Influence of Potassium Nutrition On Nitrogen Use Efficiency

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Nitrogen Use Efficiency

\[
\text{NUE} = \text{NUpE} \times \text{NUtE}
\]

Agronomic N Use Efficiency = 
N Uptake Efficiency \times N Utilisation Efficiency

\[
\frac{(\text{yield} / \text{available N})}{(\text{N acquired} / \text{available N})} \times (\text{yield} / \text{N acquired})
\]

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.
Optimising Crop Nutrition Maximises Yield and Resource Use Efficiency

French Beans

Increasing NUE with K application

Optimising Crop Nutrition Maximises Yield and Resource Use Efficiency

French Beans

*Increasing KUE with N application*

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
Xu et al. (2016) Field Crops Research 194: 75-82
Nitrogen Uptake Efficiency

\[
\text{NUE} = \text{NUpE} \times \text{NUtE}
\]

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
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

A. Topsoil foraging for P
B. Intermediate response for K
C. Steep, cheap and deep for N

Nutrients Affect Root System Architecture

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

Importance of Potassium Nutrition
Carbon Allocation & Systemic Signalling

Marschner’s Mineral Nutrition of Higher Plants, 2012
Traits Improving Nitrogen Use Efficiency

- NUtE often contributes more than NUpE to NUE when N supply is low.
- Crops with greater NUtE have faster canopy establishment, greater photosynthesis, larger harvest index, lower critical N concentrations, better N redistribution between tissues…
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**
Importance of Potassium Nutrition
Nitrogen Assimilation in Shoot

Marschner’s Mineral Nutrition of Higher Plants, 2012
Importance of Potassium Nutrition
Nitrogen Redistribution

Partitioning of Nitrogen in a Potato Plant

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
Potassium Deficiency Reduces Photosynthesis

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

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