Influence of Potassium Nutrition On Nitrogen Use Efficiency

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Nitrogen Use Efficiency

$$NUE = NUpE \times NUtE$$

Agronomic N Use Efficiency =

N Uptake Efficiency x N Utilisation Efficiency

(yield / available N) =

(N acquired / available N) x (yield / N acquired)

White et al. (2012) *Appl. Environ. Soil Sci.* 2012: #104826

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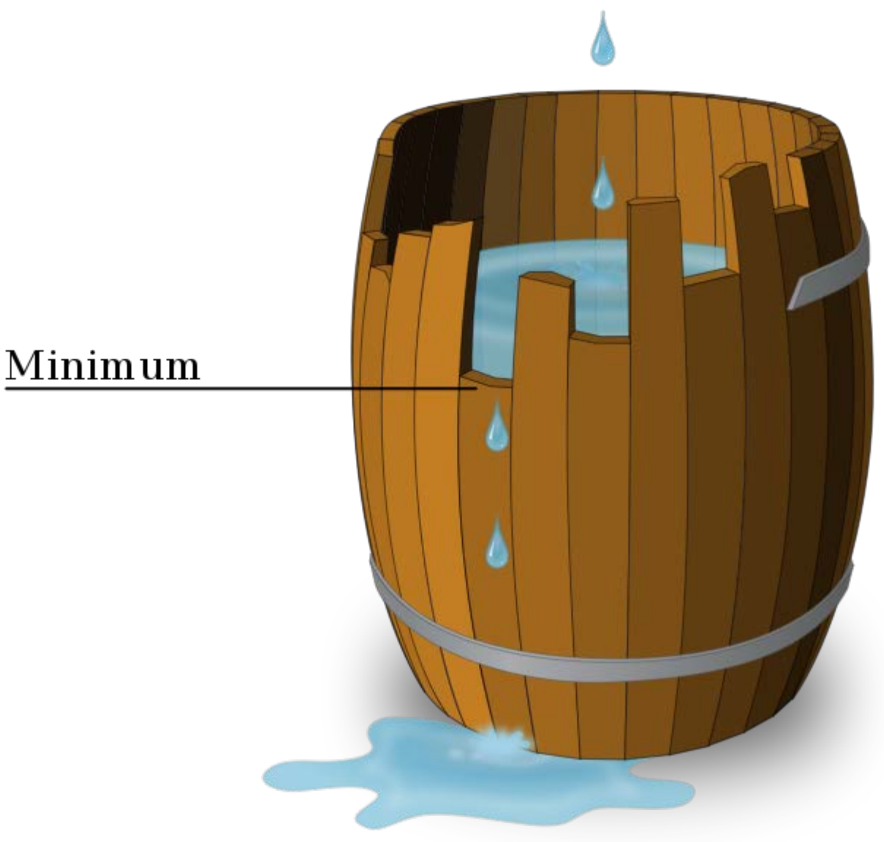
Plant Mineral Nutrition and Crop Yield
Liebig's Law of The Minimum



Crop yield is determined by a critical input that is in short supply: the limiting factor.

Inputs that do not correct the limiting factor are generally ineffective in increasing yield.

Any nutrient that limits yield will reduce the use efficiency (yield / input) of all other nutrients.

Marschner's Mineral Nutrition of Higher Plants, 2012

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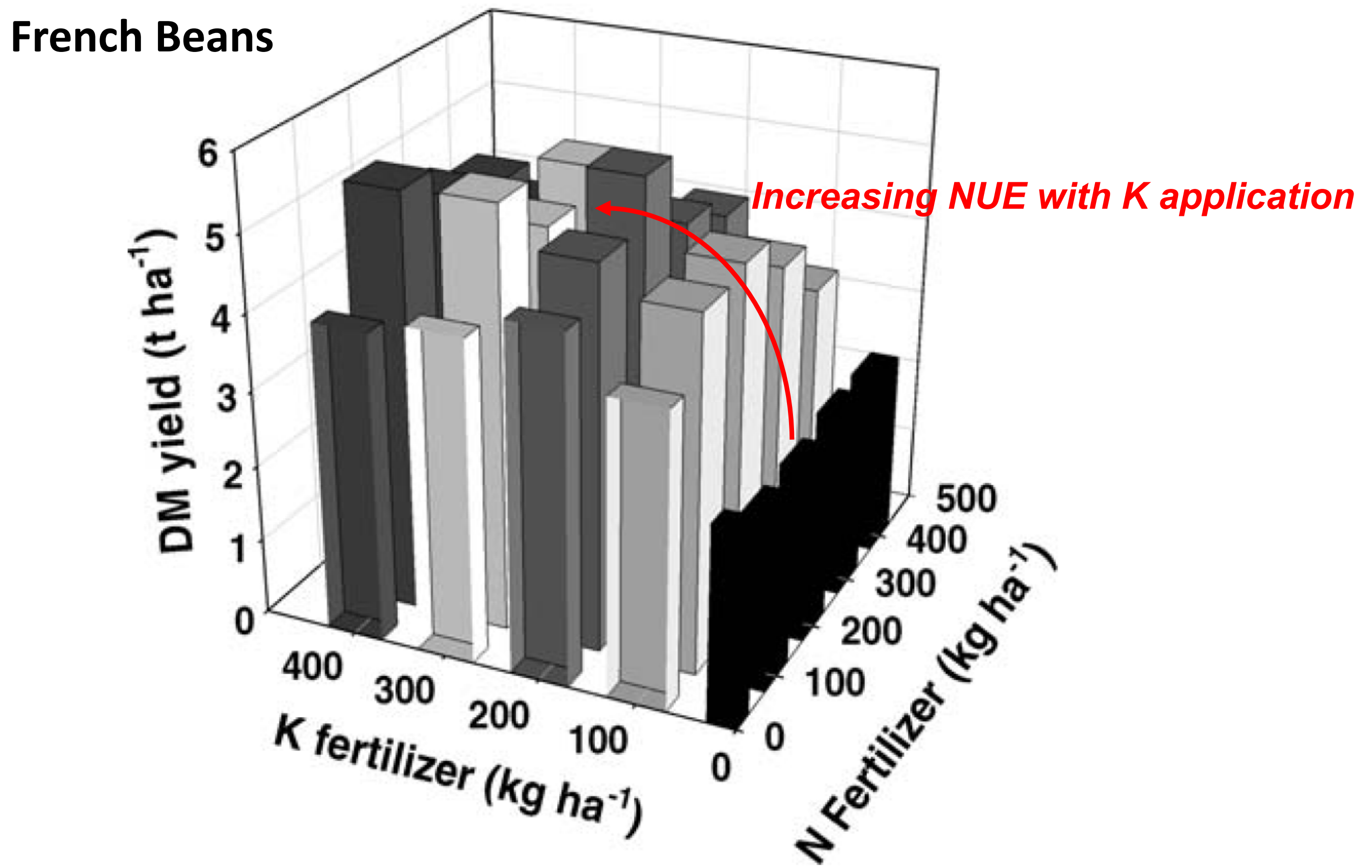
Optimising Crop Nutrition Maximises Yield and Resource Use Efficiency



Zhang et al. (2007) *Plant and Soil* 298: 81-98

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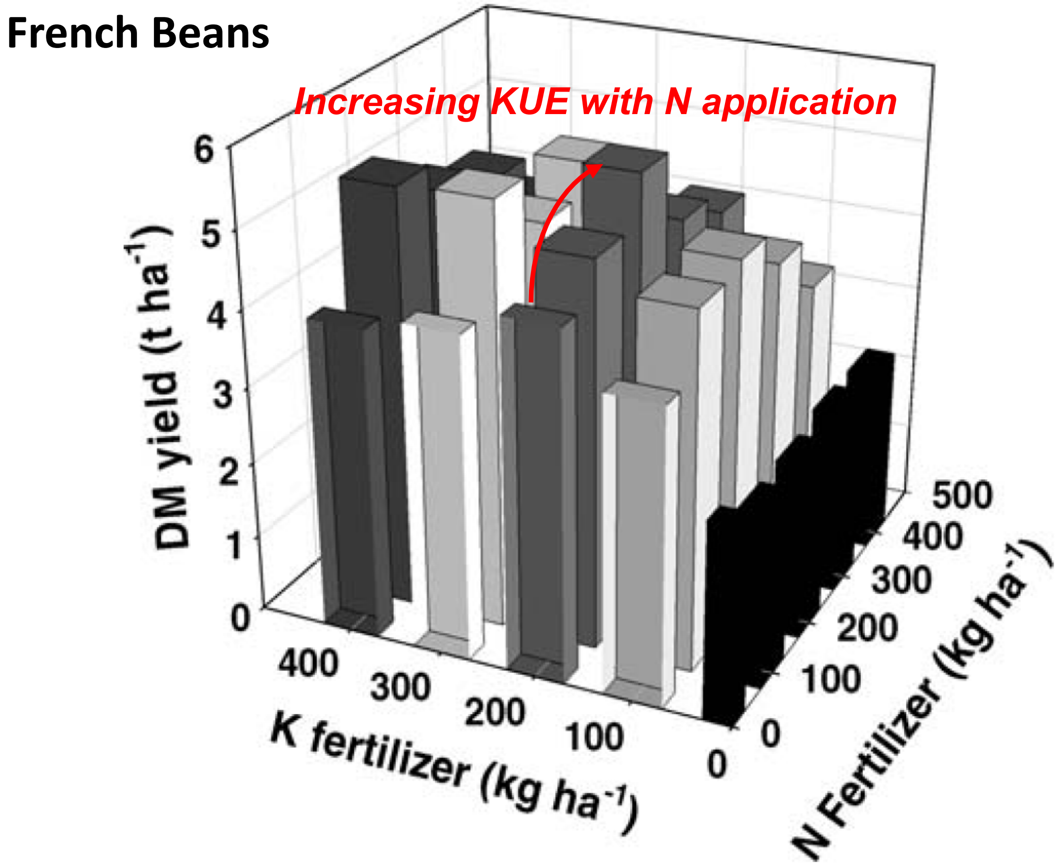
Optimising Crop Nutrition Maximises Yield and Resource Use Efficiency



Zhang et al. (2007) *Plant and Soil* 298: 81-98

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Optimising Mineral Nutrition
Crop and Environment Specific

Agronomic Models assisting fertiliser management that account for interactions between N, P and K:

- *Quantitative evaluation of the fertility of tropical soils – QUEFTS (Janssen et al. 1990)*
- *Warwick-HRI software combining N_ABLE, PHOSMOD and POTAS (Zhang et al. 2007)*
- *Nutrient Expert software for hybrid maize (Xu et al. 2016)*

Janssen et al. (1990) *Geoderma* 46: 299-318
Zhang et al. (2007) *Plant and Soil* 298: 81-98
Xu et al.(2016) *Field Crops Research* 194: 75-82

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Nitrogen Uptake Efficiency

$$NUE = NUpE \times NUtE$$

Agronomic strategies accelerating N delivery to roots

(1) Increasing N concentration in the soil solution

(2) Increasing mass flow of the soil solution

Physiological strategies accelerating N uptake by roots

(1) Increasing capacity for N transport across the plasma membrane

(2) Increasing the surface area of the root system

(3) Placement of roots in volumes with greatest N availability

White et al. (2013) *Frontiers Plant Science* 4: #193

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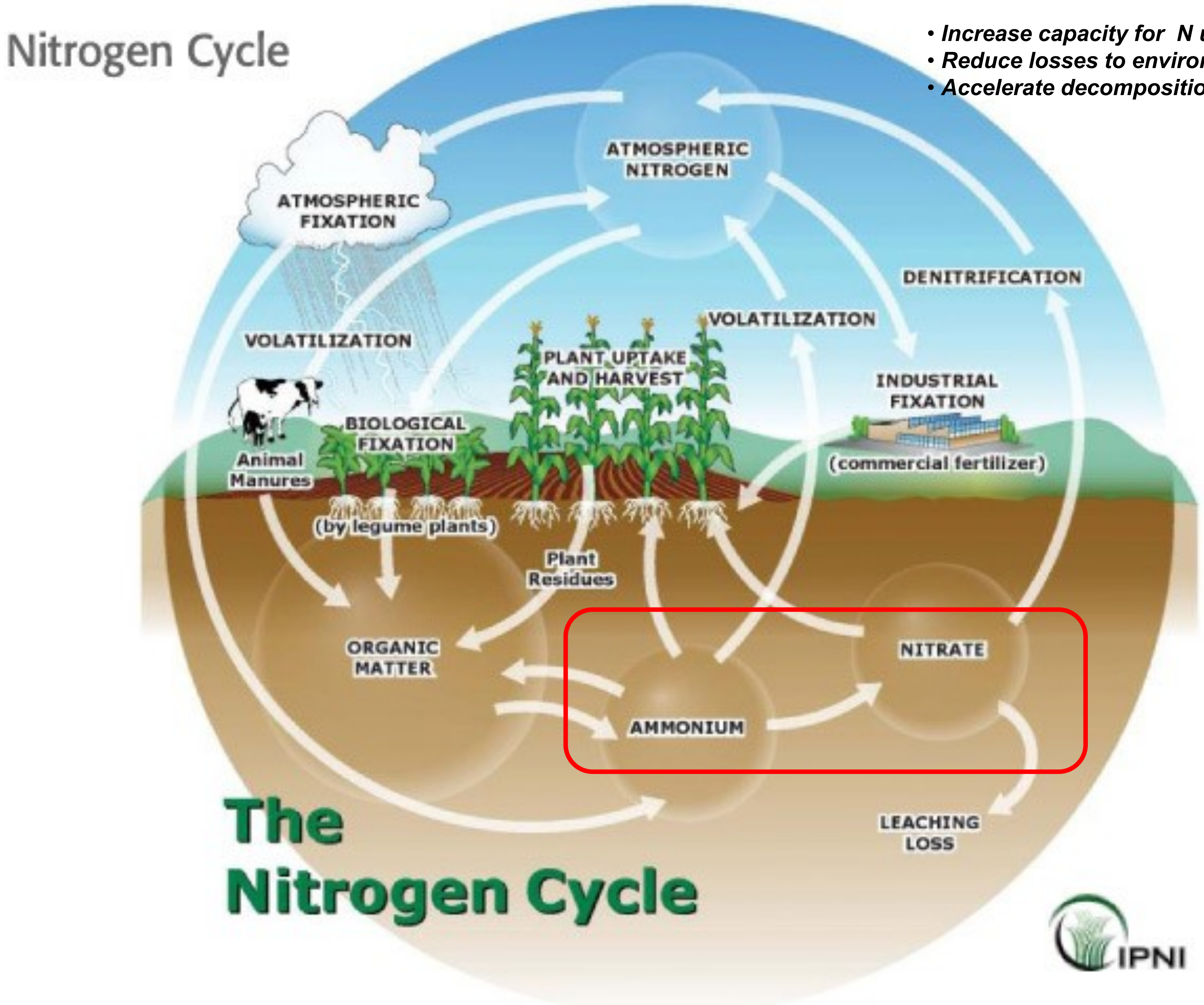
Nitrogen in Agriculture

- *Increase capacity for N uptake*
- *Reduce losses to environment*
- *Accelerate decomposition of organic matter*



Improving Nitrogen Uptake
Direct and Indirect Effects of Potassium

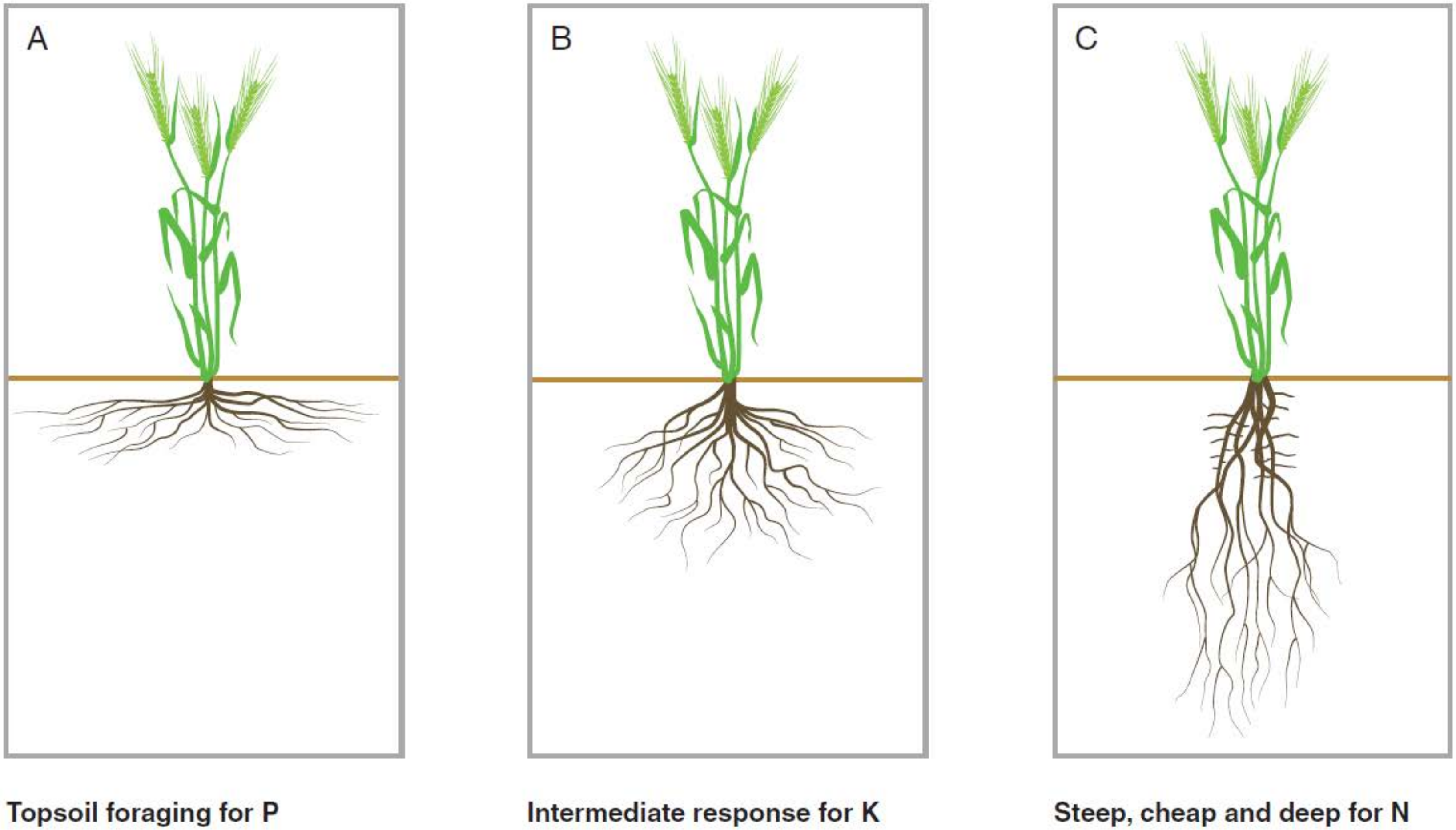
Direct effects

- K^+ and NH_4^+ compete for exchange sites in the soil
- K^+ uptake provides charge compensation for nitrate uptake

Indirect Effects

- Potassium is required by microbes and, therefore, can affect N cycle in soil (nitrification/denitrification) and N_2 fixation in legumes
- Plant K nutrition affects transpiration and, thereby, mass flow of soil solution to root surface
- Plant K nutrition affects phloem transport and, therefore, N-assimilation in shoot, carbon allocation within plants, and root architecture

Root System Architectures for Nutrient Acquisition



White et al. (2013) *Ann. Bot.* 112: 207-222

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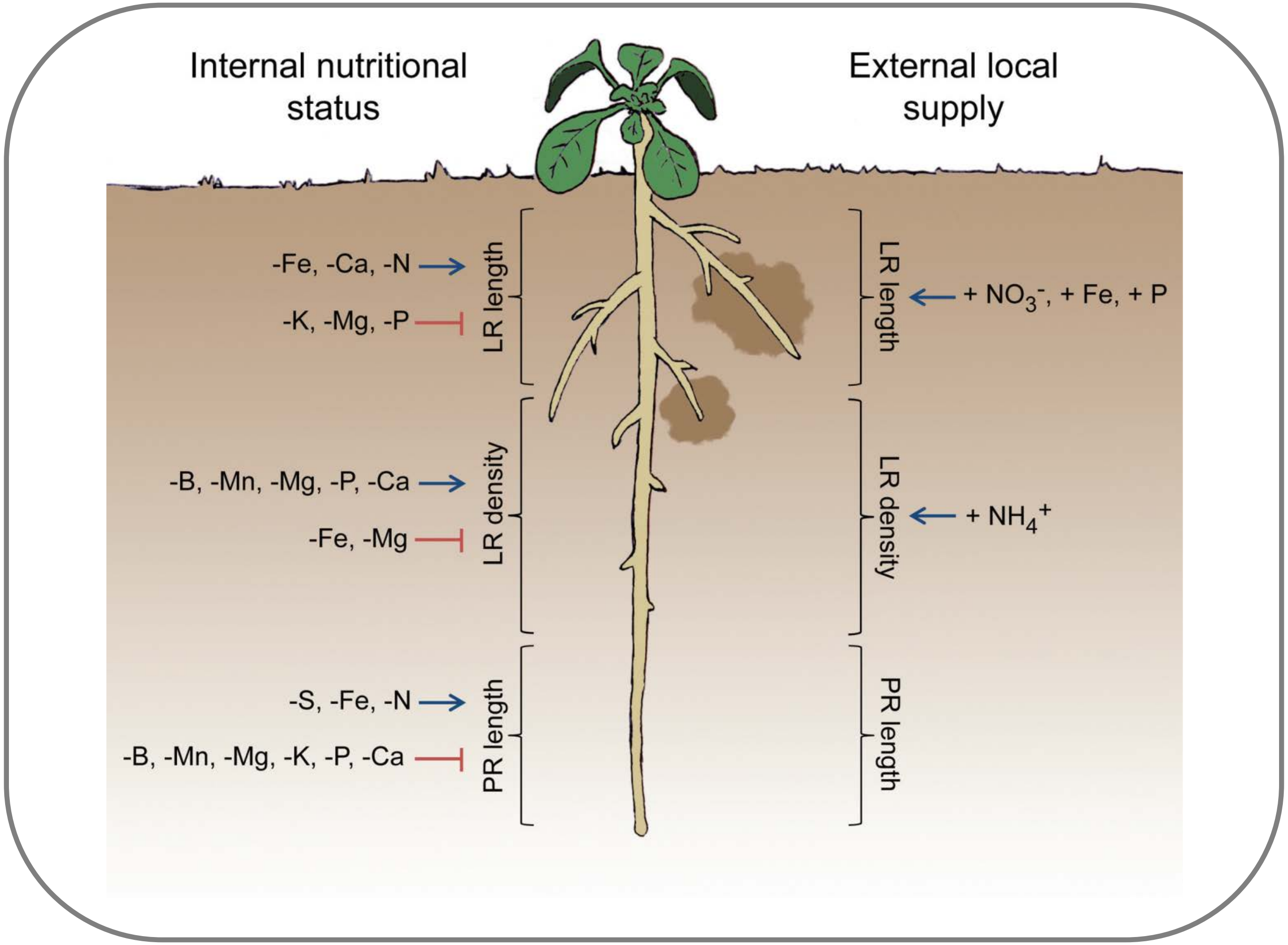
Nutrients Affect Root System Architecture



Giehl et al. (2014) *J. Exp. Bot.* 65, 769-778

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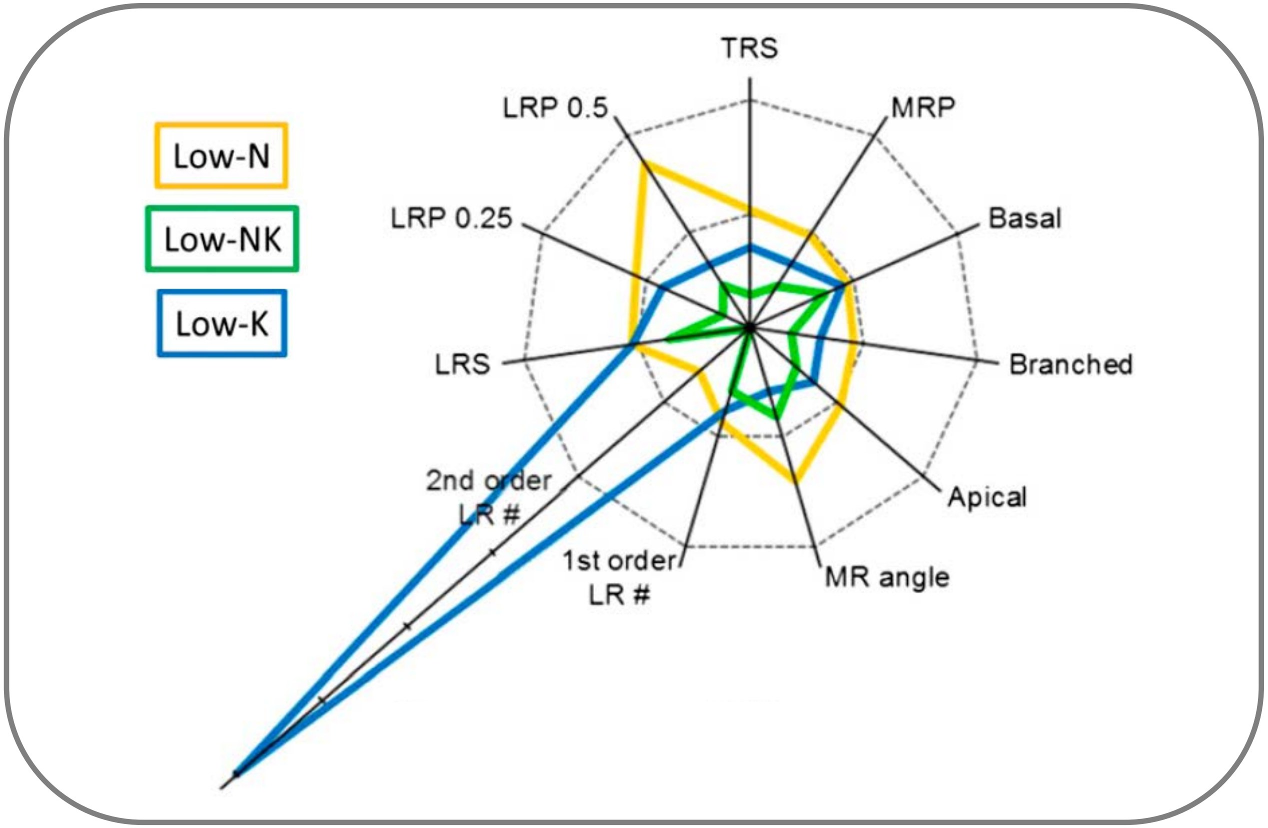
Nutrients Affect Root System Architecture



Different responses to N deficiency in presence and absence of K
Optimal response for NUpE if uncompromised by K deficiency

Kellermeier et al. (2014) *Plant Cell* 26: 1480-1496

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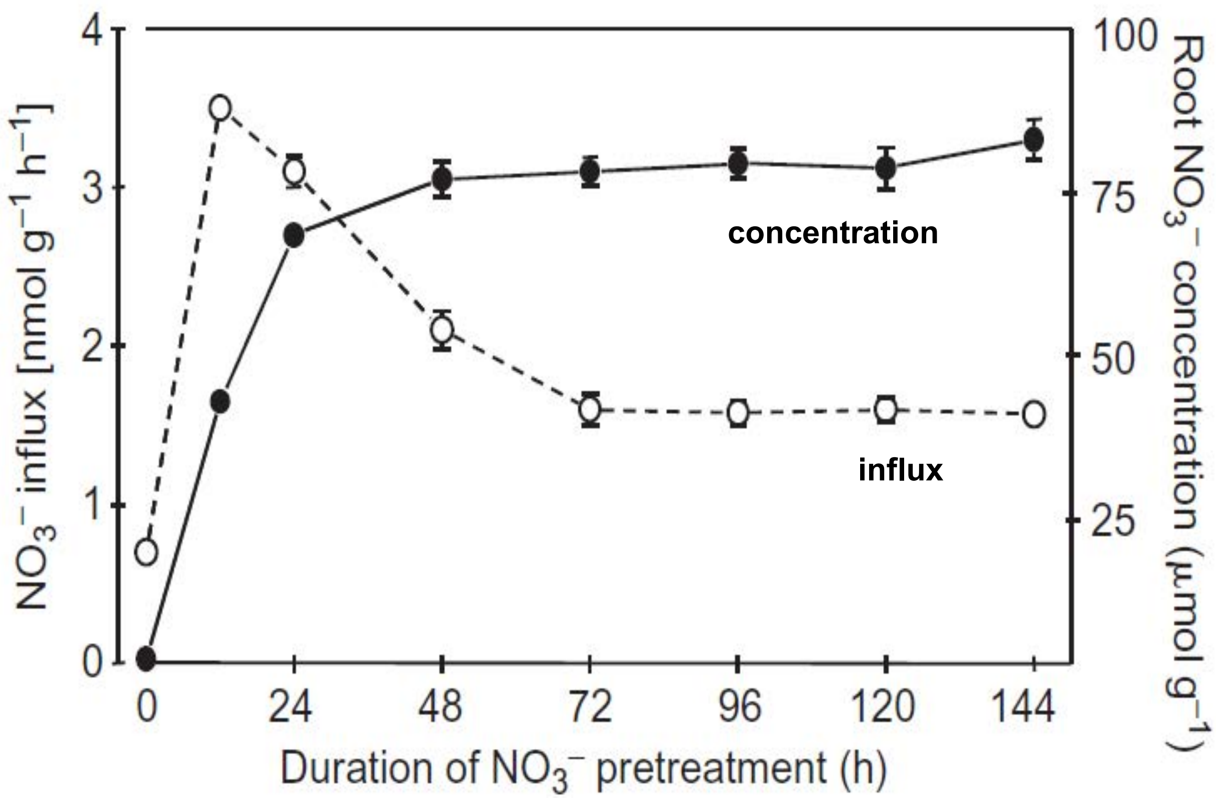
Regulation of Nitrate Uptake by Plant Nutritional Status



Siddiqi et al. (1989) *Plant Physiology* 90, 806-813
Glass et al. (1990) Plant Physiology 93, 1585-1589

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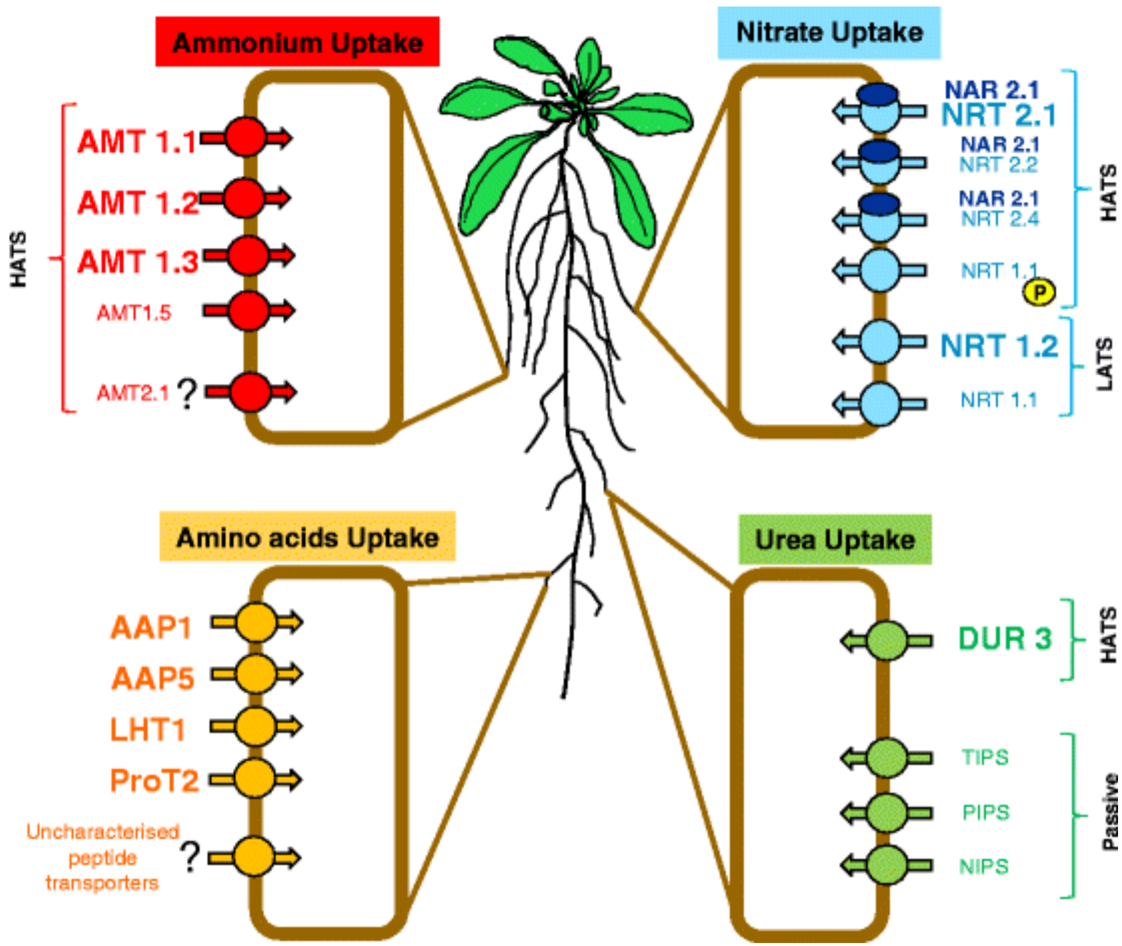
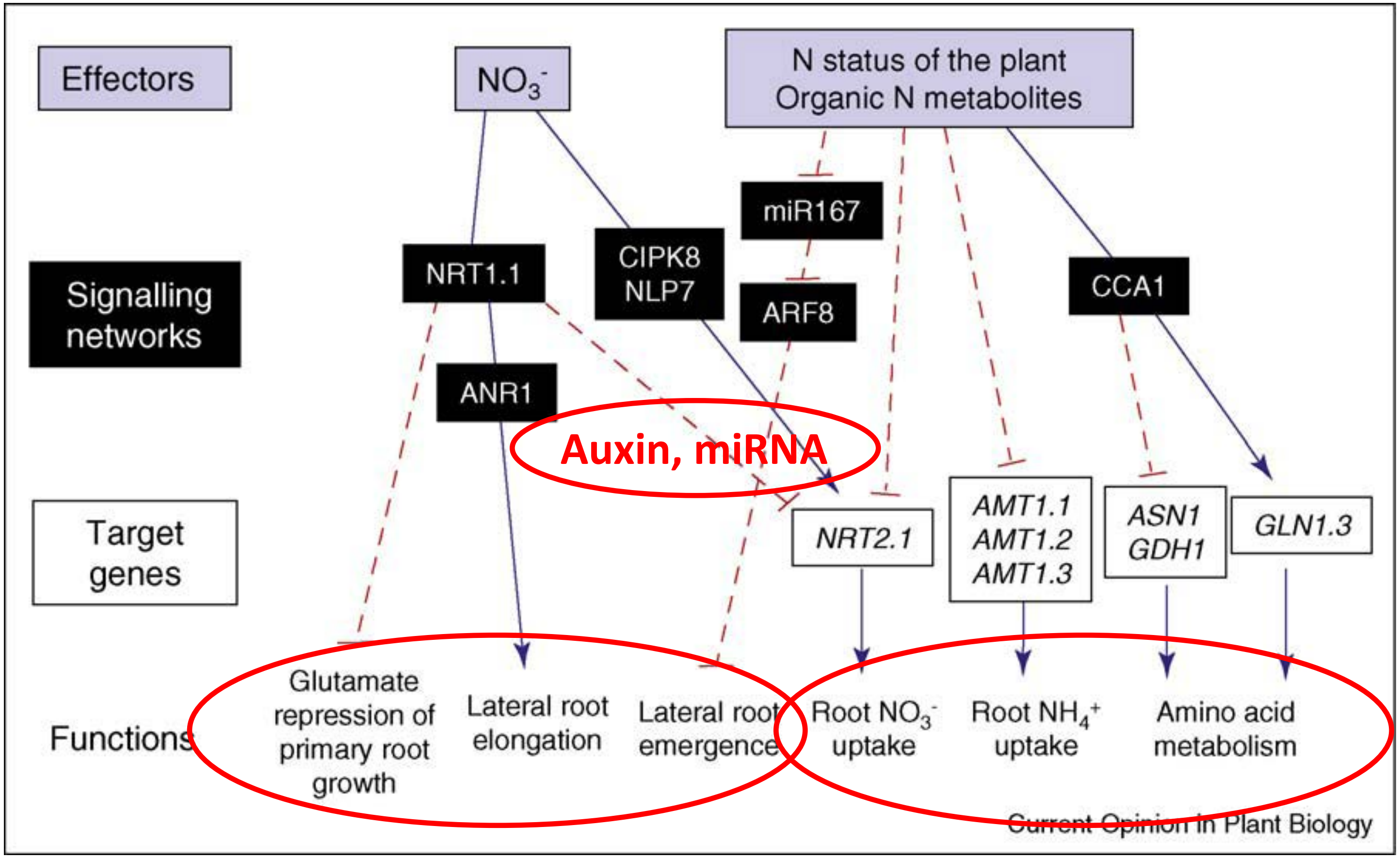
Uptake of Nitrate, Ammonium and Organic Nitrogen by Roots

HATS = high affinity transporters
LATS = low affinity transporters



Nacry et al. (2013) *Plant and Soil* 370: 1-29

Regulation of Nitrogen Acquisition



Gojon et al. (2009) *Curr. Opin. Plant Biol.* 12: 328-338

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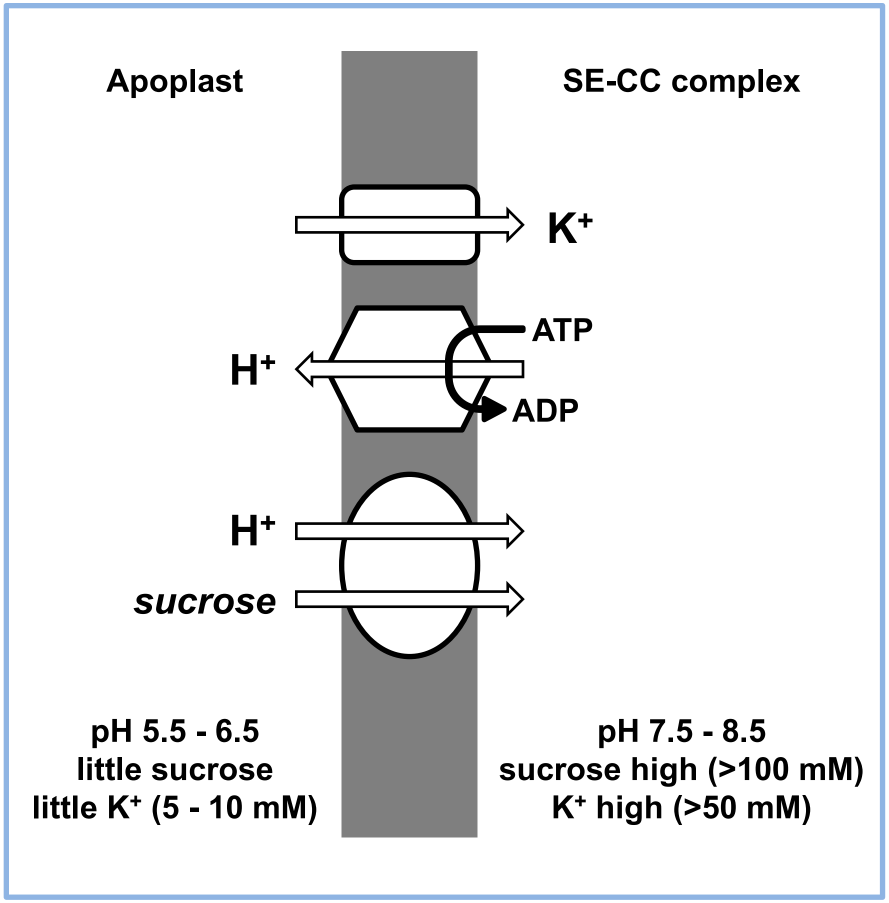
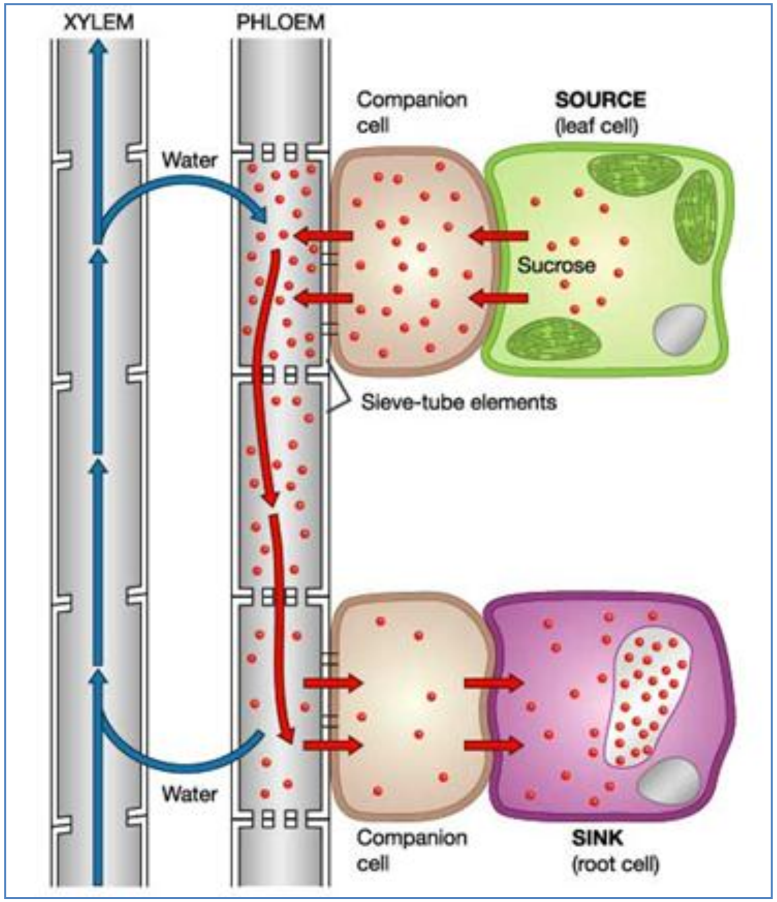
Importance of Potassium Nutrition
Carbon Allocation & Systemic Signalling





Marschner's Mineral Nutrition of Higher Plants, 2012

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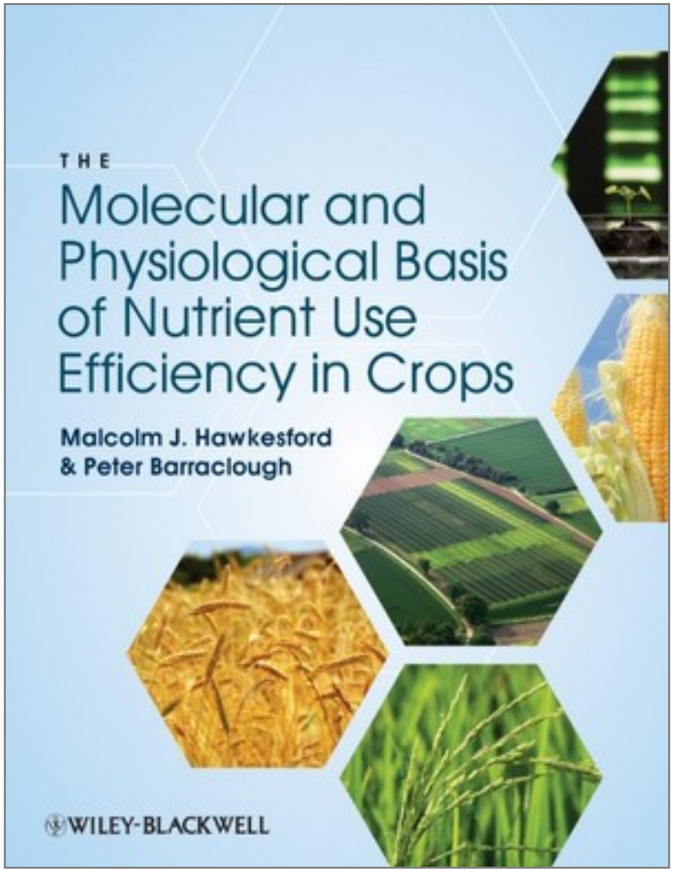
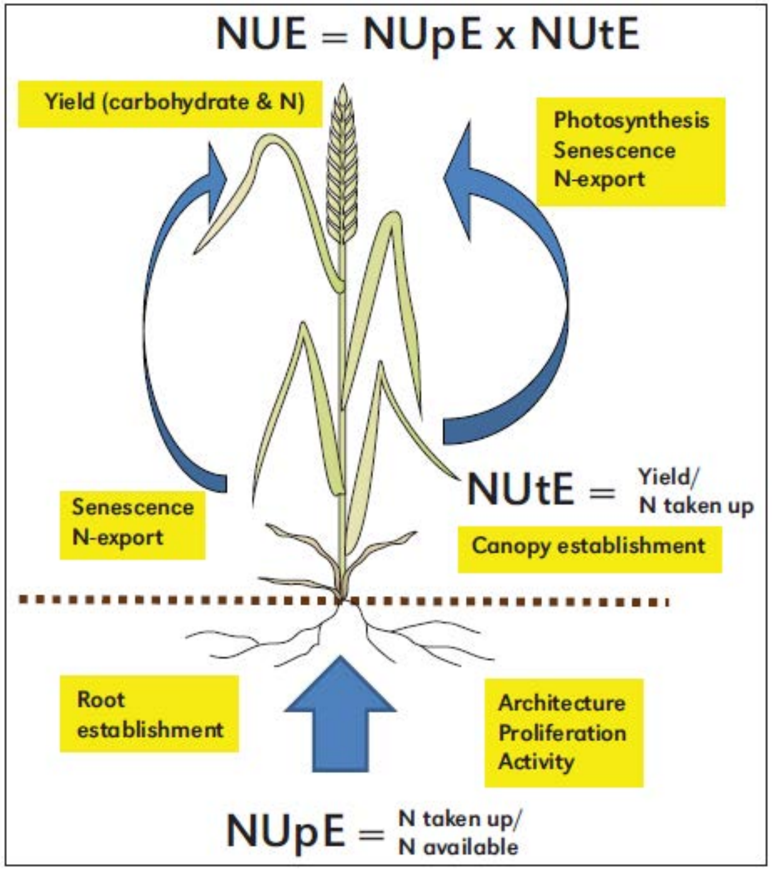
Traits Improving Nitrogen Use Efficiency

- NUtE often contributes more than NUpE to NUE when N supply low
- Crops with greater NUtE have faster canopy establishment, greater photosynthesis, larger harvest index, lower critical N concentrations, better N redistribution between tissues…





Importance of Potassium Nutrition For Nitrogen Utilisation Efficiency

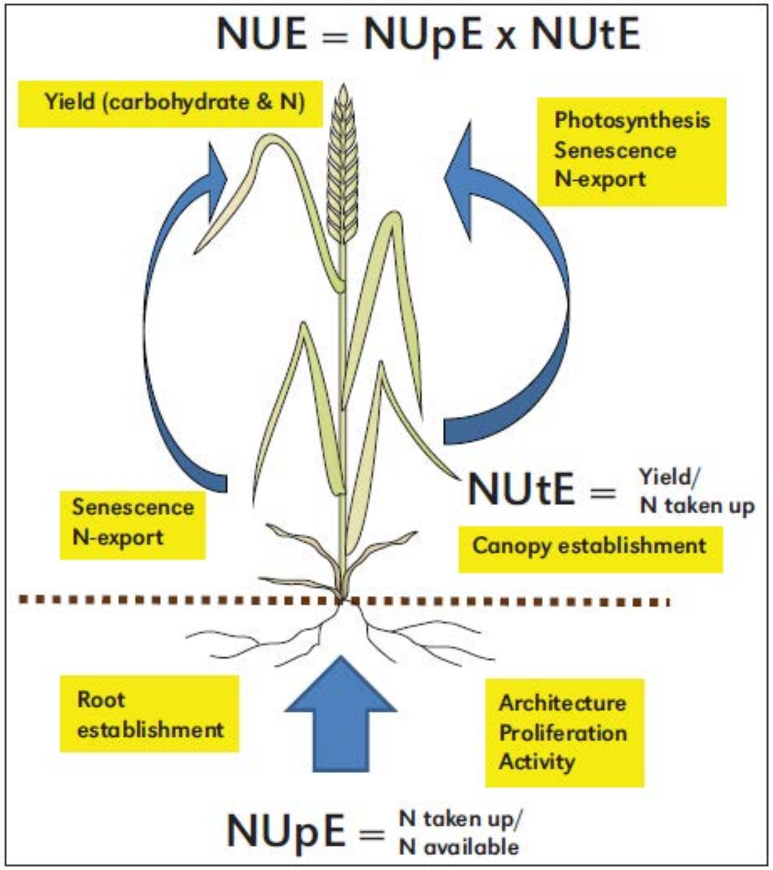
Adequate potassium nutrition affects all aspects of Nitrogen Utilisation Efficiency:

- Capacity for growth: especially cell elongation, water relations & gas exchange

- Assimilation of nitrogen: especially for photosynthesis, growth and yield formation

- Partitioning of C and N to growth of new tissues: impacts root N acquisition and photosynthesis

-Translocation of C and N to seed, harvest index and yield formation



Marschner's Mineral Nutrition of Higher Plants, 2012

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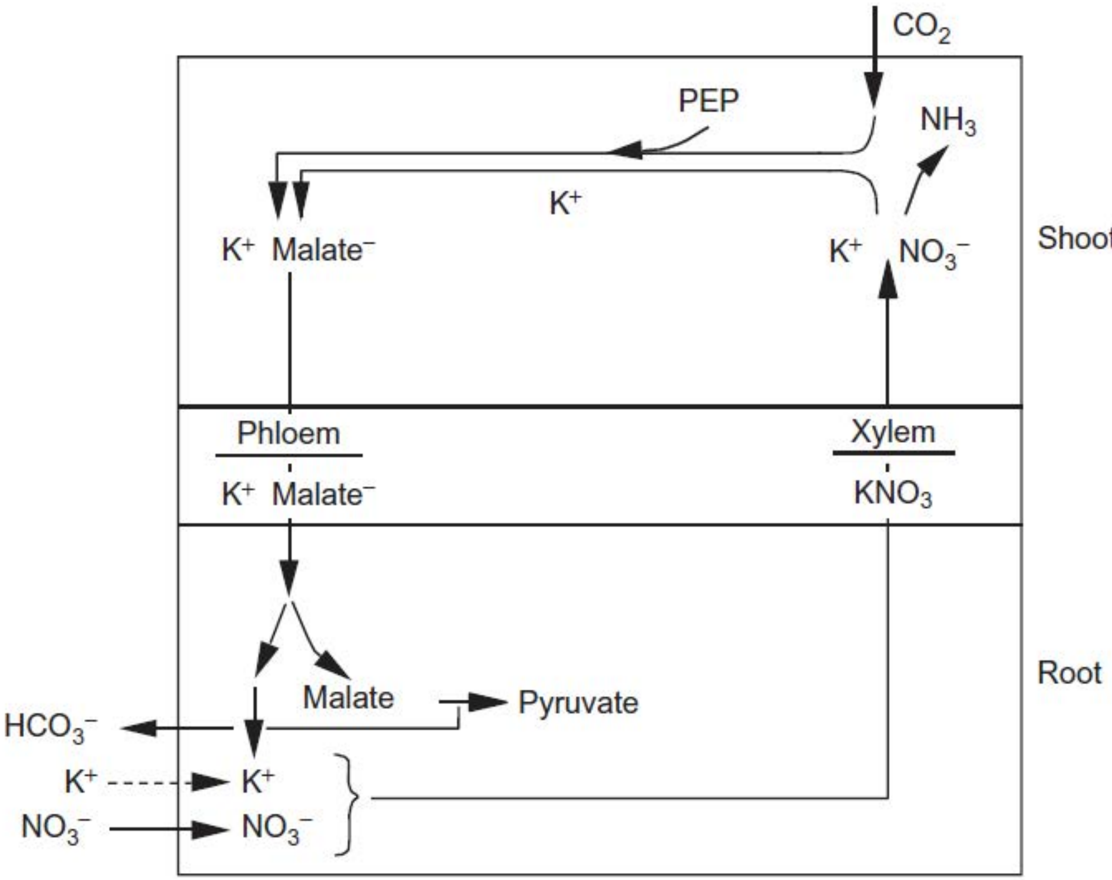
Importance of Potassium Nutrition
Nitrogen Assimilation in Shoot



Marschner's Mineral Nutrition of Higher Plants, 2012

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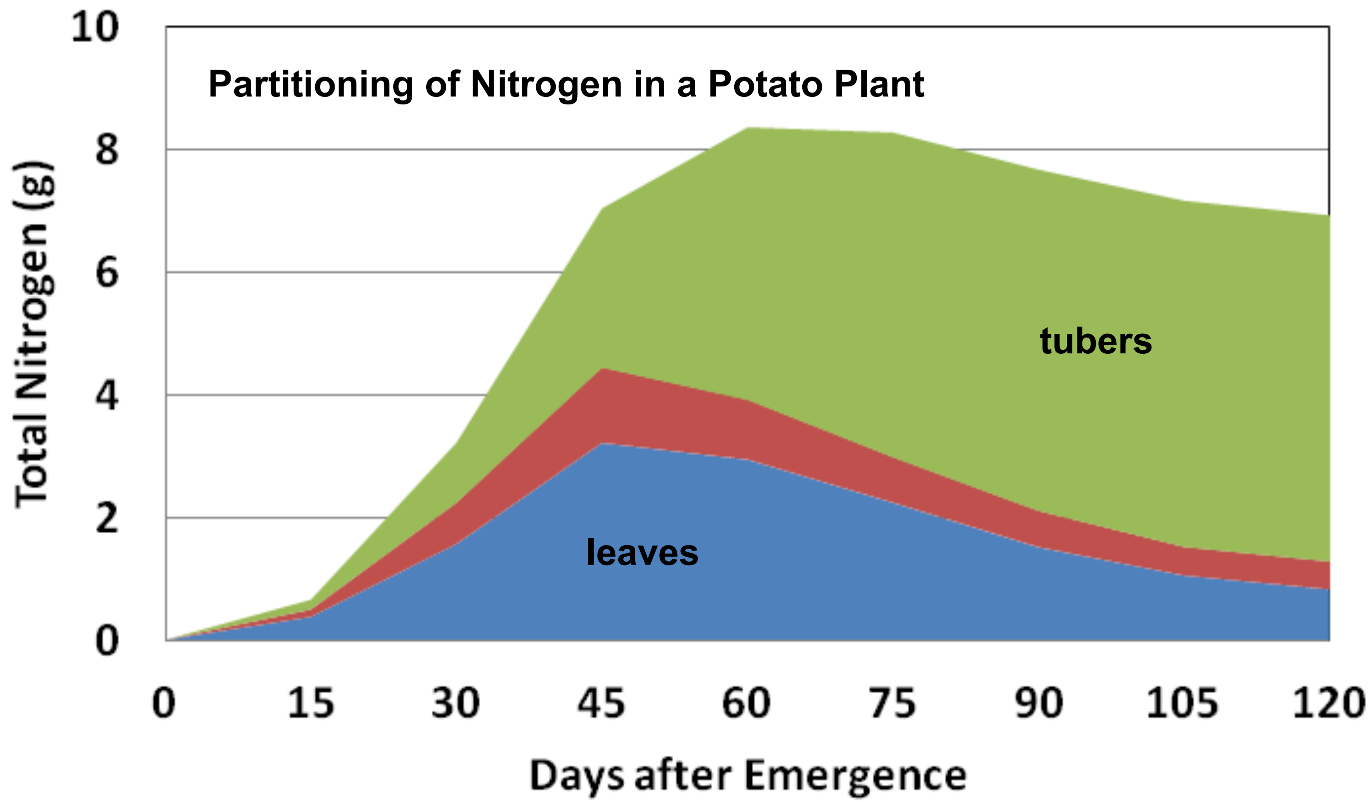
Importance of Potassium Nutrition
Nitrogen Redistribution



White PJ (2017) *Achieving Sustainable Cultivation of Potatoes.*

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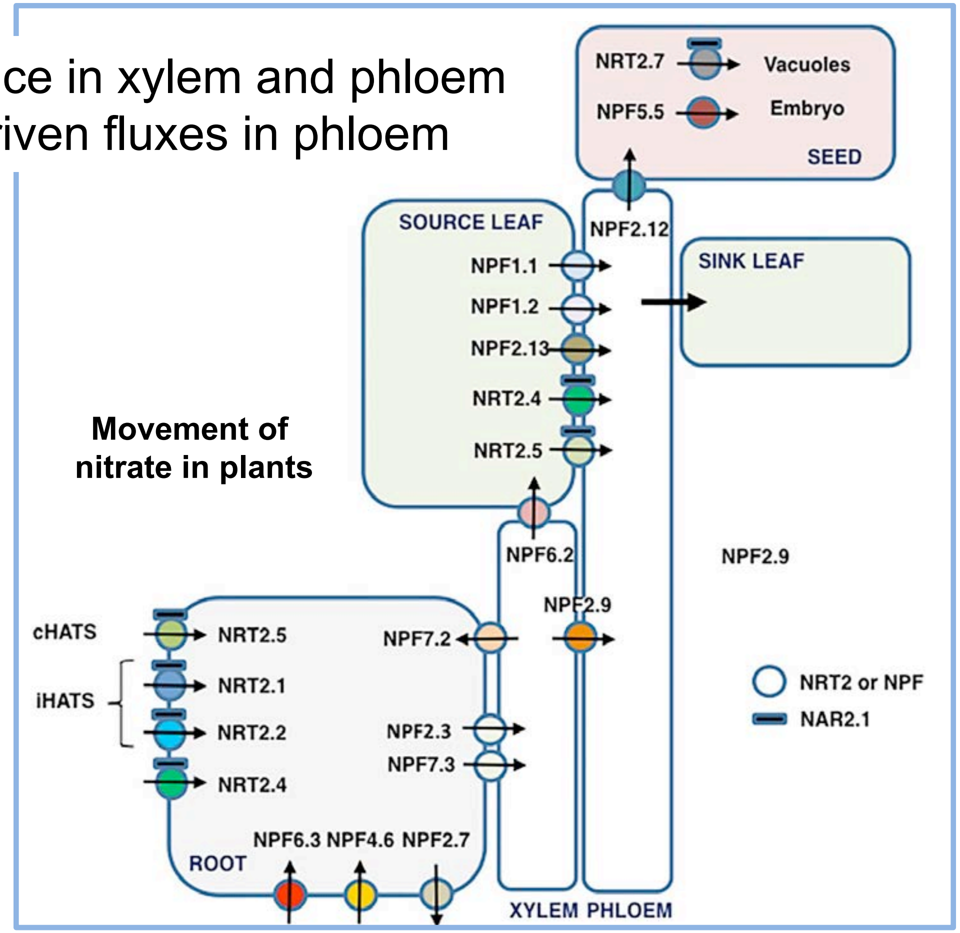
Importance of Potassium Nutrition Nitrate Uptake and Redistribution

Importance for maintaining charge balance in xylem and phloem
Importance for generating osmotically-driven fluxes in phloem



O'Brien et al. (2016) *Molecular Plant* 9, 827-856

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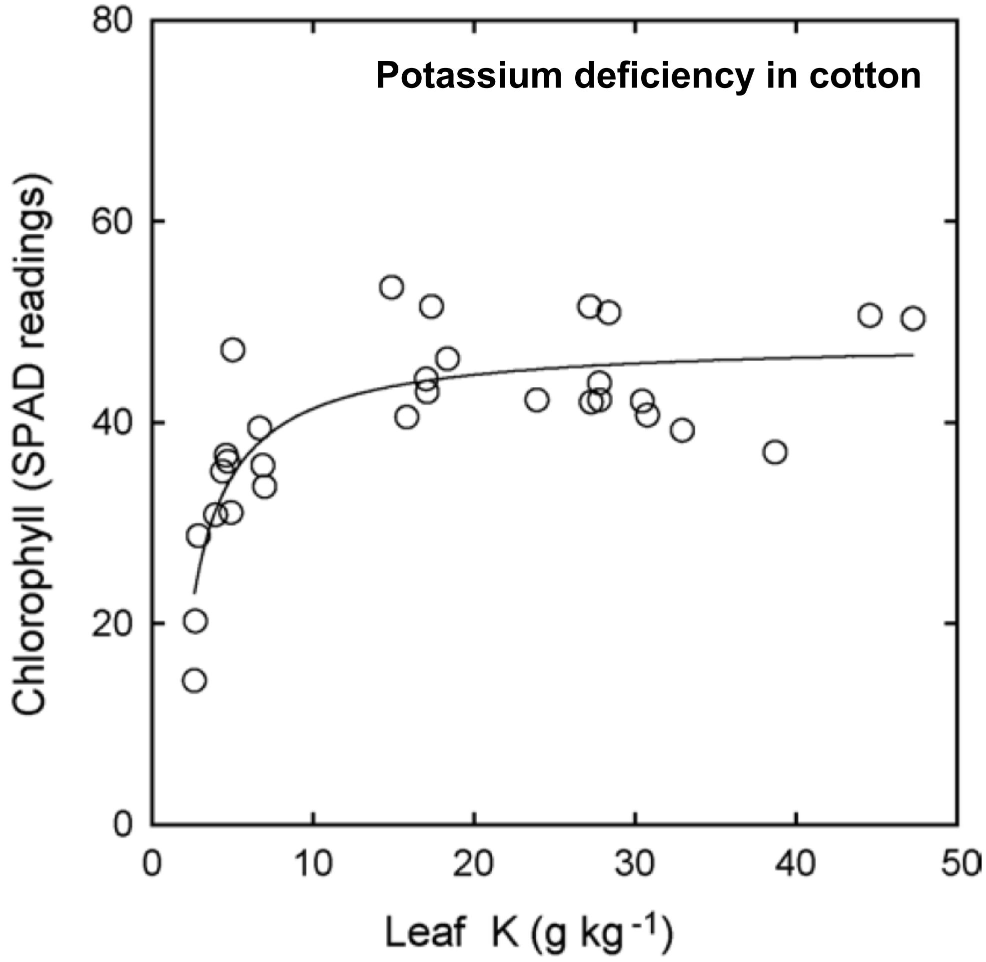
Potassium Deficiency Reduces Photosynthesis



Reddy & Zhao (2005) *Field Crops Res.* 94, 201-213

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Summary – Potassium Nutrition Influences Nitrogen Use Efficiency

Optimising Crop Nutrition
maximises yield and resource use efficiency

Optimising Potassium Nutrition
improves NUE, NUpE, and NUtE

allows root architecture and N uptake to respond to N supply
enables nitrate uptake & N assimilation in shoot
enables C and N redistribution in plant
maximises photosynthesis, harvest index, and yield