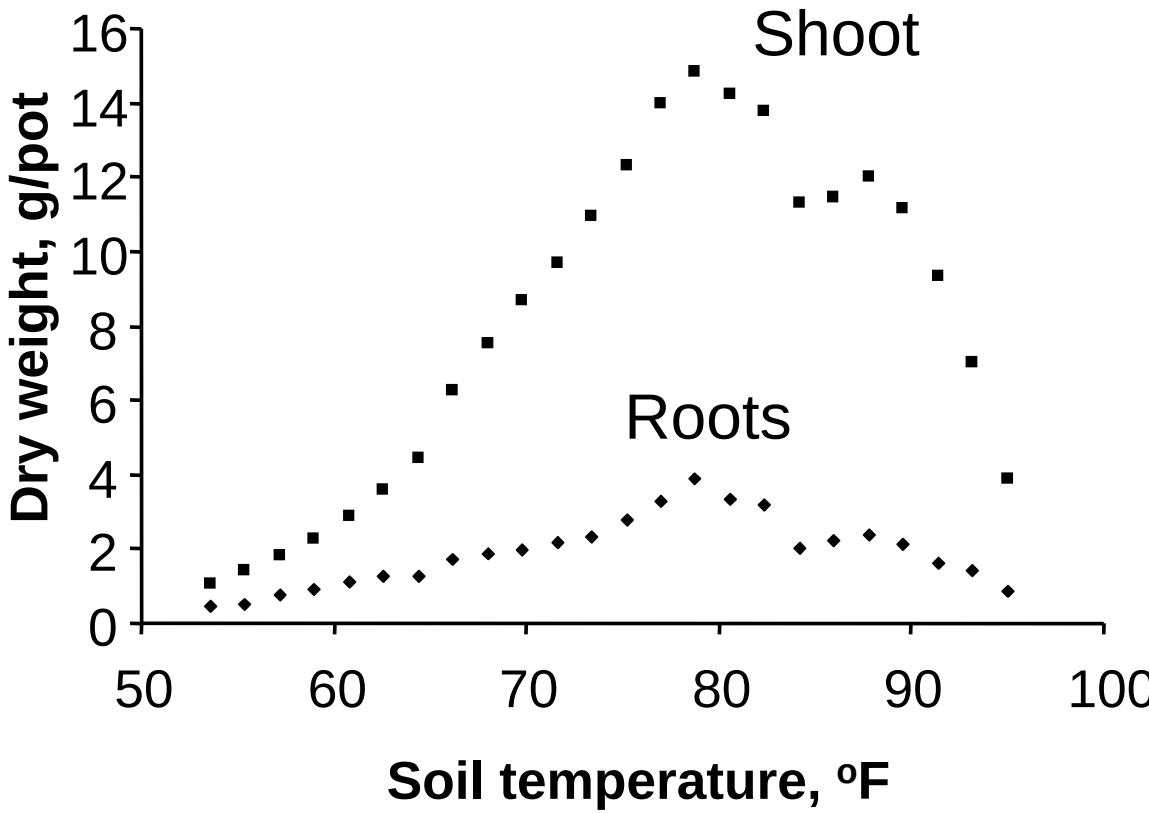
Environmental effects: soil temperature

- Air temperature held constant at 77°F
- 23 day old corn seedlings measured

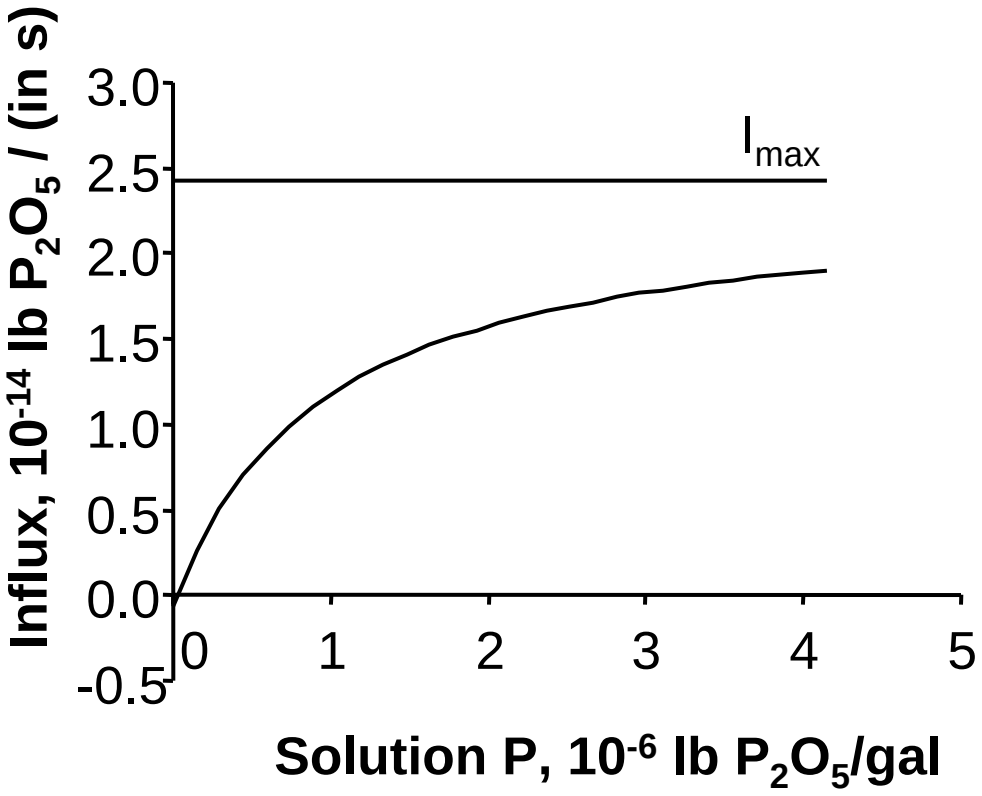


Walker, 1969

Nutrient influx by roots

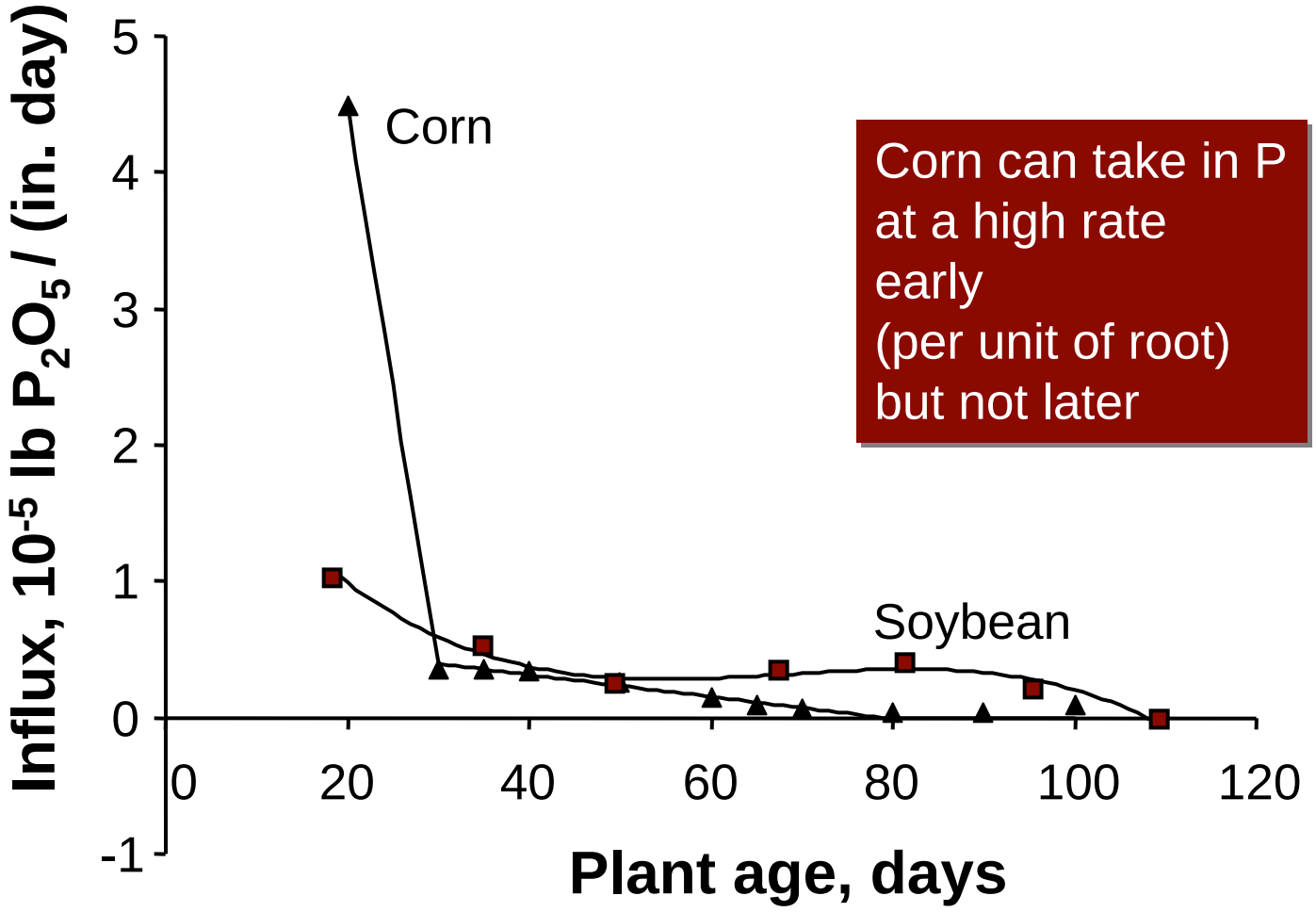
- Ions are not simply absorbed according to their ratios in solution
- Ions with this characteristic influx pattern require energy to be absorbed
  - $H_2PO_4^-$, HPO_4^{2-}
  - K^+
- Maximum influx is reached at higher solution concentrations (I_{max})

22-23 day old soybean roots



Barber, 1984; Edwards and Barber, 1976

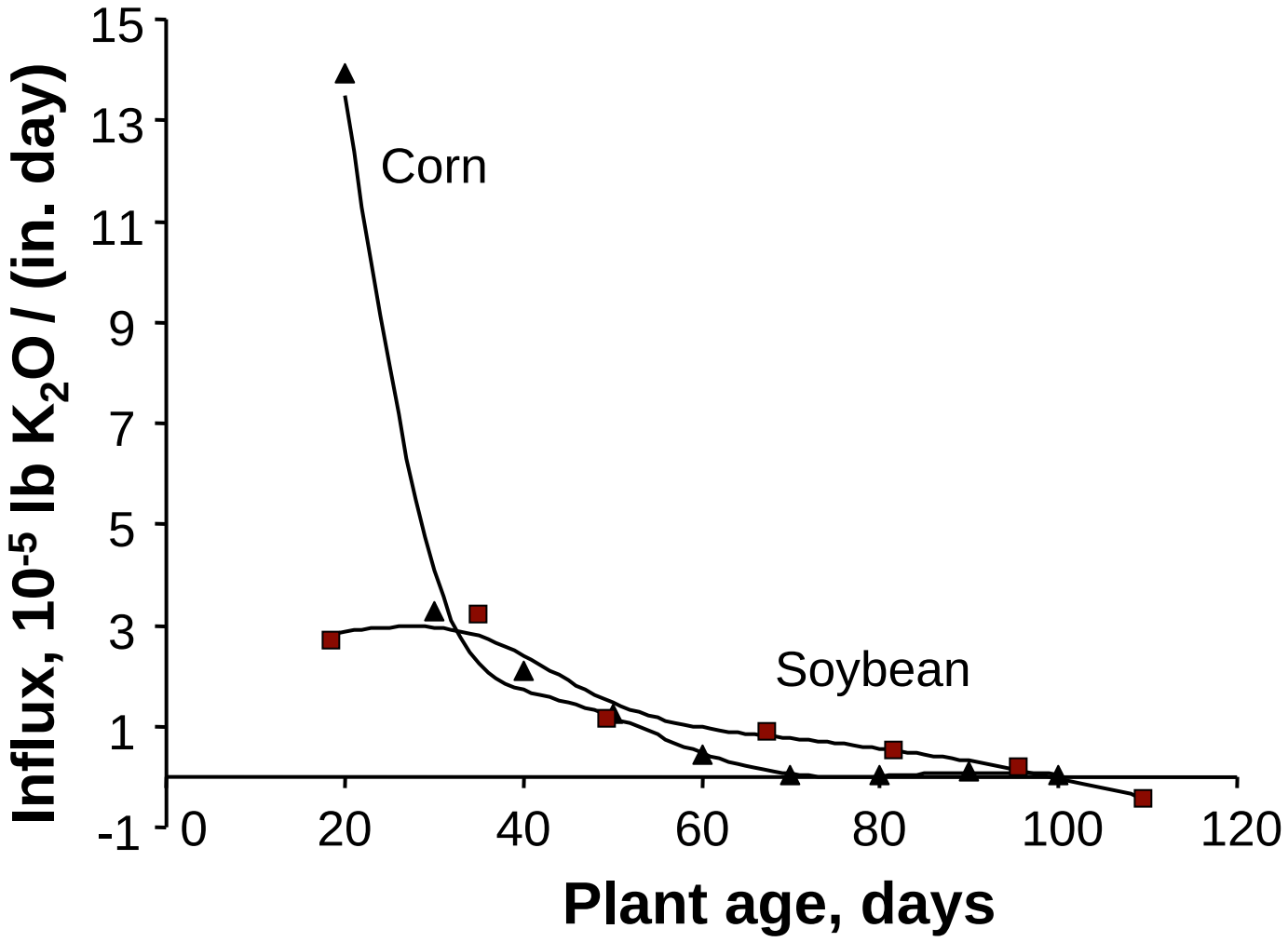
P influx varies with plant age: The case for early nutrients



Corn can take in P at a high rate early (per unit of root) but not later

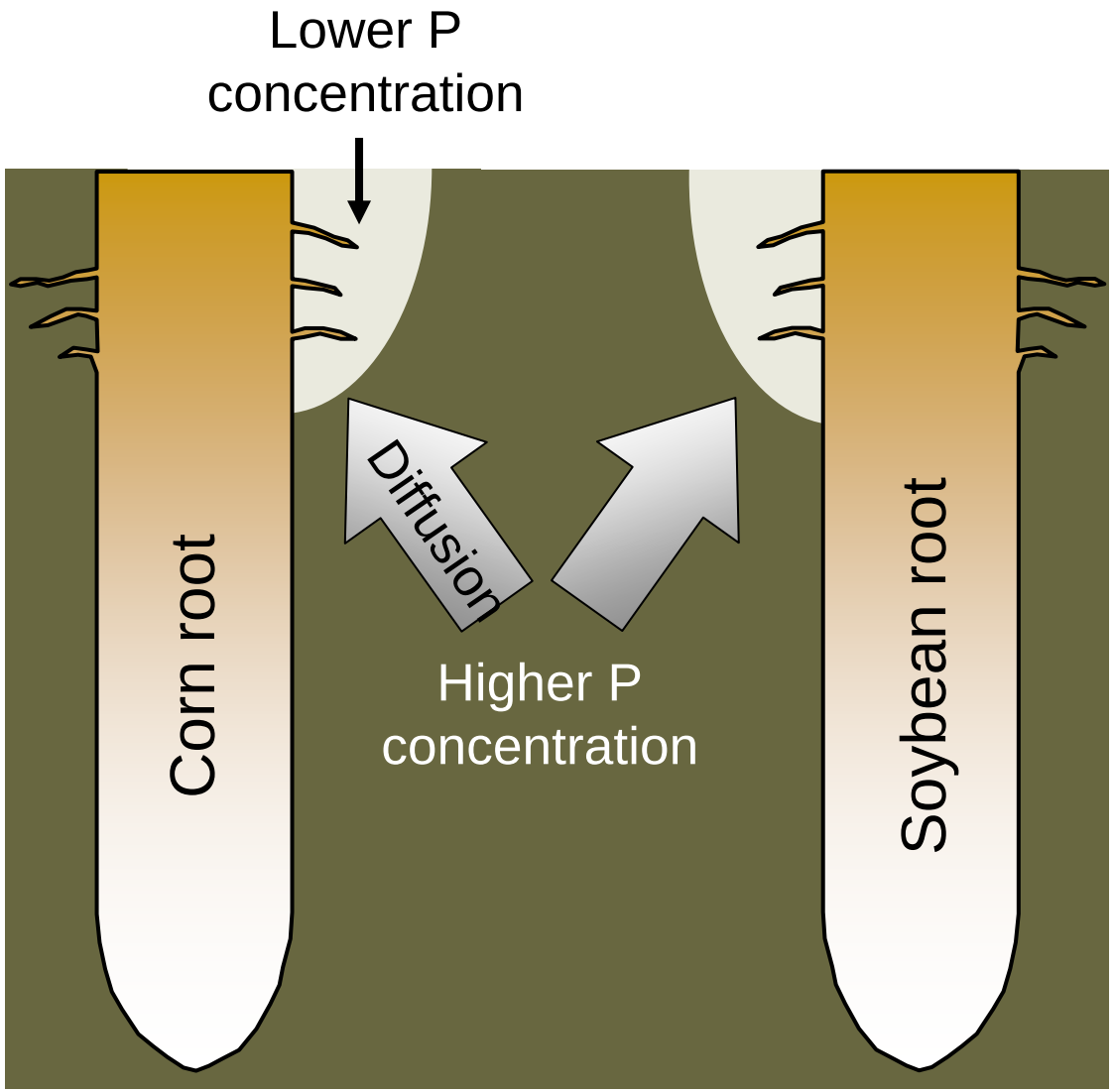
Barber, 1978; Mengel and Barber, 1974

K influx varies with plant age

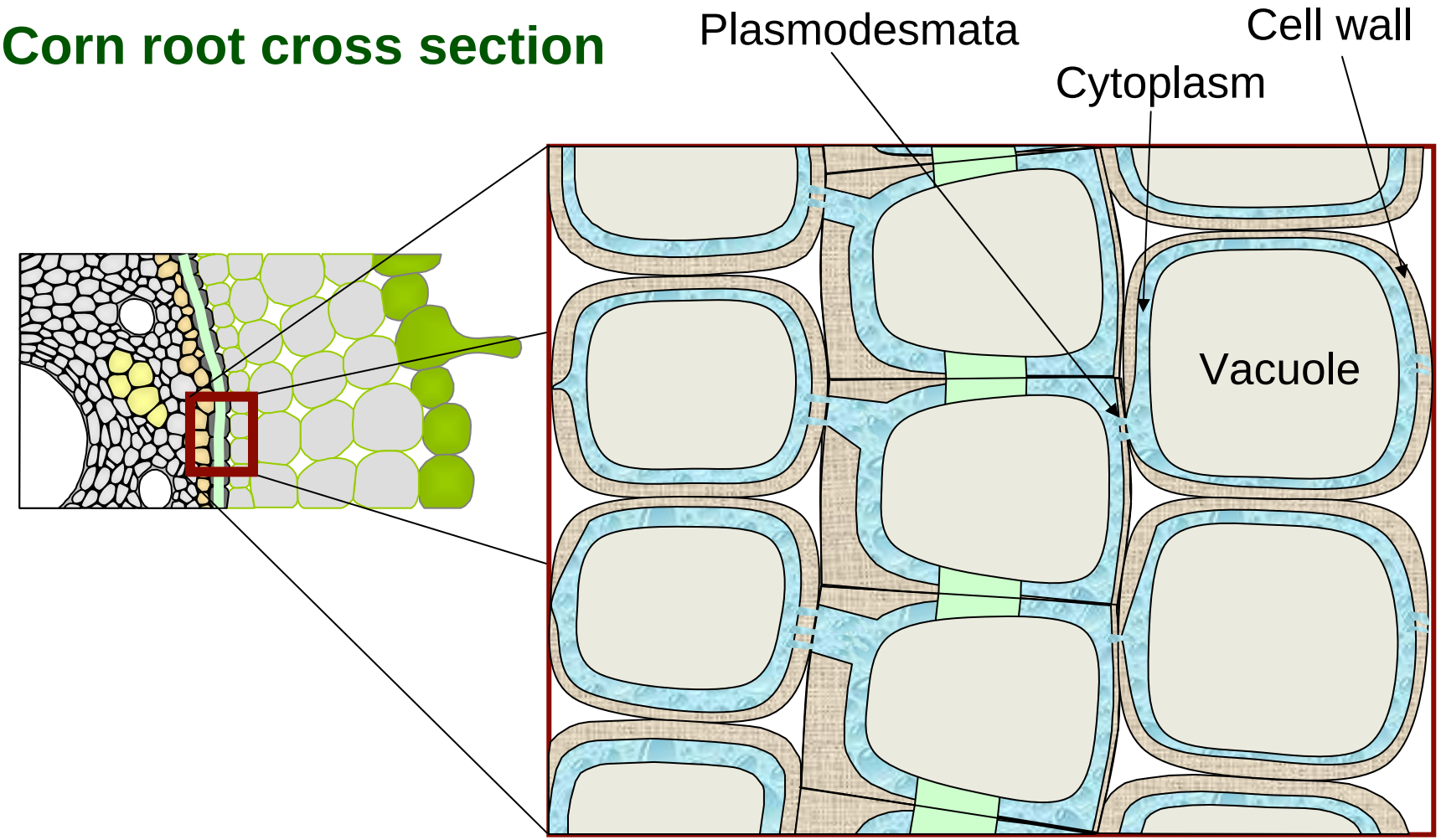


Barber, 1978; Mengel and Barber, 1974

Influx rate affects the rate of nutrient depletion



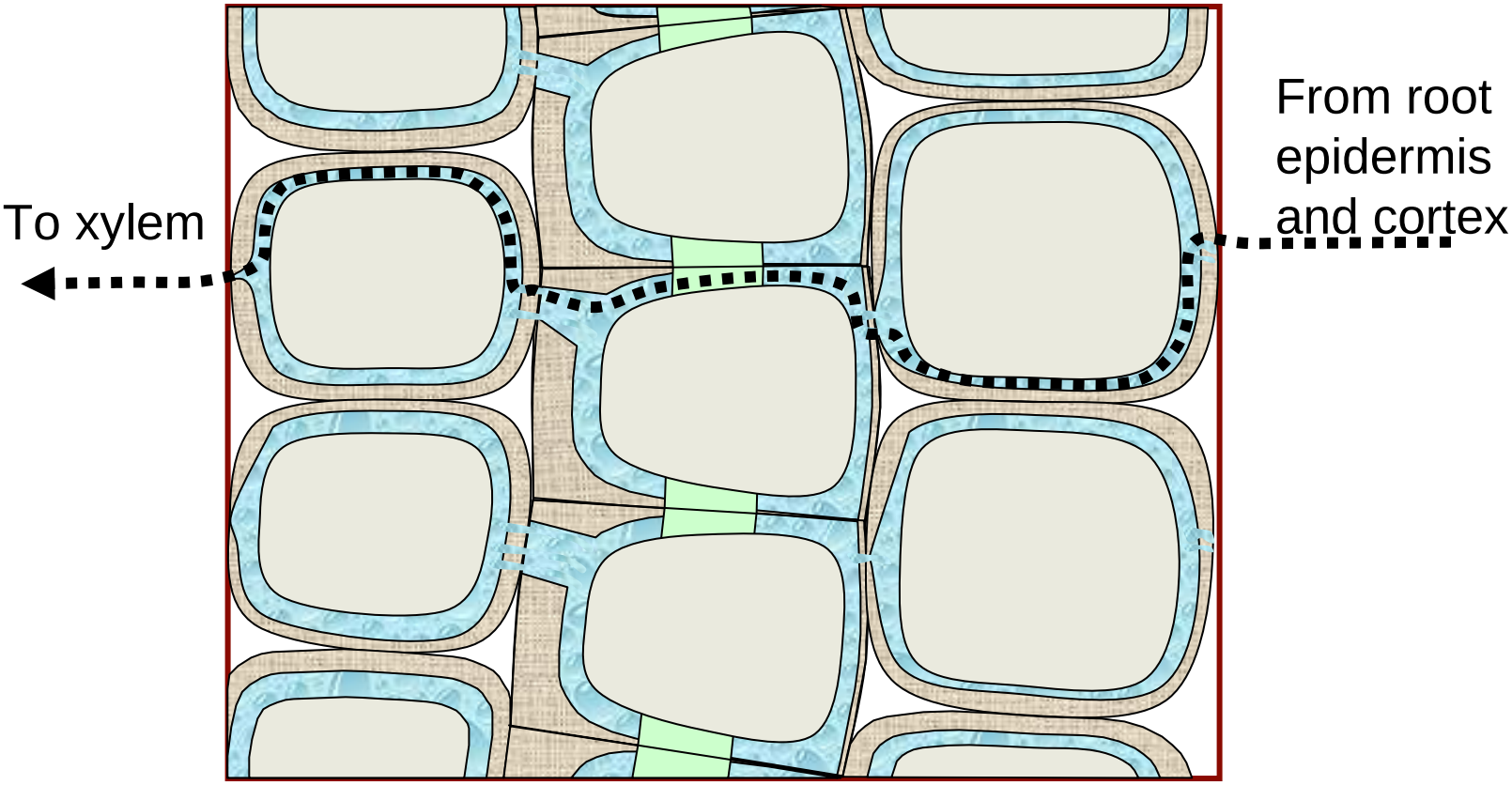
Corn root cross section



Russell, 1977

Zea mays root cross-section, mature r

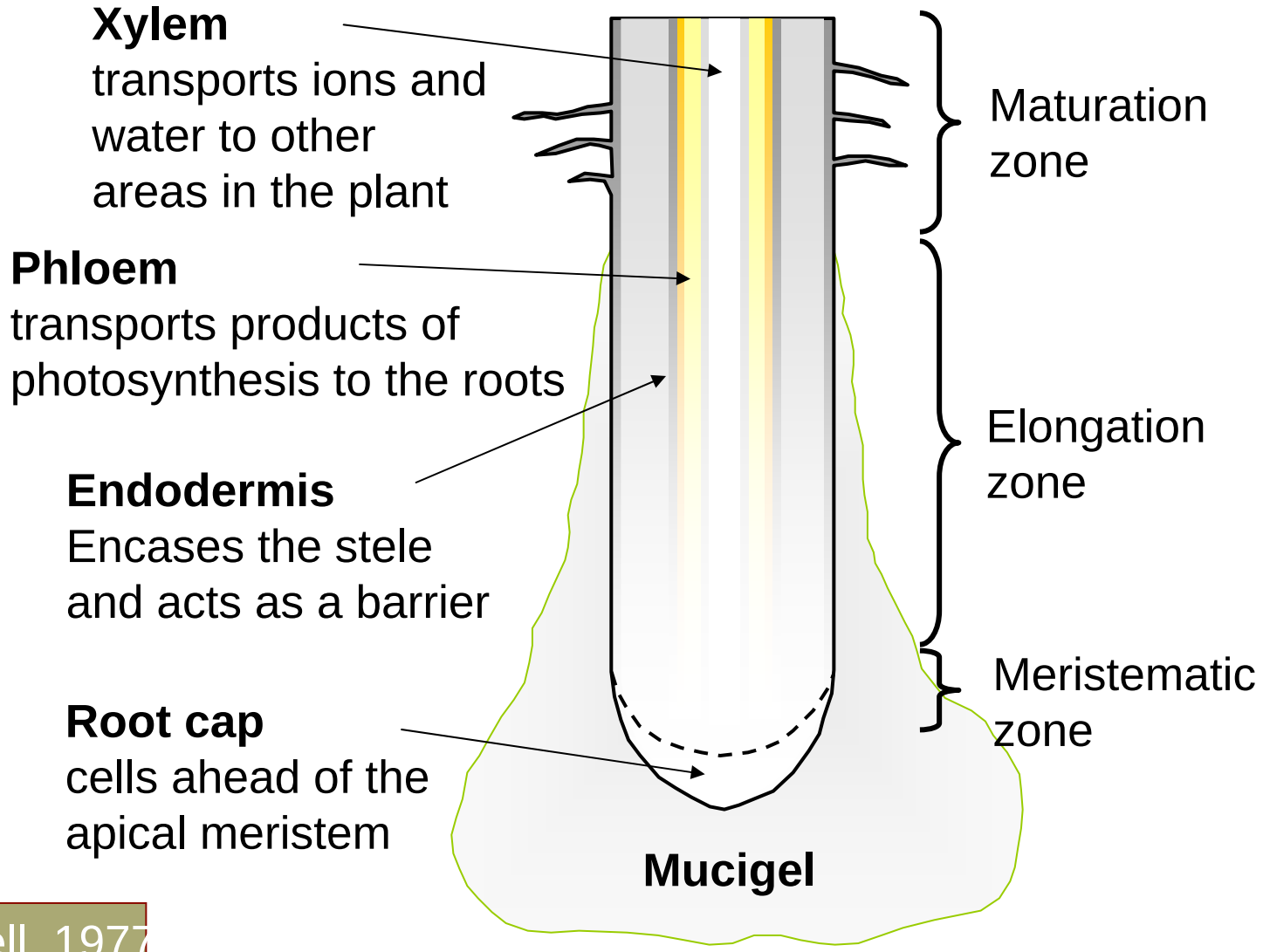
Symplasmic pathway: transport of nutrients through the cytoplasm



Marschner, 2002

Zea mays root cross-section, mature r

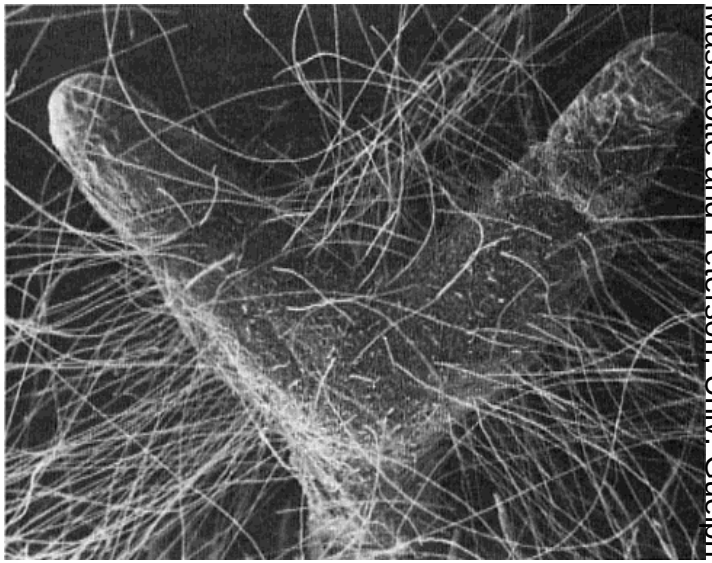
Corn root: longitudinal cross section



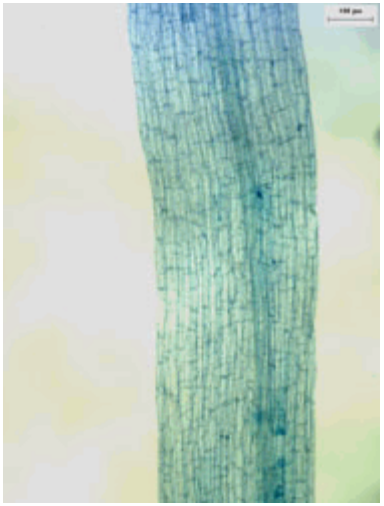
Russell, 1977

Can soil fungi affect crop response to placement?

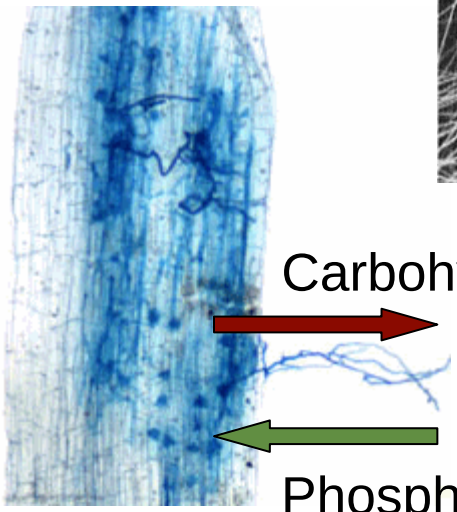
Mycorrhizae increase accessible soil volume



Without mycorrhizae



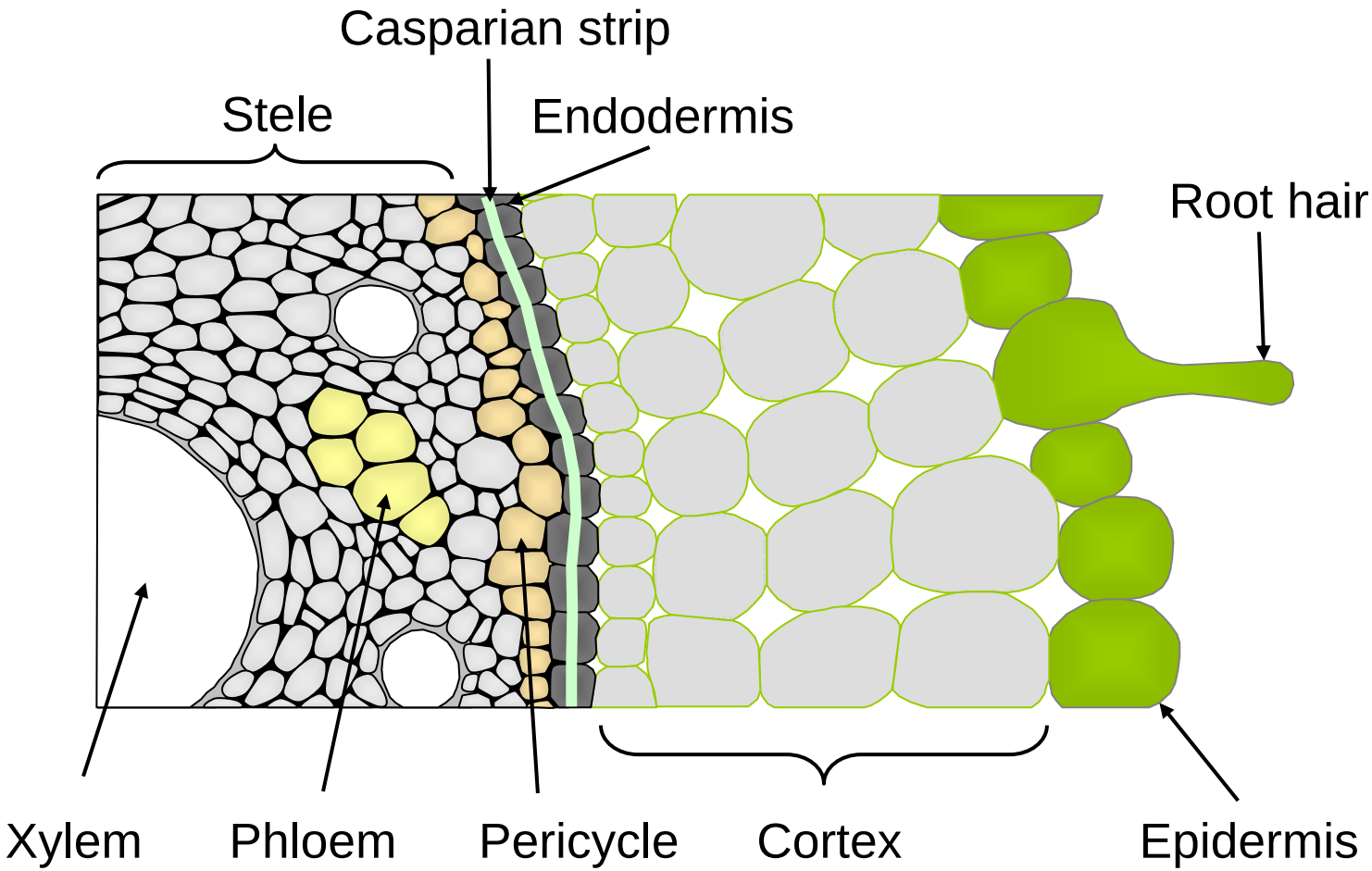
With mycorrhizae



Matching roots with P and K supplies

- Distribution of nutrients and active roots must match
- Examples:
  - Soil moisture impacts
  - Nutrient concentration….source….time….place

Corn root: horizontal cross section



Russell, 1977

Zea mays root cross-section, mature r

Nitrification: Converts ammonium to nitrate

Step 1: conversion to nitrite by the *Nitrosomonas* bacteria

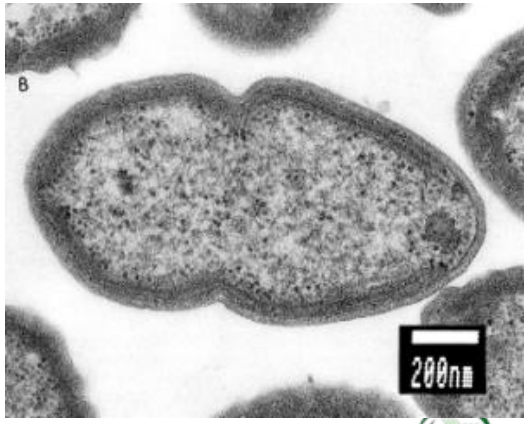
$$2NH_4^+ + 3O_2 \rightarrow 2NO_2^- + 4H^+$$

Step 2: conversion to nitrate by the *Nitrobacter* bacteria

$$2NO_2^- + O_2 \rightarrow 2NO_3^-$$

Important components of the reaction:

- Requires oxygen
- Reaction is acid-forming



Nitrosomonas (Natl. Inst. Res. Environ.)

Havlin et al., 200

Reaction of urea

Urea hydrolysis at pH 6.5 – 8.0

$$CO(NH_2)_2 + H^+ + 2H_2O \xrightarrow{\text{urease}} 2NH_4^+ + HCO_3^-$$

Urea hydrolysis at pH < 6.5

$$CO(NH_2)_2 + 2H^+ + 2H_2O \xrightarrow{\text{urease}} 2NH_4^+ + H_2CO_3$$

- Initially acid-consuming… then acidifying
- pH will not increase above 9.3

Koelliker and Kissel, 1988

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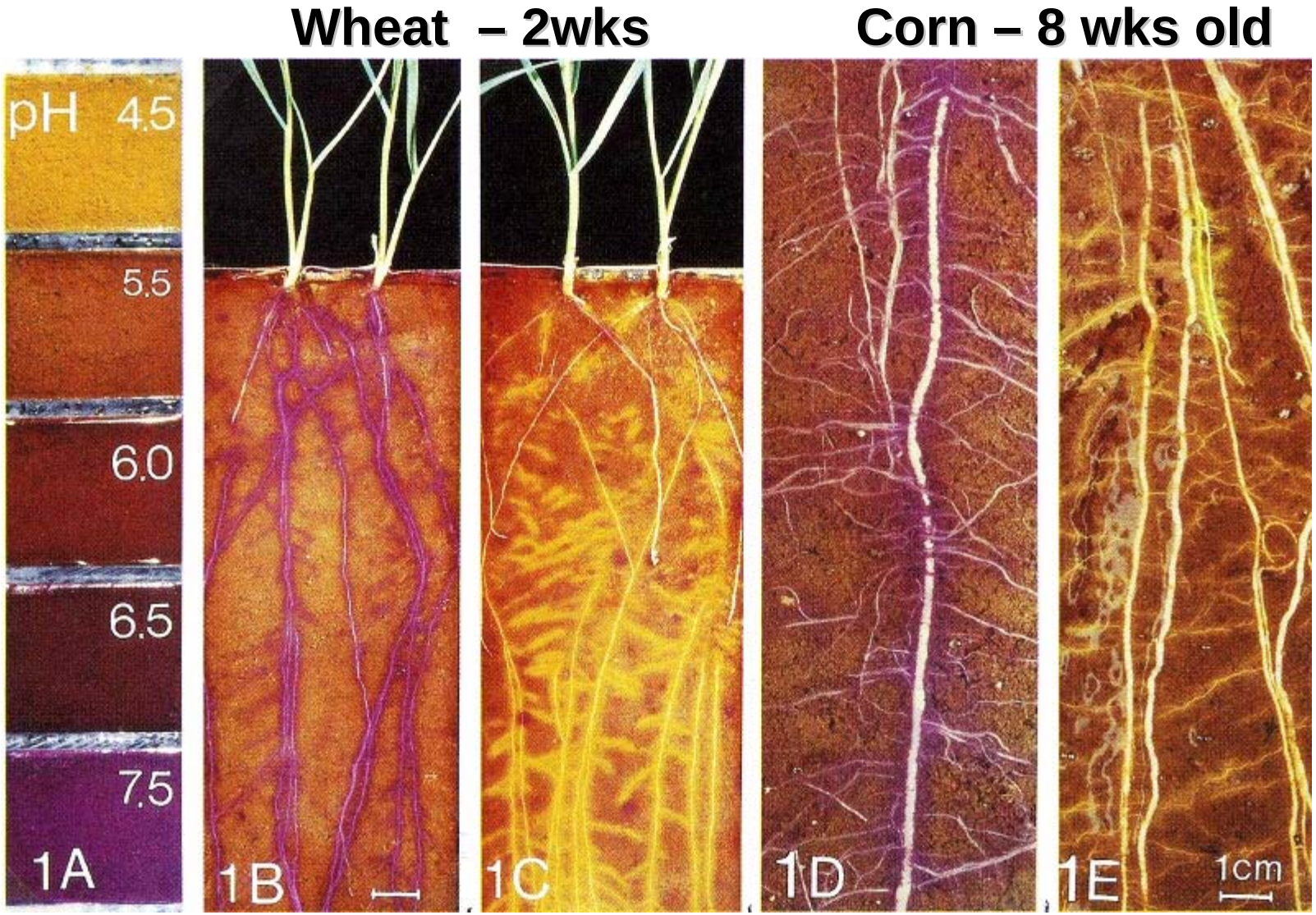
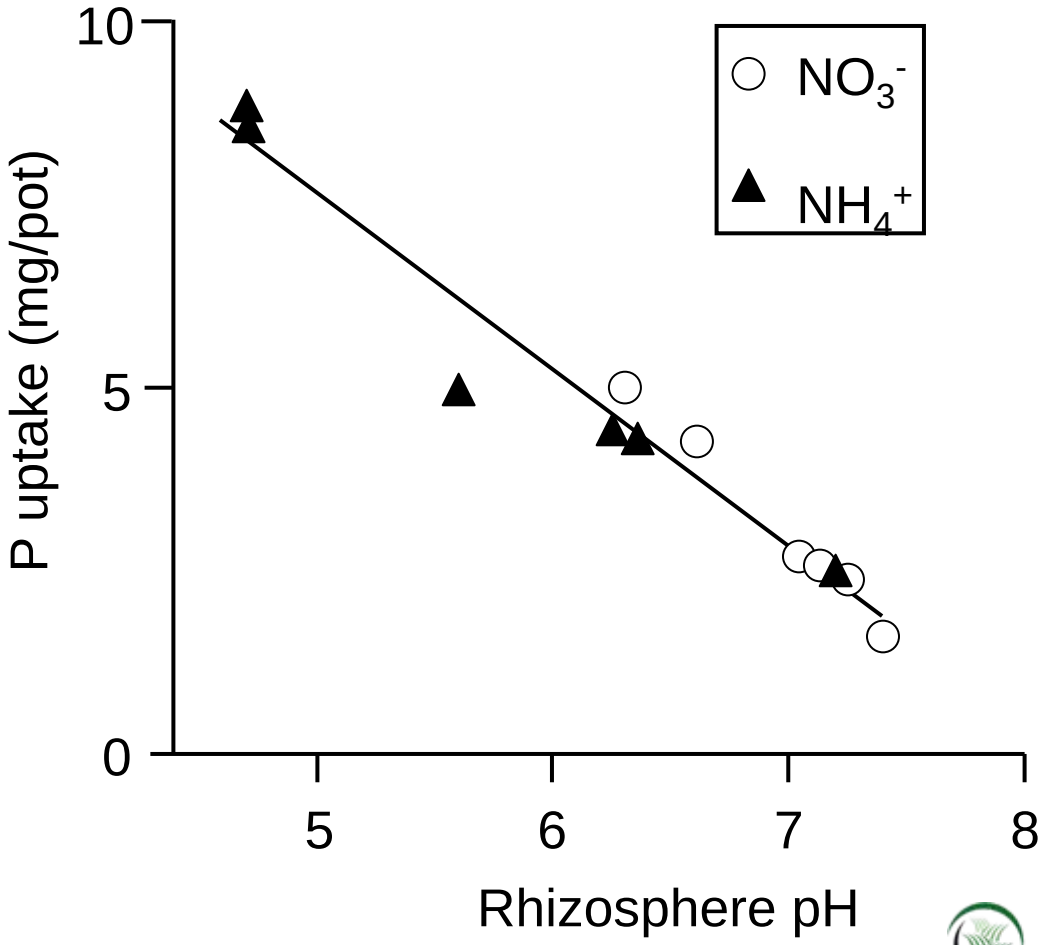

Wheat – 2wks
Corn – 8 wks old
pH 4.5
5.5
6.0
6.5
7.5
1A
1B
1C
1D
1E
1cm
Scale
NO3-N
NH4-N
NO3-N
NH4-N
200 kg N per ha

Rhizosphere pH affects early P uptake

- 3 wk. old soybean
- P uptake increased as rhizosphere pH decreased
- P concentration in roots and shoots increased with NH_4^+ nutrition



Riley and Barber, 197

Consequences of fertilizing with NH_4^+ based fertilizers

Soil chemical changes in five orchards (12-40 years old) receiving broadcast fertilizer and sprinkler irrigation

	in row	alley	Sign.
pH_w	4.2	6.7	*
Ca (ppm)	736	2592	**
Al (ppm)	621	27	**
Bases (%)	56	99	*

*,**, significantly different at p<0.05, 0.01

Neilsen et al. 1995
Can. J. Soil Sci. 75

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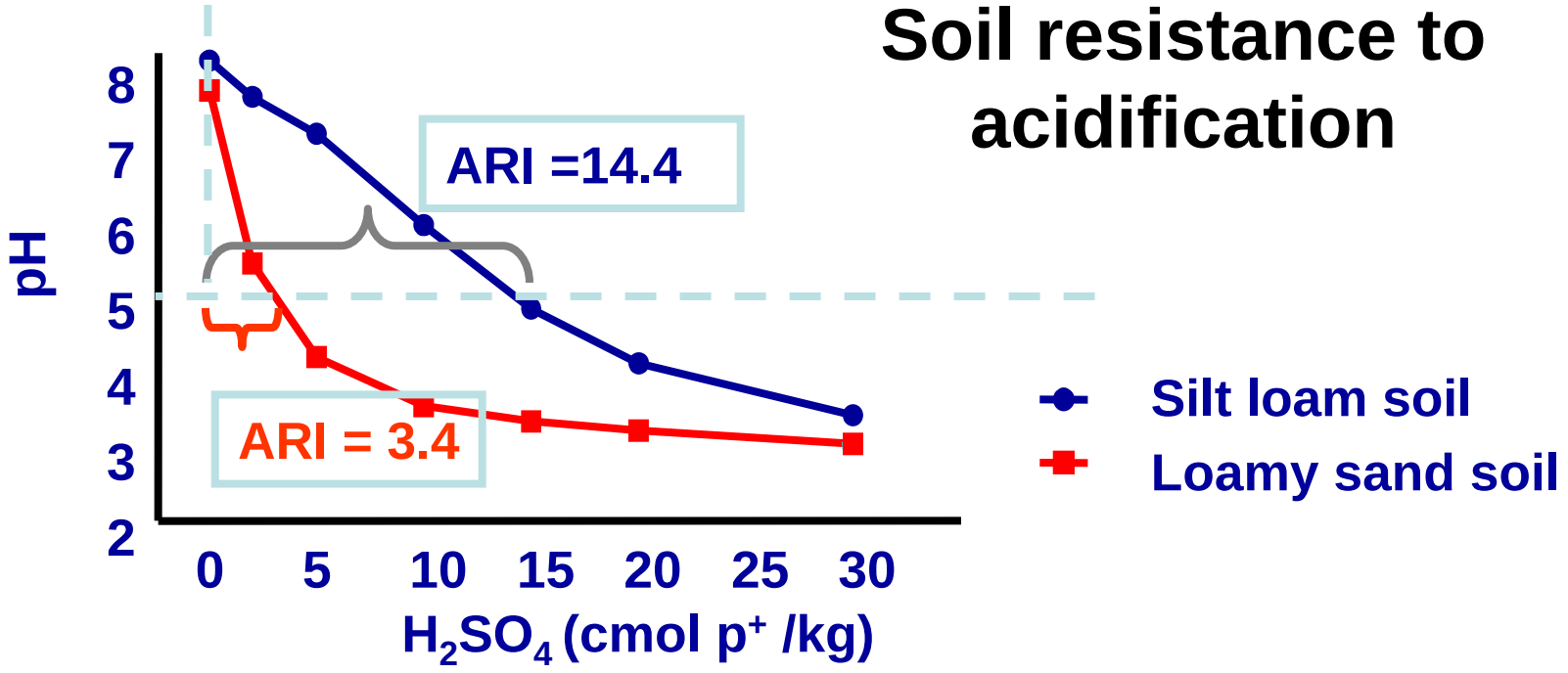
Consequences of fertilizing with NH_4^+ based fertilizers

Soil chemical changes in 20 orchards (3-5 years old) receiving drip irrigation and fertigation

	pH	Ca	Mg	K	B
			(ppm)		
Alley	7.0	1235	144	211	0.97
Beneath emitters	6.2	911	114	88	0.19
Significance	***	**	**	**	****

Neilsen et al. 1995
Can. J. Soil Sci. 75

Consequences of fertilizing with NH_4^+ based fertilizers



ARI = amount of acid required to reduce soil pH to 5.0

Neilsen et al. 1995
Can. J. Soil Sci. 75

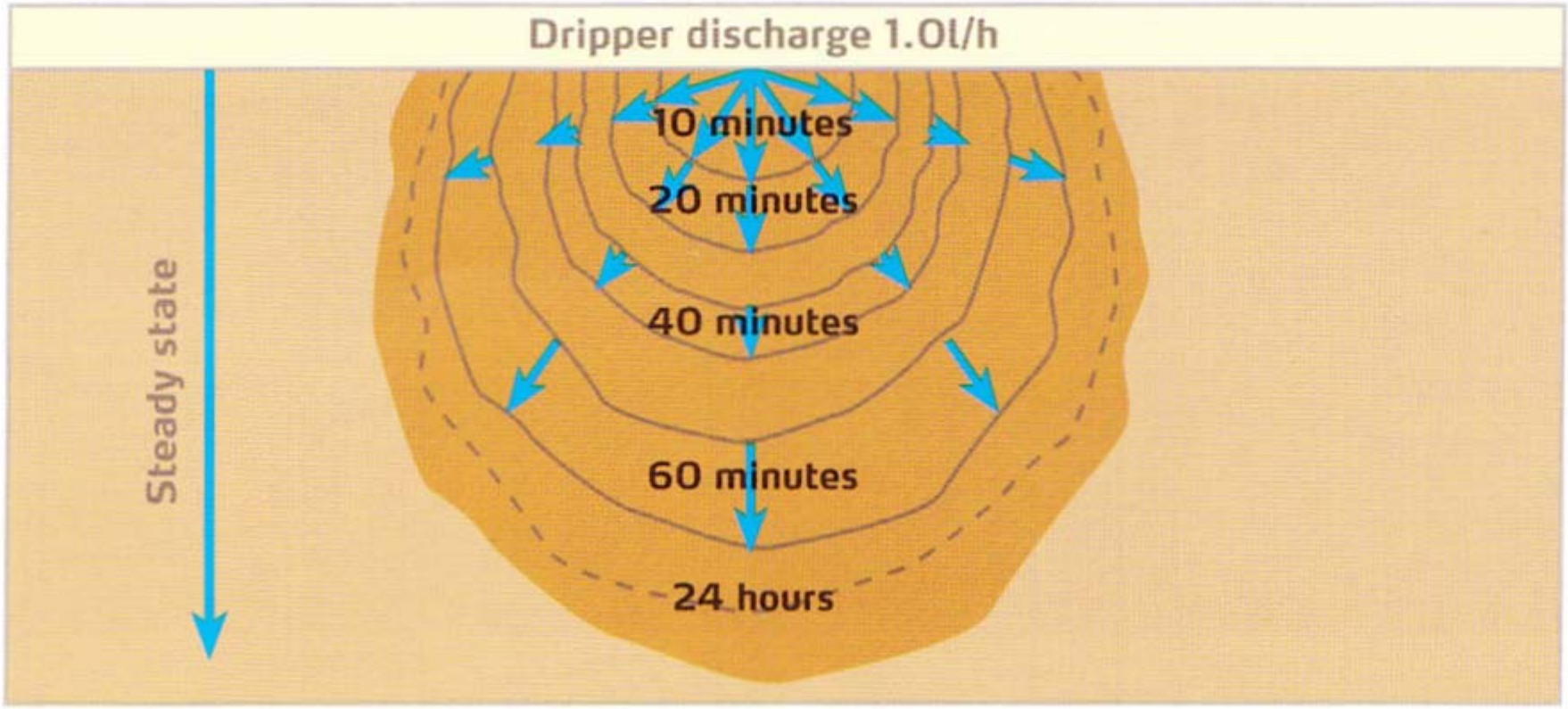
Practical uses of the Acidification Resistance Index (A.R.I.)

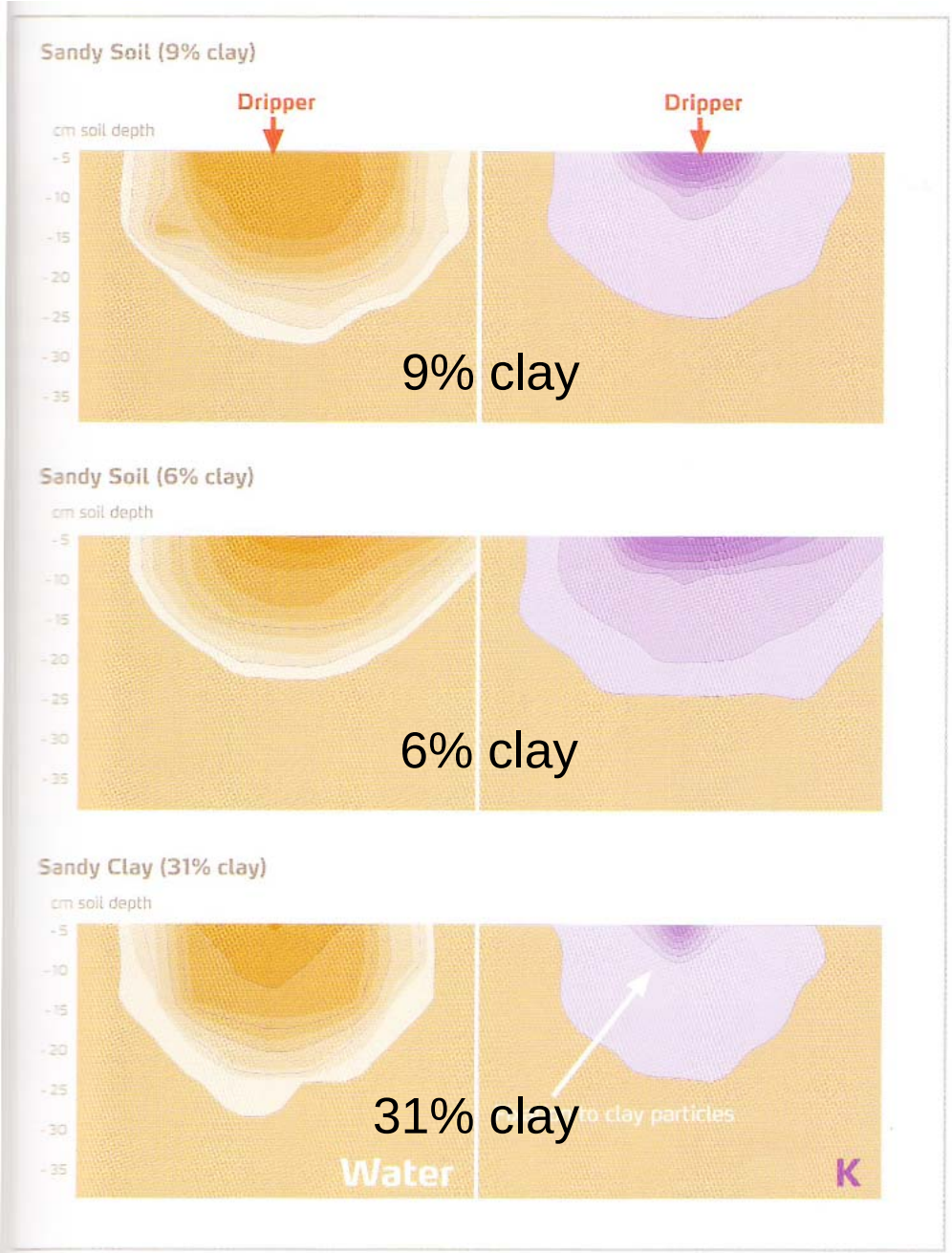
- **A.R.I. can be related to common soil test measurements:**

$$A.R.I. = -19.9 + 0.72 (\Sigma \text{ extractable Ca, Mg, K, Na}) + 2.9 \text{ pHw}$$

- **A.R.I < 5 - use nitrate forms of N fertilizer**
- **A.R.I. 5-15 - requires frequent pH monitoring if ammonium based fertilizers are used**

Typical wetted soil volume following a one-hour irrigation





Relative movement of K in three soils:

Relative movement of P in three soils:

YARA

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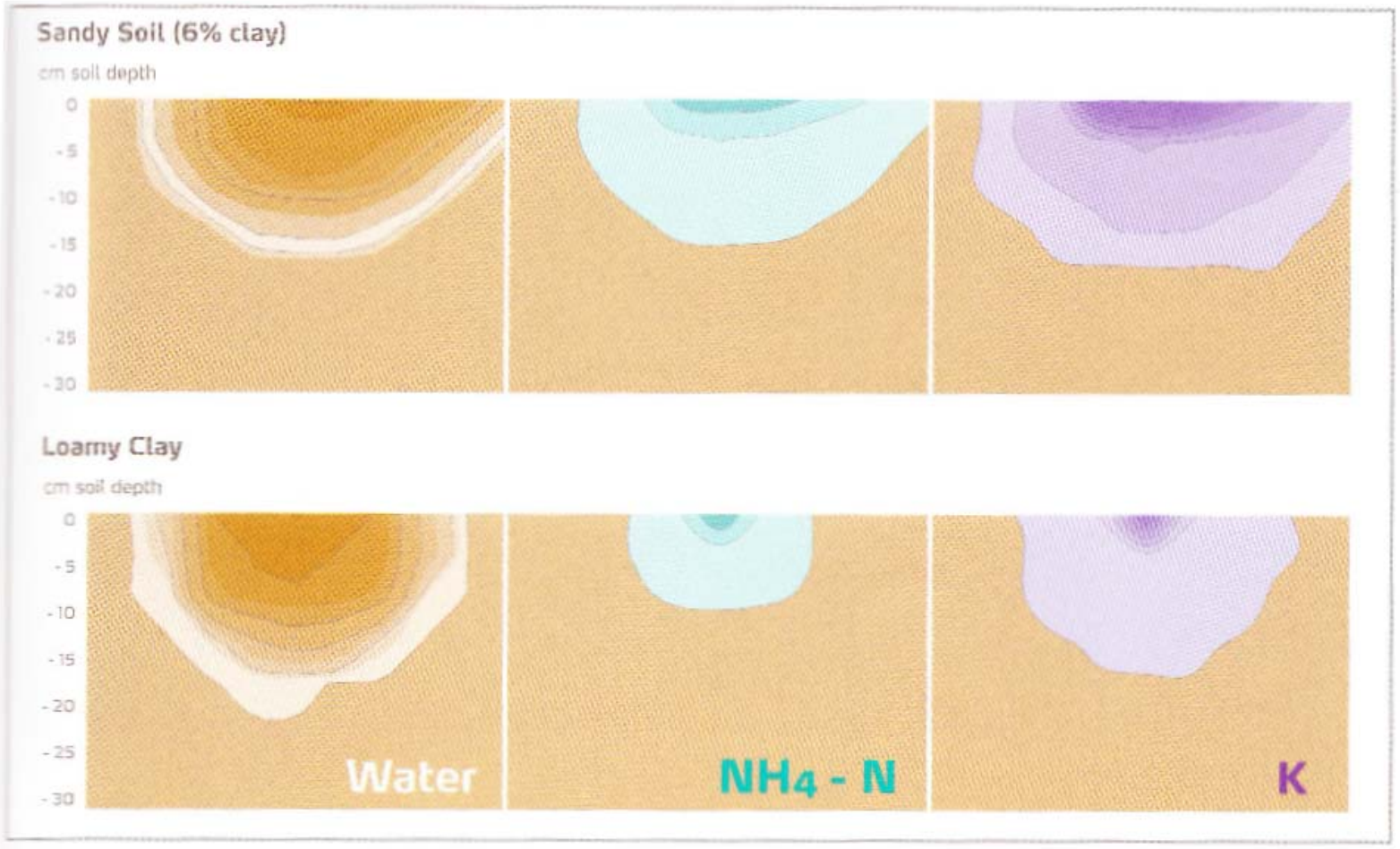
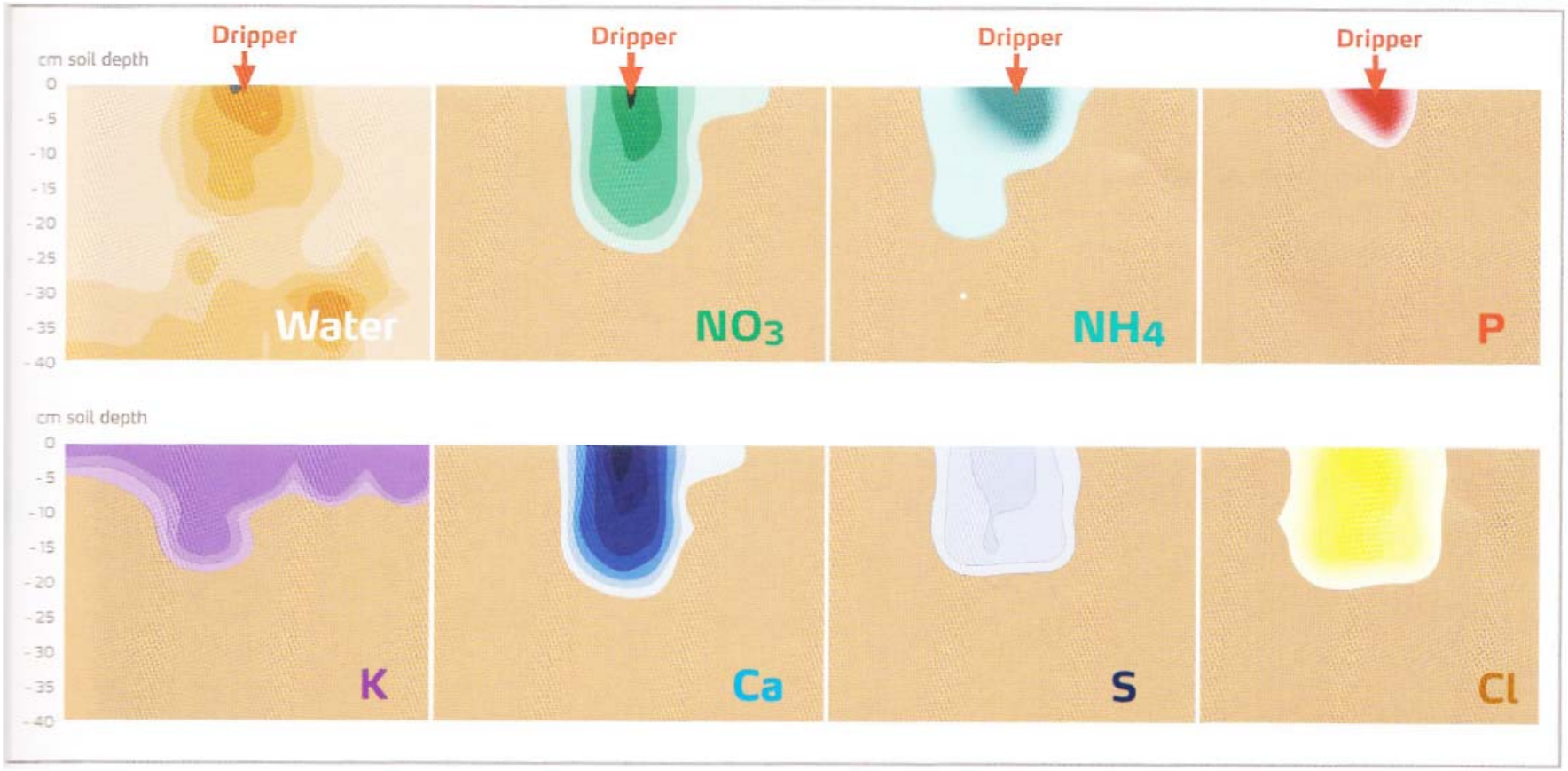
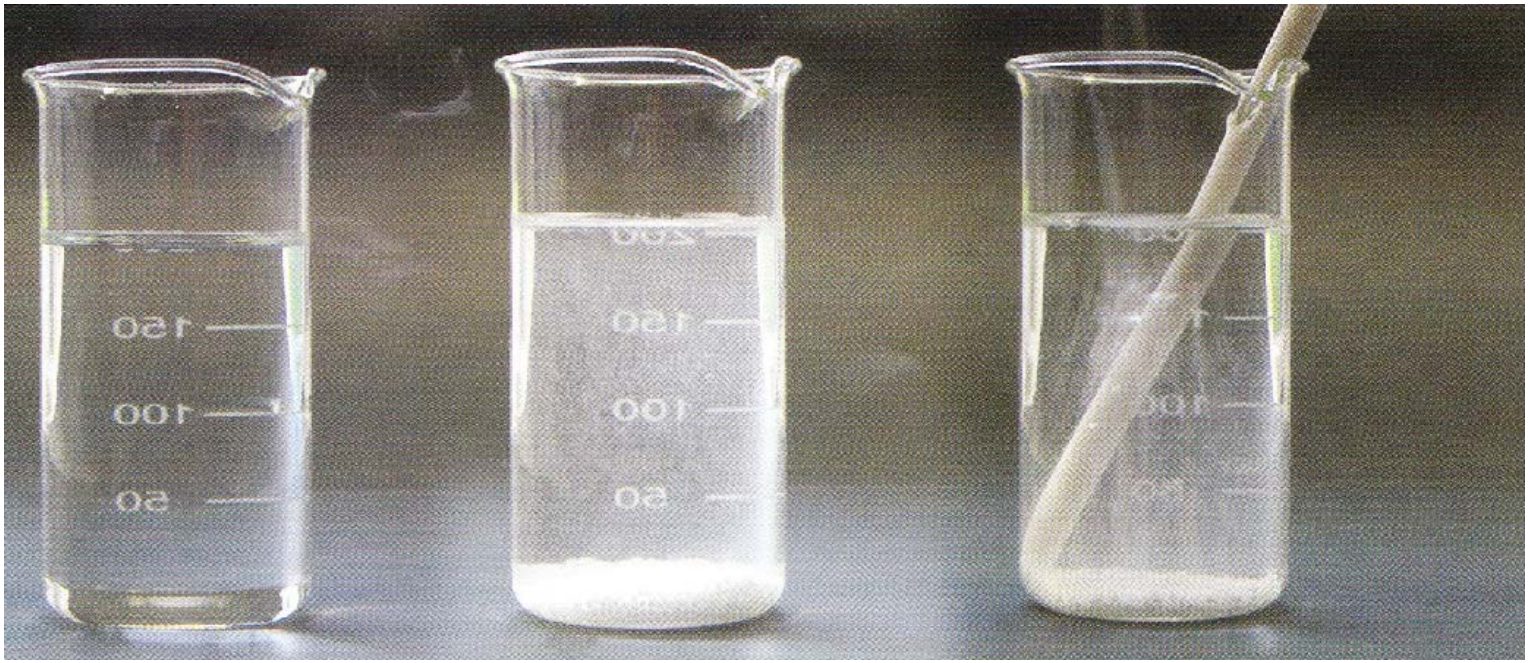
Relative movement of nitrate and ammonium in three soils:

Relative mobility of ammonium and potassium in two soils:

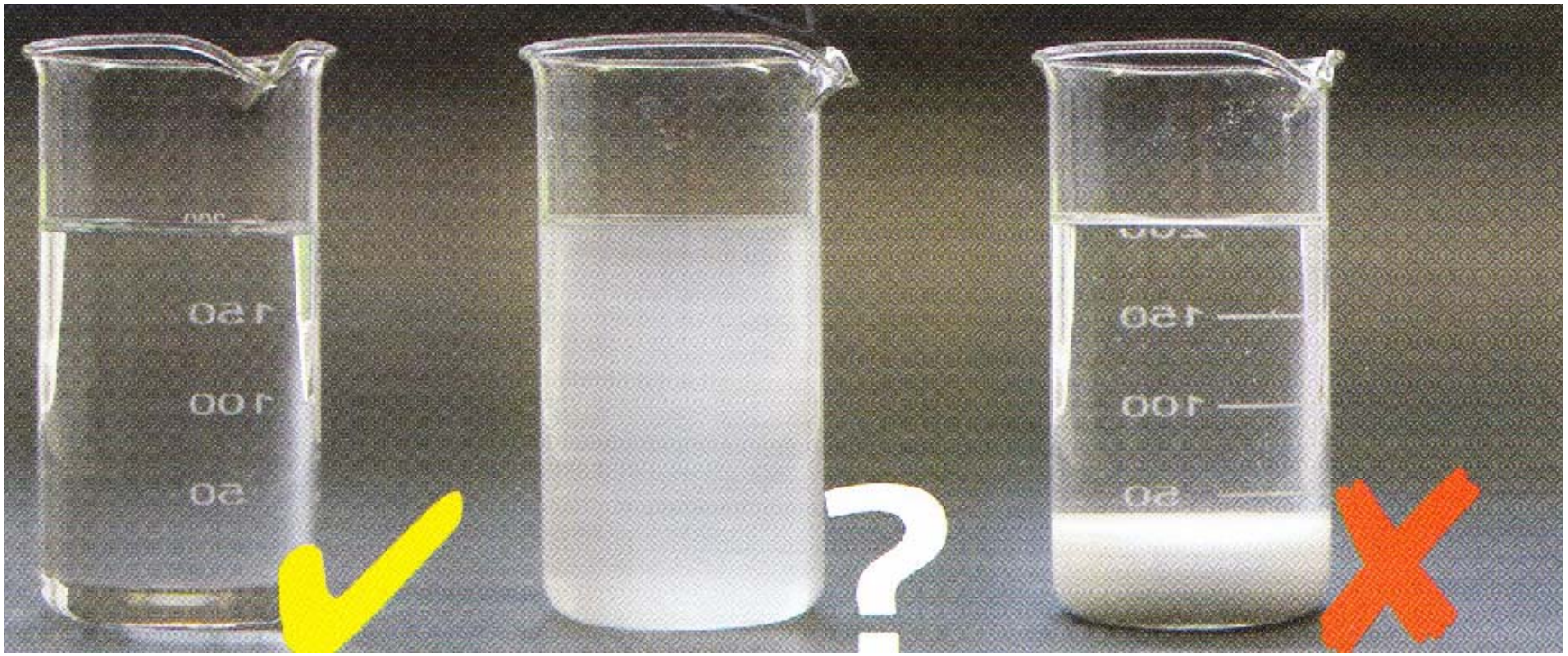


Relative mobility of various nutrients in a sandy clay soil (9% clay)





1. Fill the jar with irrigation water
2. Slowly add the appropriate quantity of fertilizer
3. Stir adequately…. add the next fertilizer

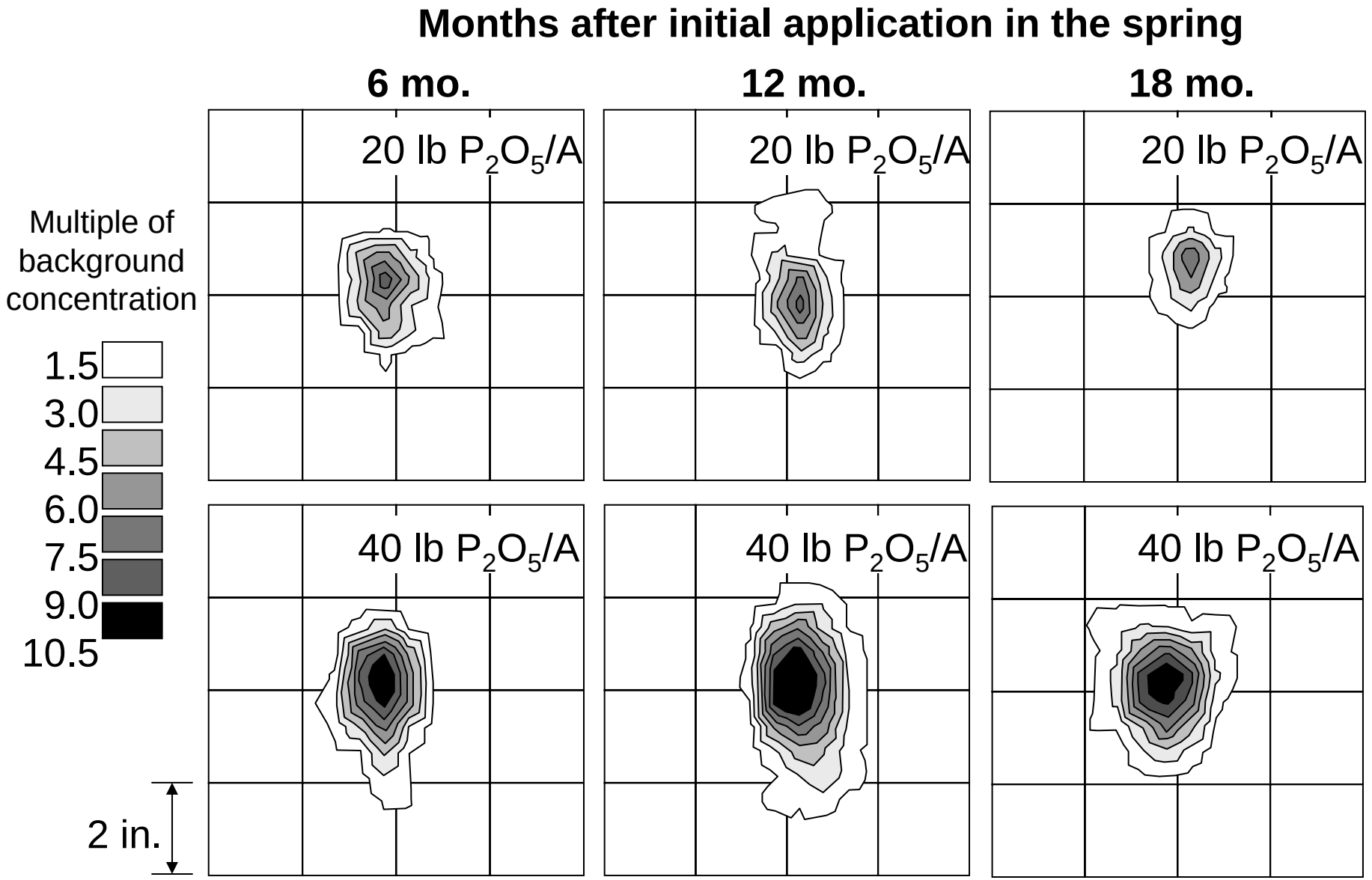


The mixture is compatible…

mix same order and concentration in the field

Continue to check the bottom of the jar- cloudiness may result from impurities… may be ok

This mixture is NOT compatible and cannot be used



Stecker et al., 2001

Matching supply to demand

- **amount**
- **timing**

Timed to meet demand

Foliar sprays

Summer

N is withdrawn from leaves and stored in roots and woody tissue

N is stored in leaves

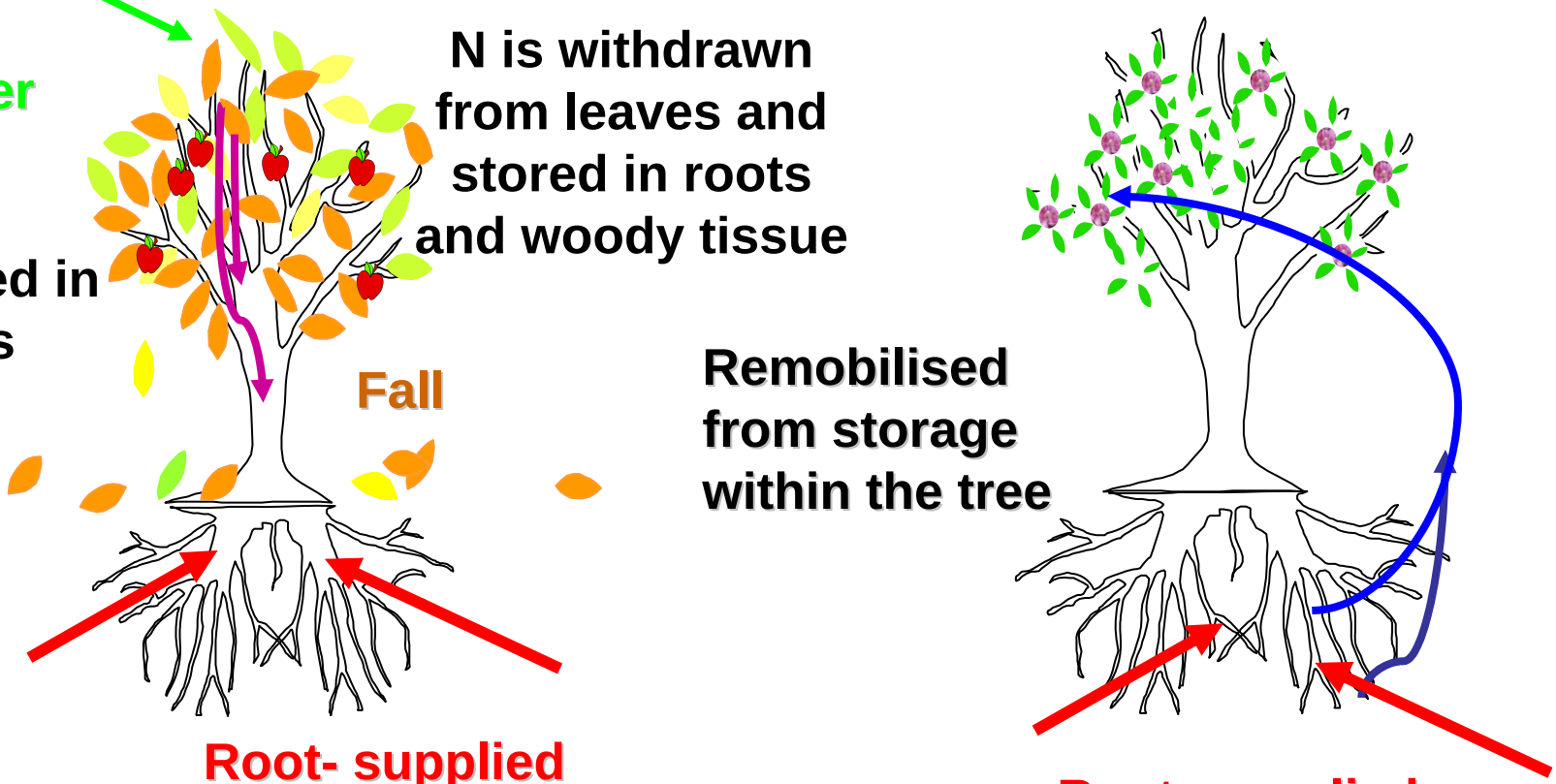
Fall

Root- supplied

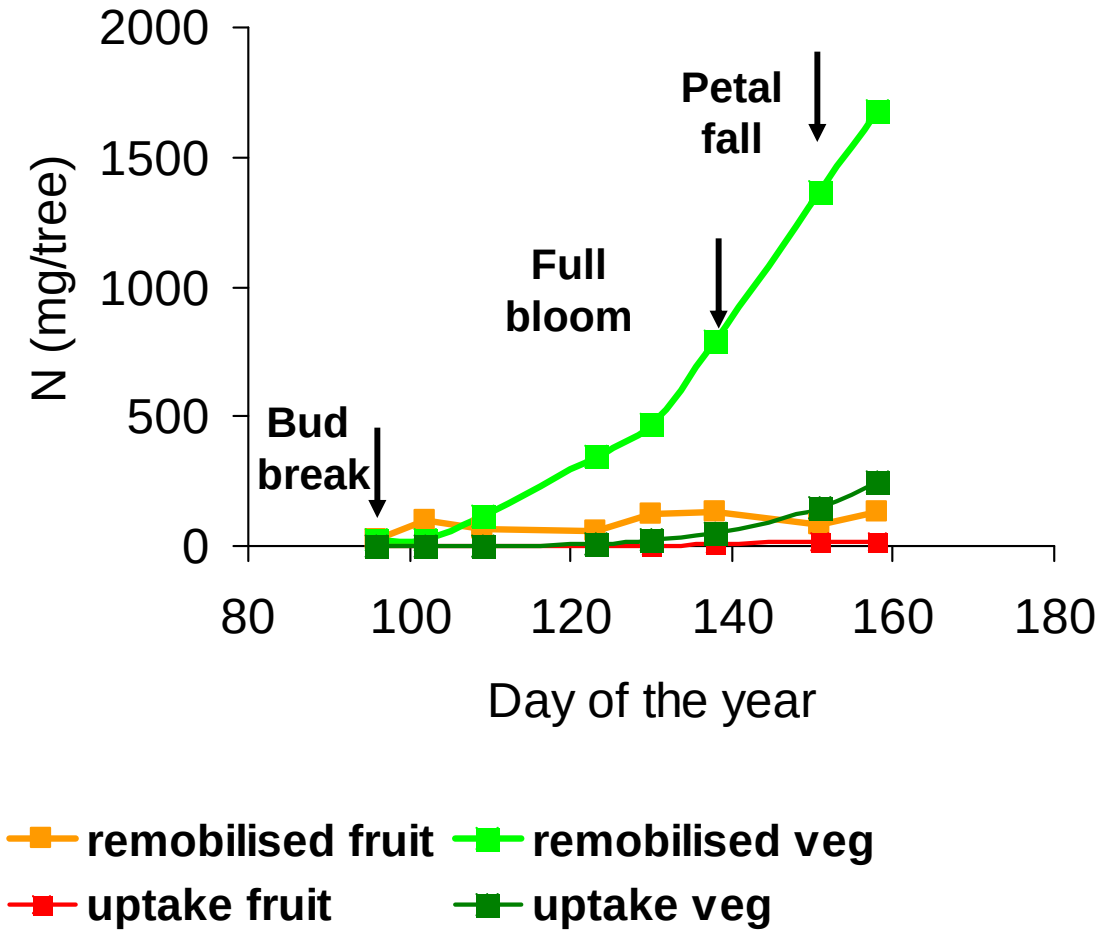
Sources of N for growth in the spring

Remobilised from storage within the tree

Root- supplied after bloom



Timing of remobilisation of N and root uptake from 15N studies



- **Before full bloom leaf growth supported by remobilised N**
- **Root uptake occurs mainly after bloom to support shoot and fruit growth**
- **N inflow into fruit occurs mainly after cell division**

Guak et al. 2003
J. Exp. Bot 54

Conclusions

Mobile nutrients

- **Water management (scheduling, irrigation method) and timing of N application determines the retention of N in the root zone and availability.**
- **Aided by improved understanding of plant demand and nutrient cycling - and time of root uptake**
- **Fertigation allows precise timing of nutrient additions**
- **However, N may be concentrated at the edges of the wetted zone and become available later in the season**

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Conclusions

Immobile nutrients

- **Fertigation can improve maintenance of root-zone K status and K availability, without detrimentally affecting fruit quality- many forms available**
- **Fertigation improves the mobility and effectiveness of P applications**
- **Organic amendments may improve P availability in irrigated systems… still under investigation**

Conclusions

- **Soils receiving acidifying fertilizers have increased sensitivity to acidification under drip irrigation**

- **Susceptibility to acidification can be assessed with empirical relationships derived from buffer curves and soil test for bases**

Redistribution of salts
In wet zone boundary
around the emitter

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