How Can Factors Influencing Soil K Acquisition by Crop Roots be Used to Improve K Rate Recommendations?

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ars Agricultural Research Service
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K Fertility Problems on the Rise

Soil test K = Optimum

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Iowa State University Soil Test K Interpretations and K Fertilizer Recommendations for Corn and Soybean

	1999			2002			2013		
		K Fertilizer			K Fertilizer			K Fertilizer	
Soil Test Category	Soil Test K	Corn	Soy-bean	Soil Test K	Corn	Soy-bean	Soil Test K	Corn	Soy-bean
	ppm	lb. K_2O/acre		ppm	lb. K_2O/acre		ppm	lb. K_2O/acre	
Very Low	0-60	120	90	0-90	130	120	0-120	130	120
Low	61-90	90	75	91-130	90	90	121-160	90	90
Optimum	91-130	40	65	131-170	45	75	161-200	40	66
High	131-170	0	0	171-200	0	0	201-240	0	0
Very High	171+	0	0	201+	0	0	241+	0	0

ISU PM 1688, 2013

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Improving K Fertility

- Consider basic soil processes
- Consider root growth and function
- Connect soil and plant characteristics to develop better K recommendations

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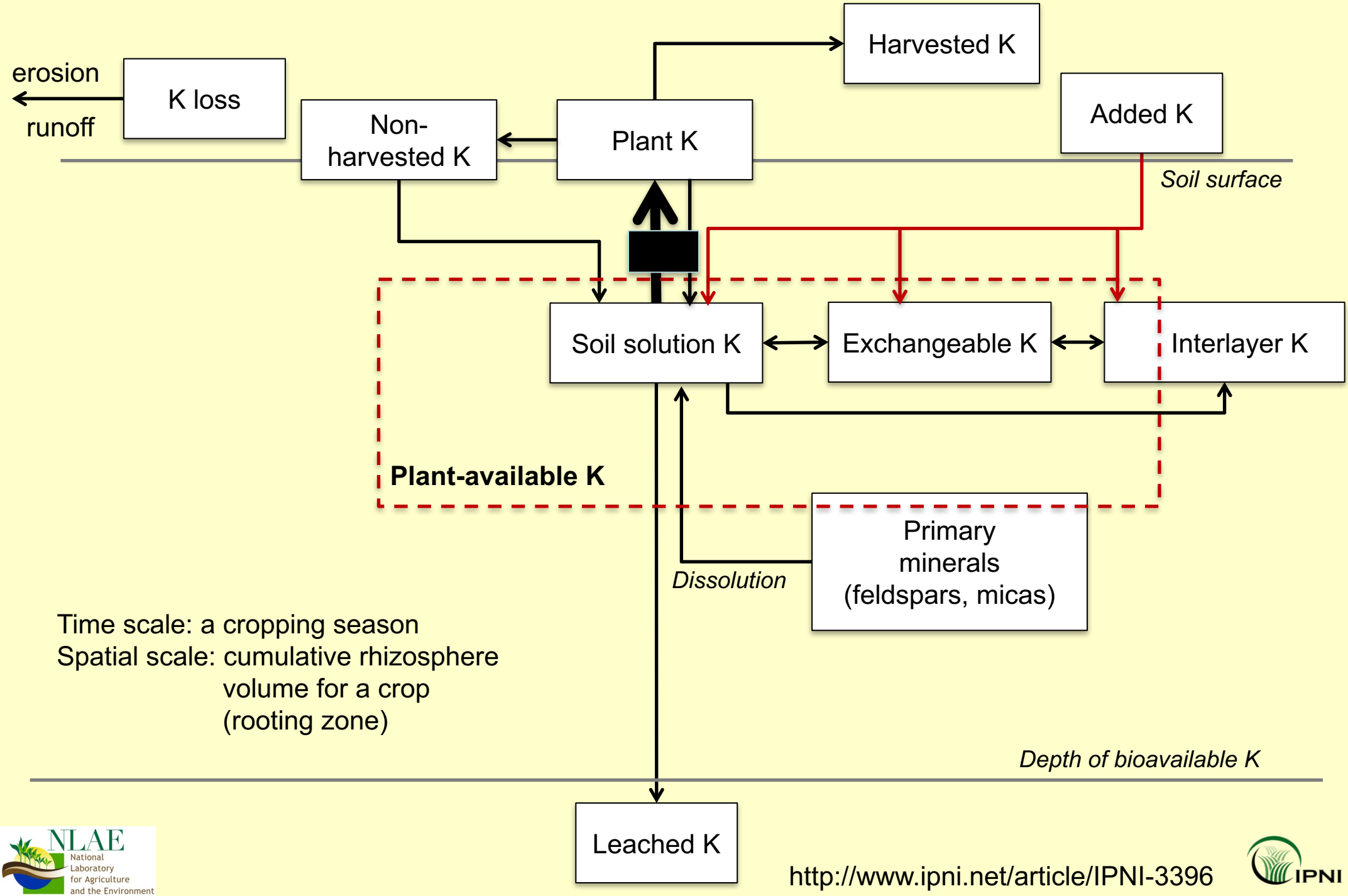
erosion
runoff
K loss
Non-harvested K
Plant K
Harvested K
Added K
Soil surface
Soil solution K
Exchangeable K
Interlayer K
Plant-available K
Primary minerals (feldspars, micas)
Dissolution
Time scale: a cropping season
Spatial scale: cumulative rhizosphere volume for a crop (rooting zone)
Depth of bioavailable K
Leached K
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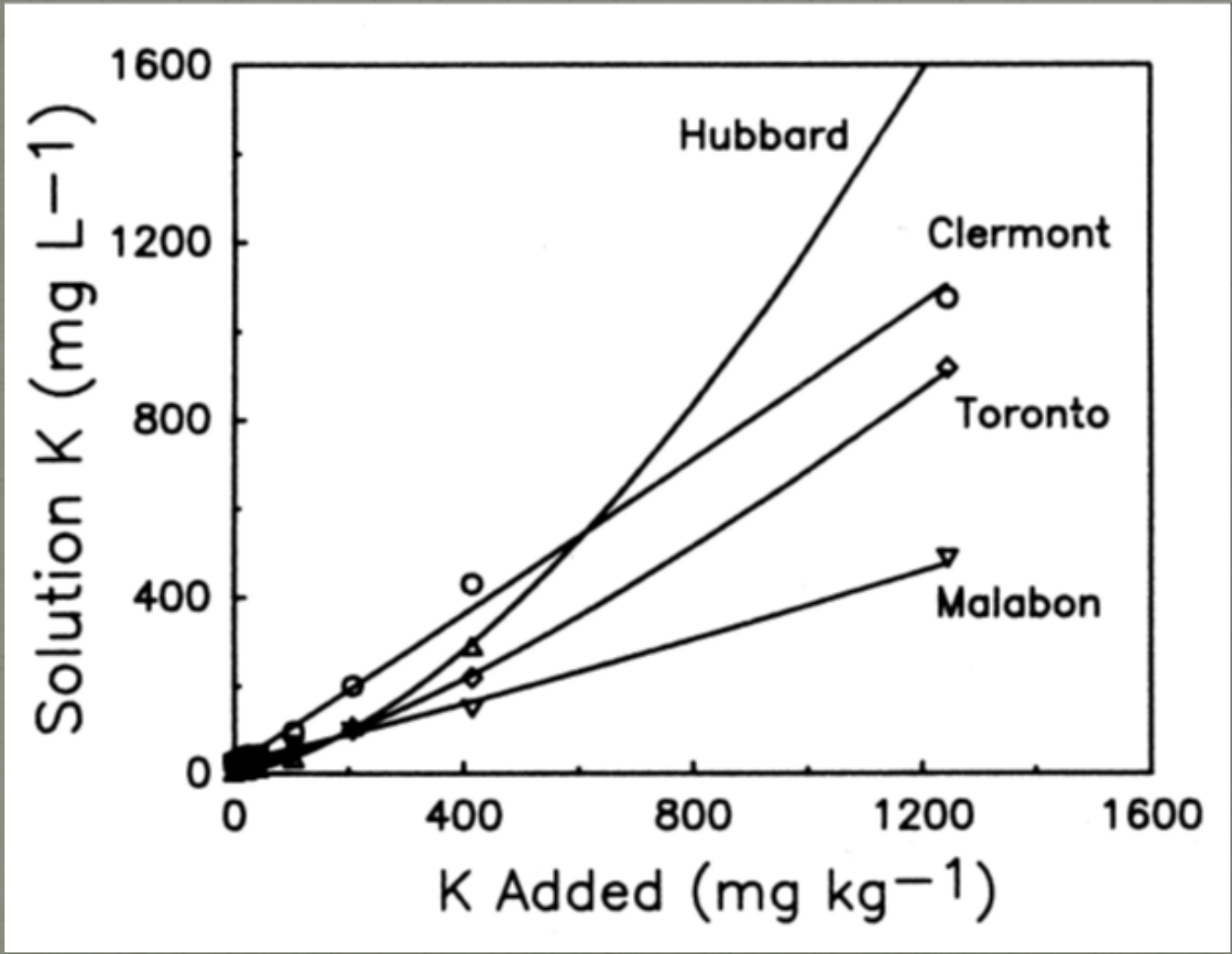
http://www.ipni.net/article/IPNI-3396
IPNI

K fertilizer increases soil solution K



Kovar and Barber, 1990

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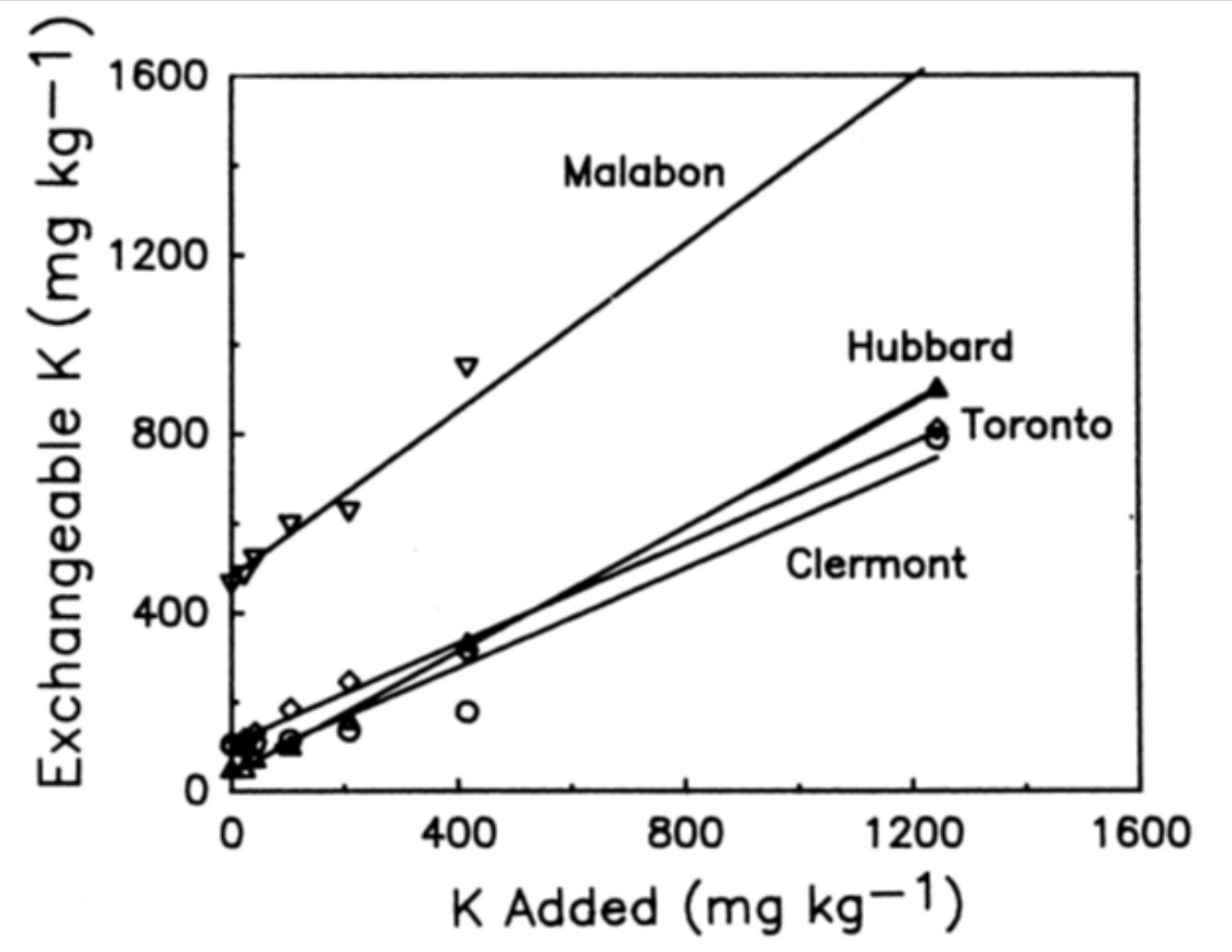
K fertilizer increases soil exchangeable K



Kovar and Barber, 1990

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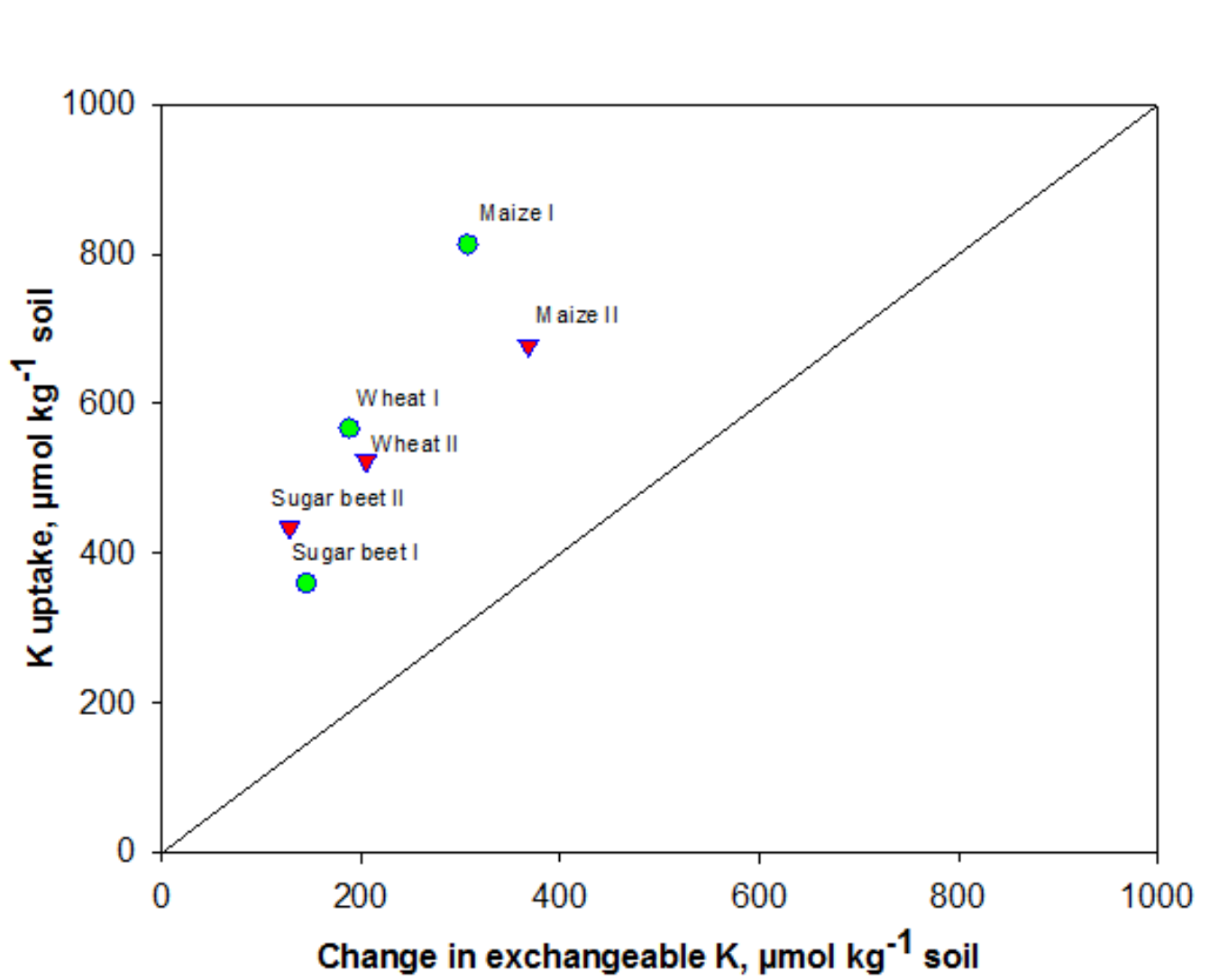
Non-exchangeable K supplies K to roots



Modified from Samal et al. (2010)

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What K fertilizer rate is needed in this field?

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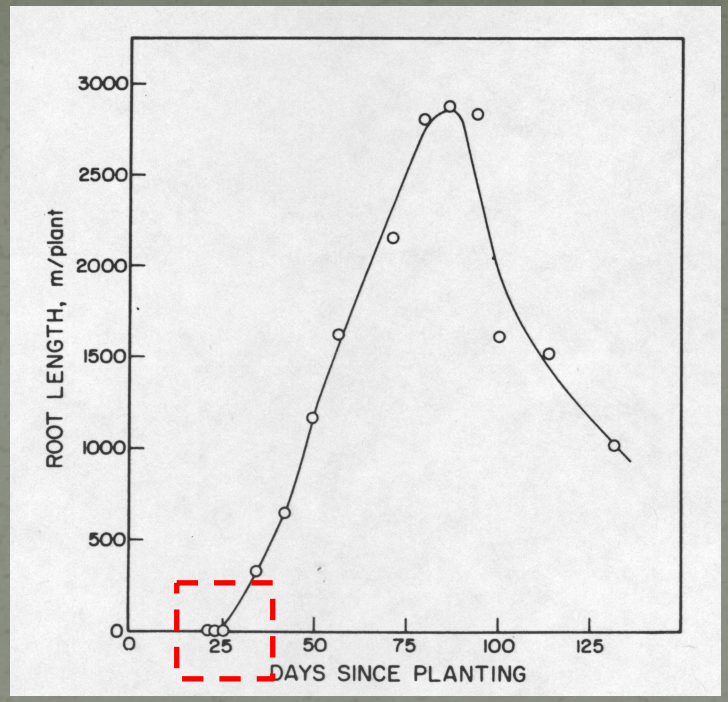
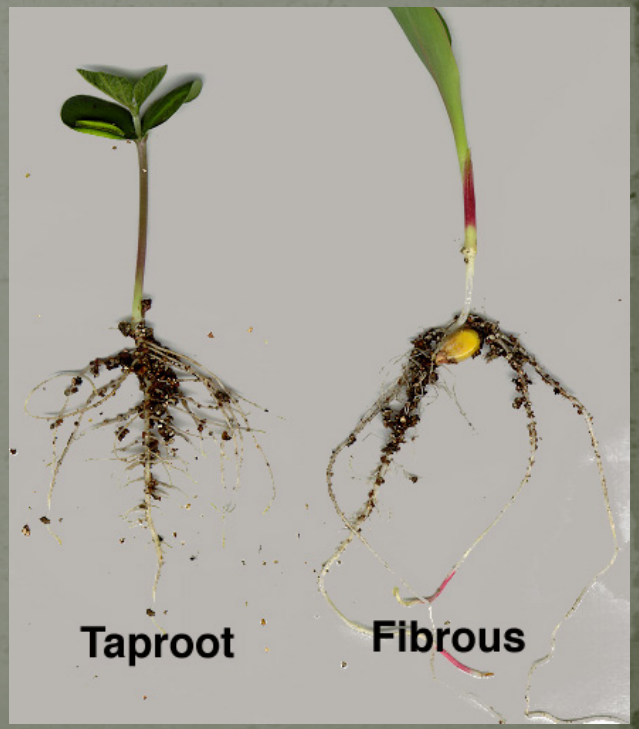
Why consider the roots?

- Inherent soil physical and chemical properties affect root growth and function
- Changes in root growth and function can cause changes in crop response to K fertilizer, even when soil supply of K is more than adequate

Photo: D.L. Karlen



Barber, 1995



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Soil Bulk Density and Water Content Affect Maize Root Growth and K Uptake (18 d after planting)

Bulk Density	Water Content	Root Growth	K Influx
g cm^{-3}	% (w/w)	10^{-6} cm s^{-1}	10^{-13} mol cm^{-1} s^{-1}
1.2	10.7	1.00a†	1.82a
	14.2	1.95cd	2.82b
	19.0	2.43e	3.38c
1.4	10.7	1.24ab	1.97a
	16.3	1.94cd	3.66c
	19.0	2.24de	4.53d
1.6	10.7	1.12a	2.17a
	14.2	1.63bc	2.09a
	19.0	2.32de	3.62bc

†Means followed by same letter not significantly different ($p<0.05$)

Seiffert et al., 1995

Are deep roots active?

- Most soil K test – crop response relationships are based on a 0 to 15 cm sample
- In many environments, and particularly in soils that can store significant plant-available water, roots grow deeper into the soil
- The adoption of reduced tillage or no-till can also result in the 0 to 15 cm layer (especially the top 5 cm) becoming relatively enriched, and the soil layers below becoming depleted (stratification)

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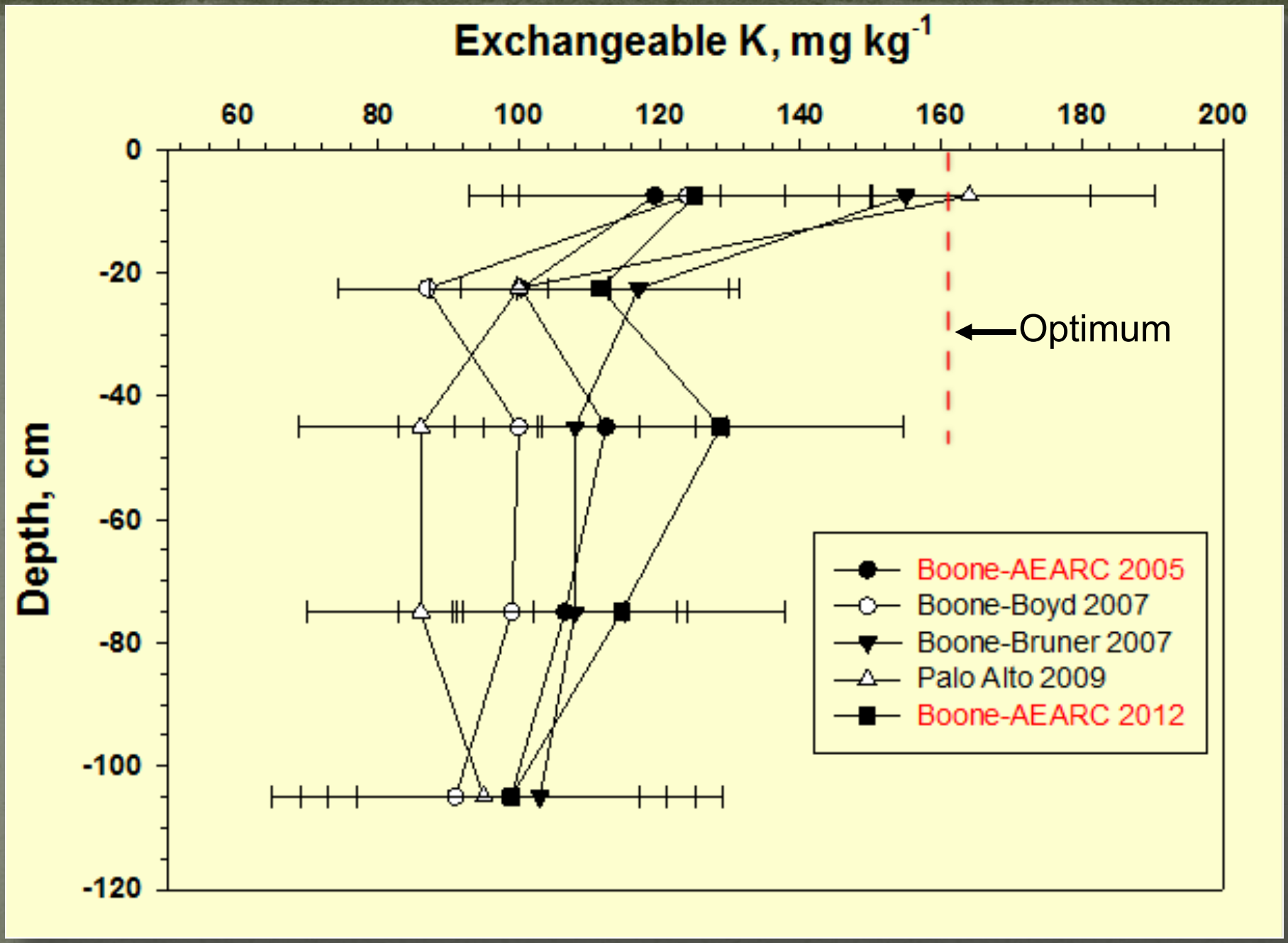
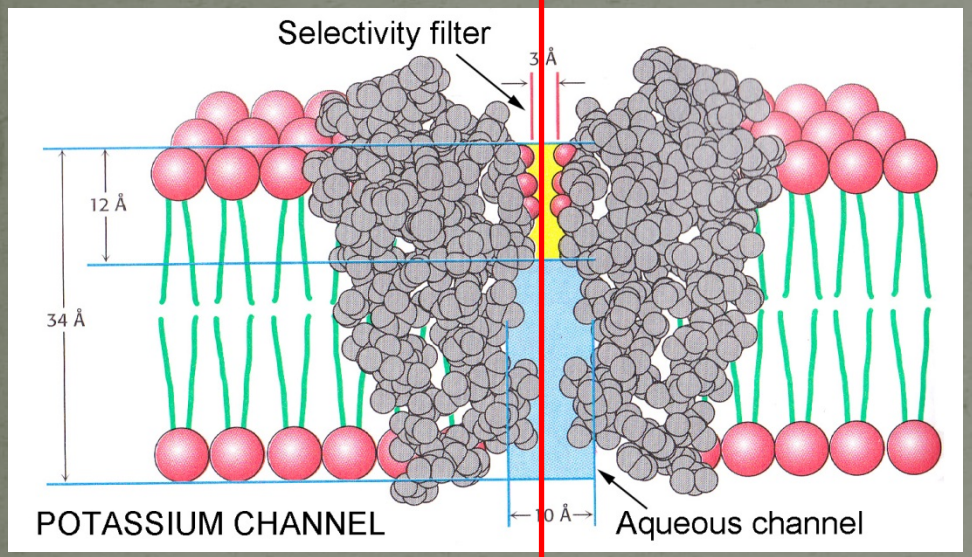


Kovar and Karlen, 2014

Potassium Supply and Uptake by Roots

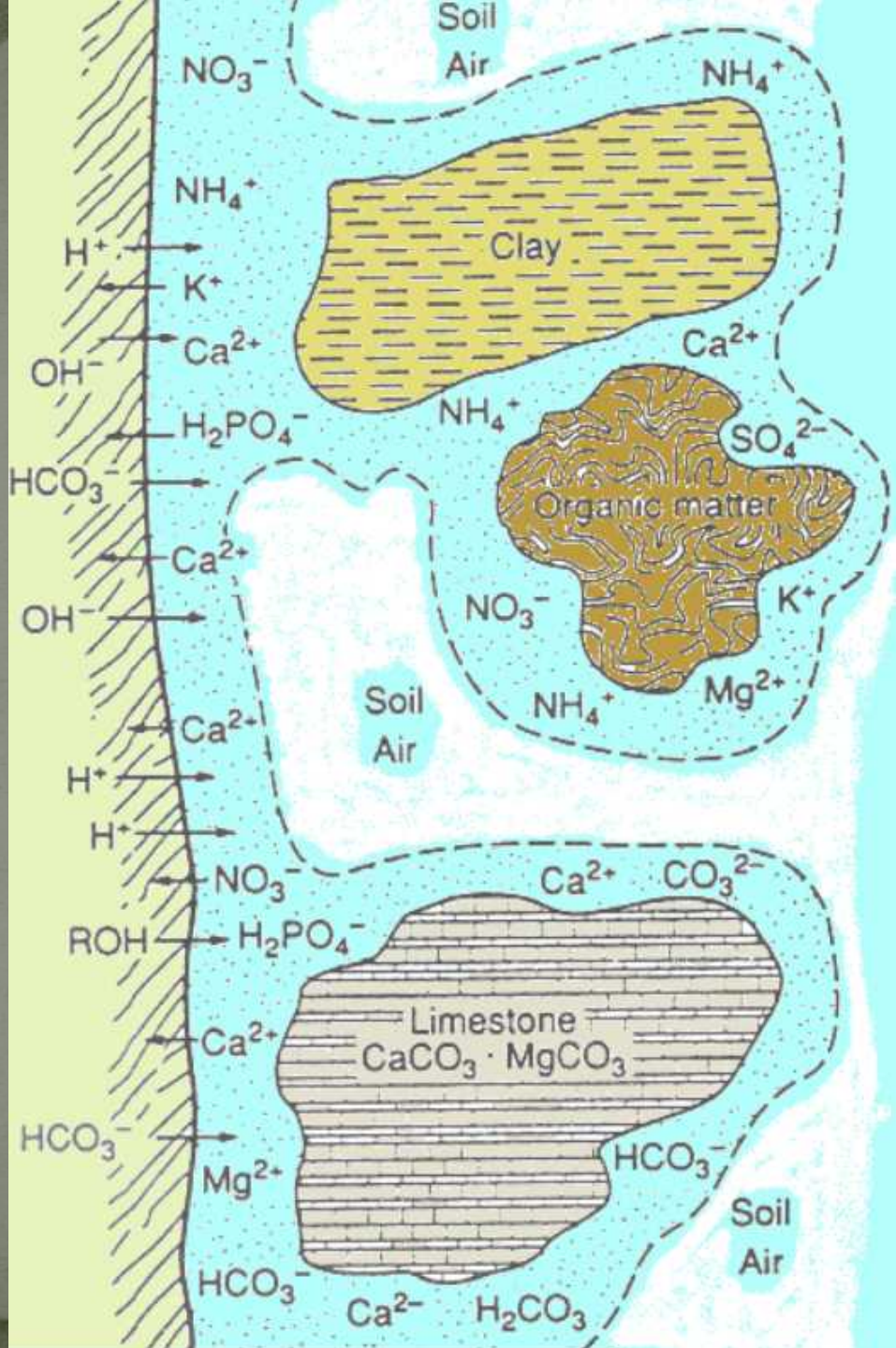
inside



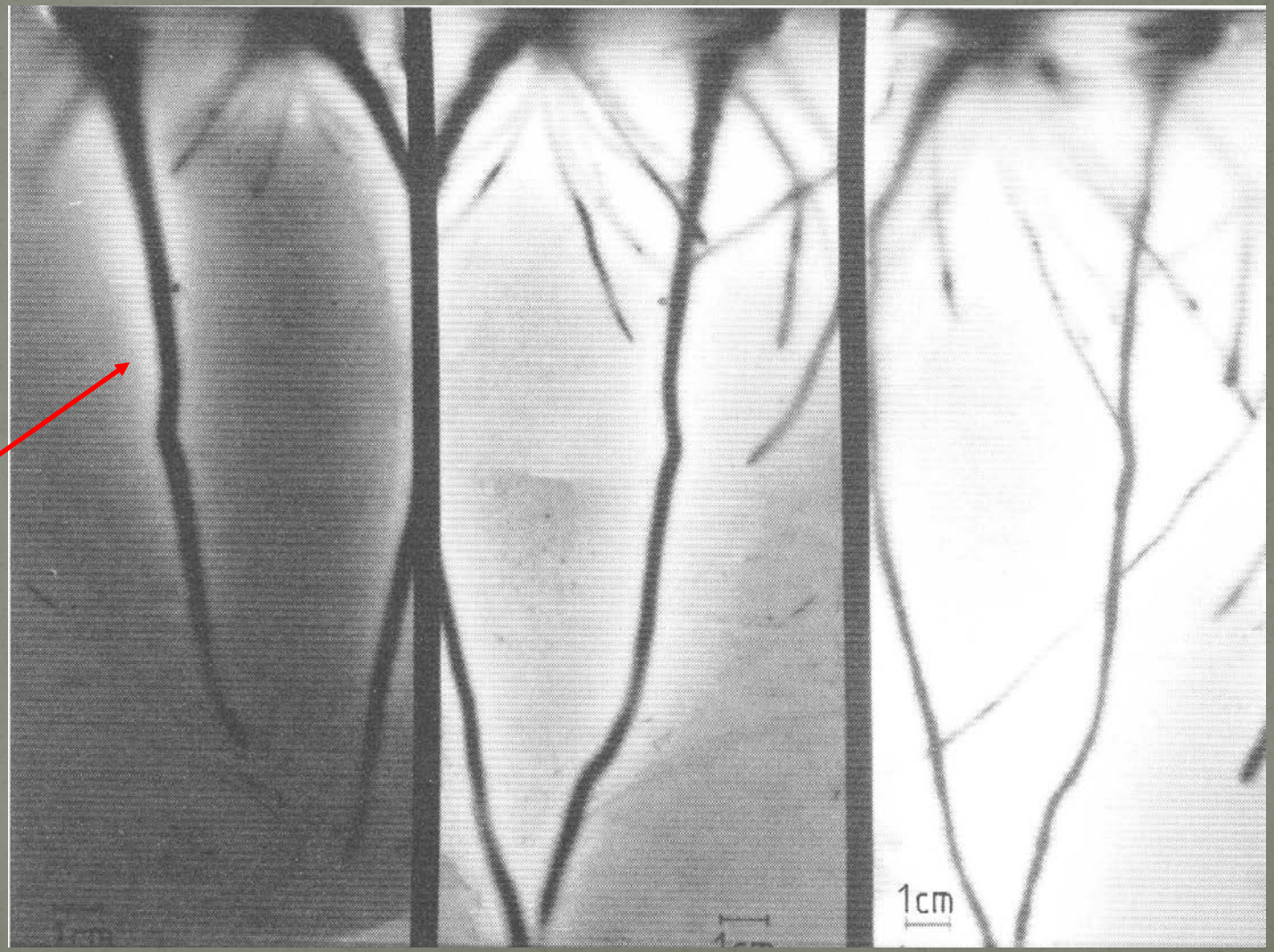
outside

Protein channels and carrier proteins transport K+ across root cell membranes

http://www.acbrown.com/neuro/Lectures/Mmbr/NrMmbrMode.htm



Autoradiograph of ^{86}Rb depletion from soil and uptake by growing roots



Concentration gradient = diffusion

Walker and Barber, 1962

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Measuring rhizosphere nutrient concentrations

Micro-suction Cup

Sample Holders

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Changes in rhizosphere soil solution concentrations of P, K, Ca, and Mg with distance from the root surface after 10 days of plant growth

Nutrient	Solution Concentration (mg L^{-1})					
	Maize		Cottonwood		Switchgrass	
	<1mm	>8mm	<1mm	>8mm	<1mm	>8mm
P	0.85b*	1.12a	0.89b	1.05a	1.02a	1.09a
K	4.70b	5.09a	4.85b	5.15a	5.09a	5.11a
Ca	23.8a	25.2a	28.3a	25.8a	25.5a	25.5a
Mg	15.0a	13.8a	13.6a	14.8a	15.8a	16.4a

*Values within a species/nutrient combination followed by the same letter are not significantly different at the 0.05 level.

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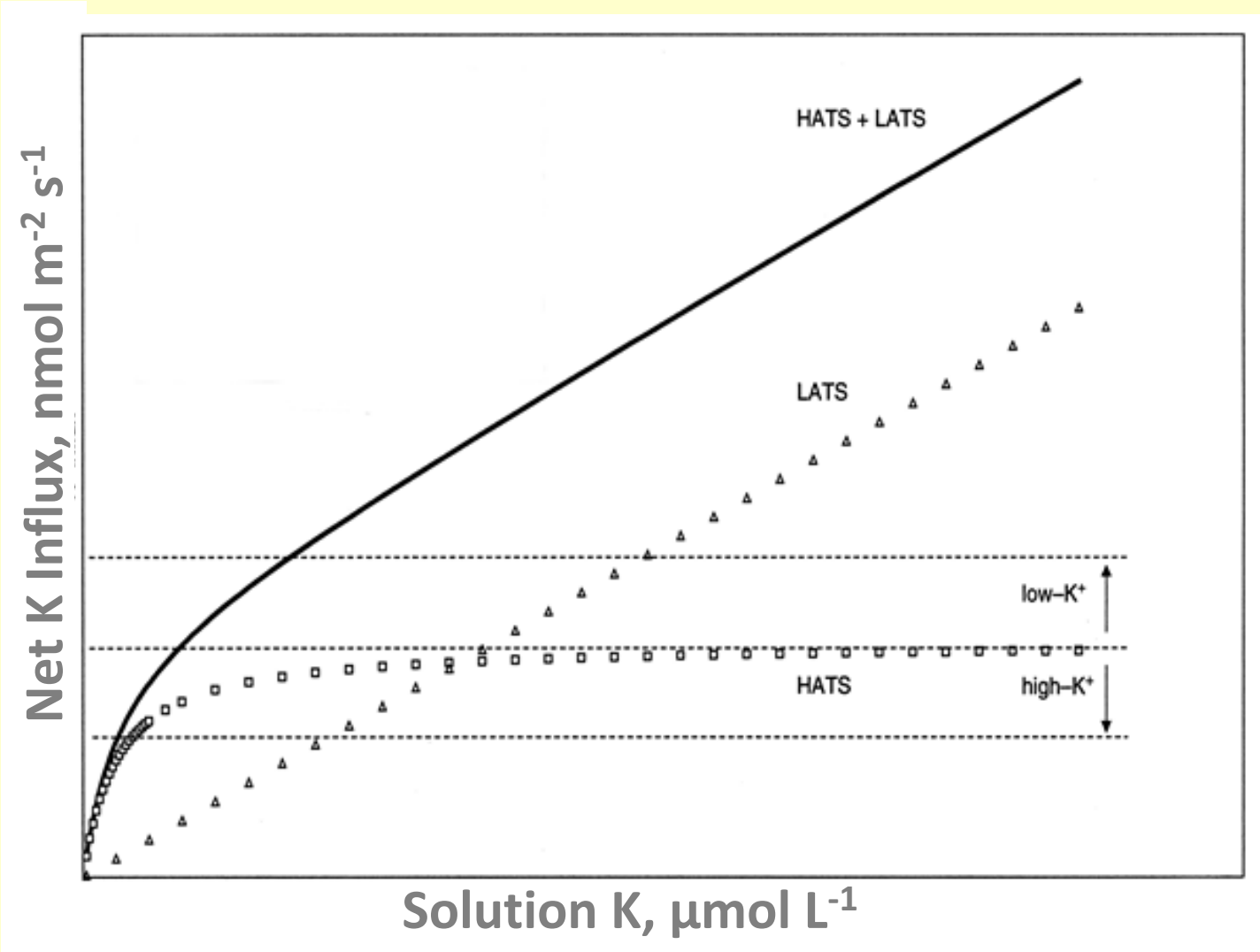
Wang et al., 2005

Root K influx increases with increasing solution K concentration



Modified from Britto and Kronzucker (2008)

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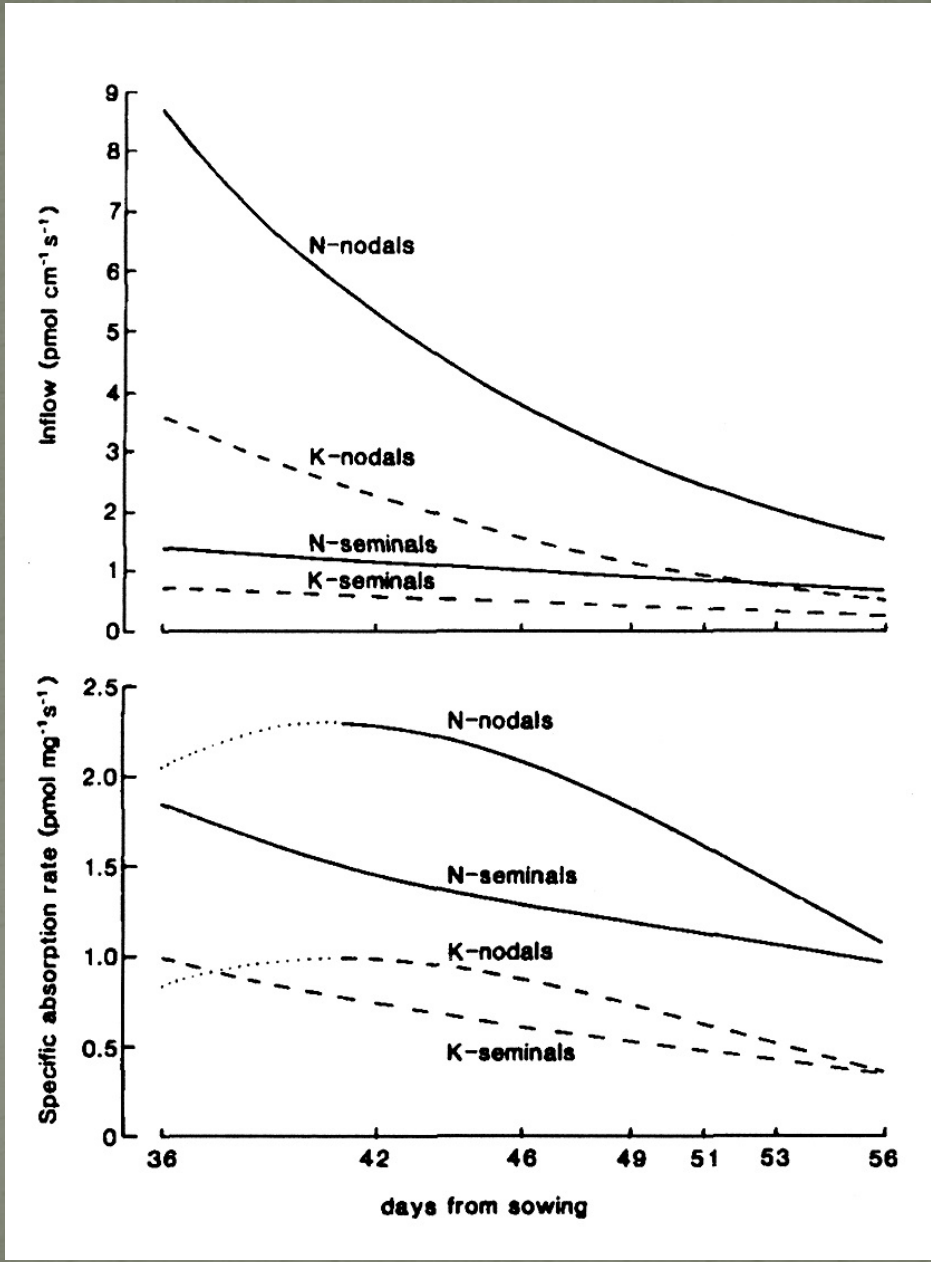

K uptake rates may differ among root types on the same plant

- Winter wheat grown in solution culture
- K influx 2 to 6 times higher for nodal roots
- Uptake rate per unit root decreased with plant age

Kuhlmann and Barraclough, 1987

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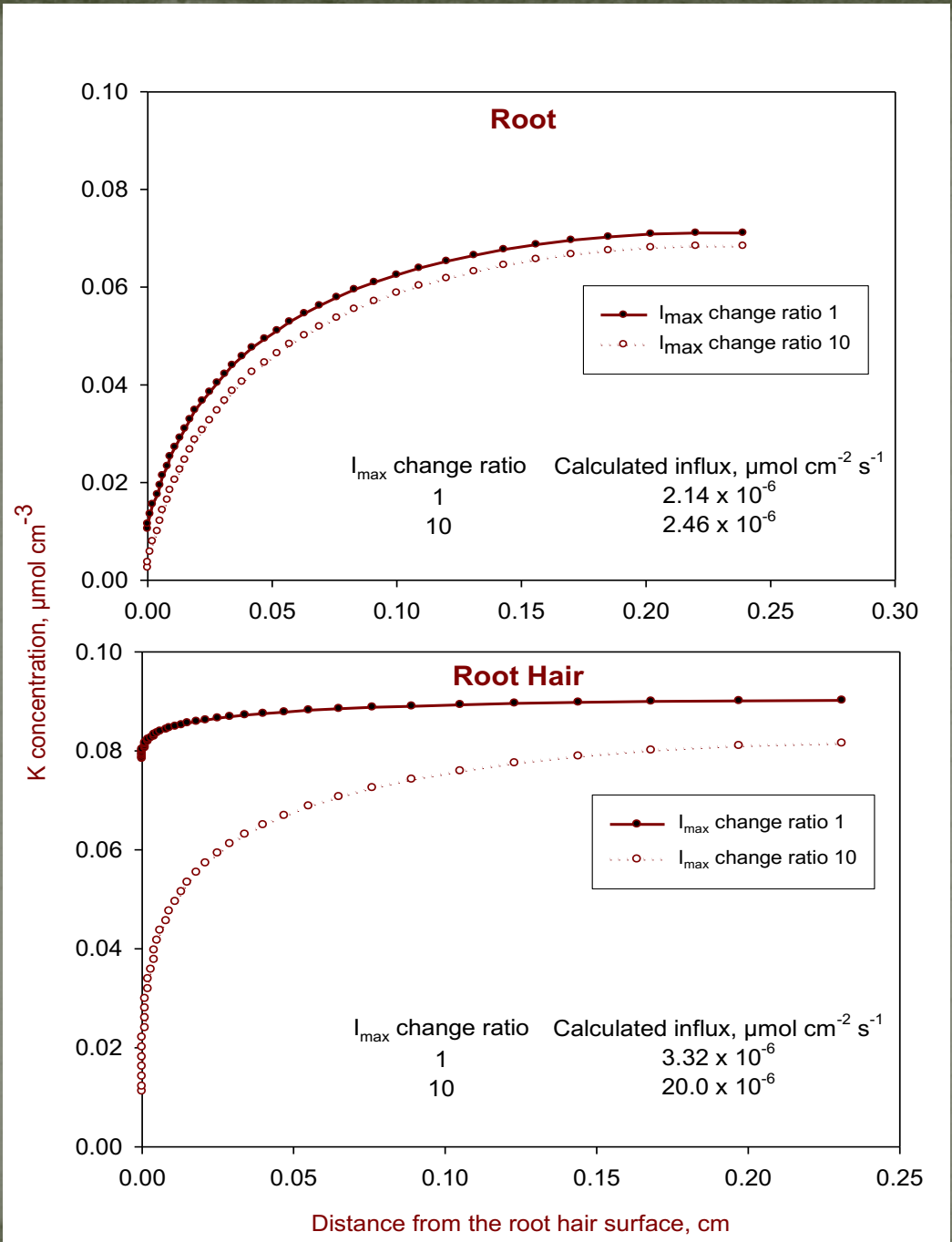

Root hairs are more responsive to changes in K influx rates

- Winter wheat grown in low K soil
- 10-fold increase in Imax of root hairs = increased gradient = greater diffusive flux
- K influx 6-fold higher for root hairs

Modified from Samal et al. (2010)

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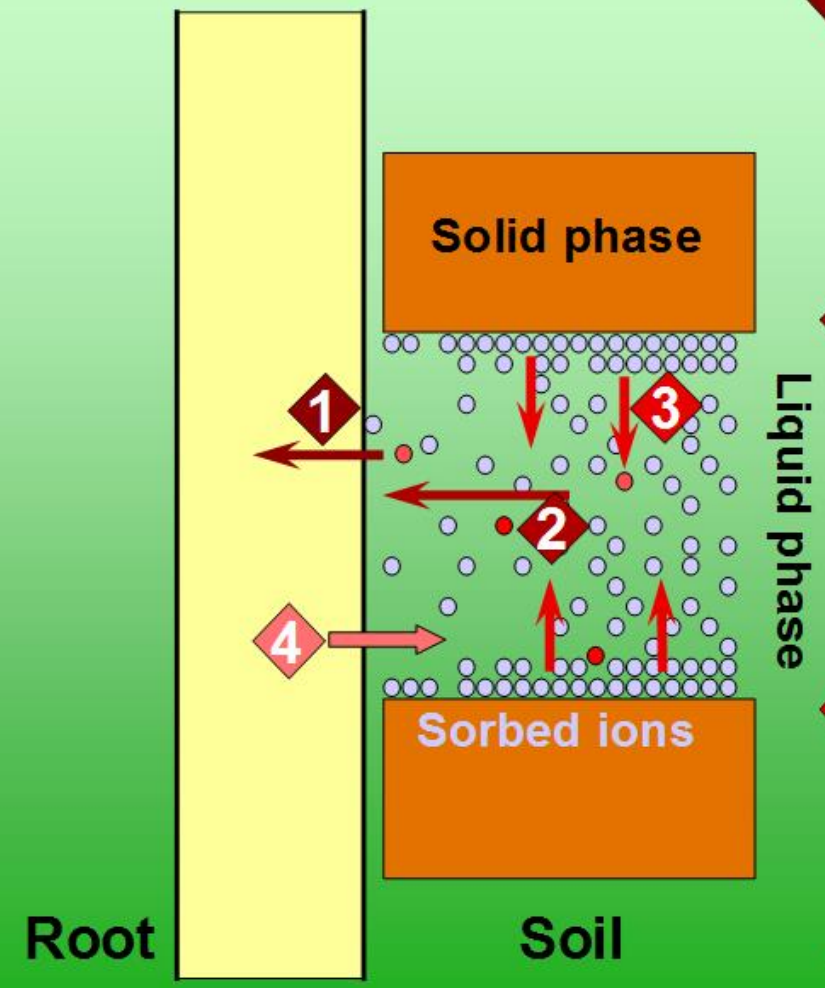
Modelling concepts of nutrient uptake model NST 3.0

NST 3.0.lnk



Soil-root system

1 Influx

$$In = \frac{I_{max}\,(C_L - C_{Lmin})}{K_m + C_L - C_{Lmin}}$$

2 Transport

$$F_{mass\ flow} = C_L\, v_0$$

$$F_{diffusion} = -D_L\, \theta\, f\, \frac{dC_L}{dx}$$

3 Sorption / Desorption

$$dC = b\, dC_L^{\,a} + c$$

4 Exudation

Modified from Samal et al. (2009)

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Main Points

- Soil test-crop response relationships can be quite site specific
- Differences in soil K pools, the efficiency of soil K supply processes and soil and climatic factors influencing crop root systems and activity can be major contributors to this site specificity
- The potential for different soil sampling strategies and combinations of soil analytical tests to account for these differences and provide a more generic understanding of site K fertility should be explored
- Fertilizers are expensive, so deciding where K inputs are needed, and then how much K is needed, in what form and when and where in space and time are critical decisions for farmers and advisors

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Additional Thoughts…

- Need a better way to evaluate K flux as it relates to K acquisition ➔ may be only way to improve K fertilizer recommendations
- Must consider root traits, and how K requirements differ among crop species and even within species
- Models can help us
- Scale is important

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