University of California

Nitrogen Management Training

for Certified Crop Advisers

Competency Area 3

Nitrogen Uptake and Utilization In Plants

Patrick Brown
Department of Plant Sciences
UC Davis

UC Cooperative Extension | University of California Agriculture and Natural Resources

Outline

Part 1:

- Basics of Nitrogen forms, uptake and assimilation
- Controls of N uptake rate
- Consequences of excess N on the plant

Competencies:

- What are the key functions of nitrogen in plants
- What are the consequences of nitrate form on rhizosphere soil pH and why.
- How and why do plants regulate N uptake
- What are some of the consequences of excess N on crop quality

Part 2:

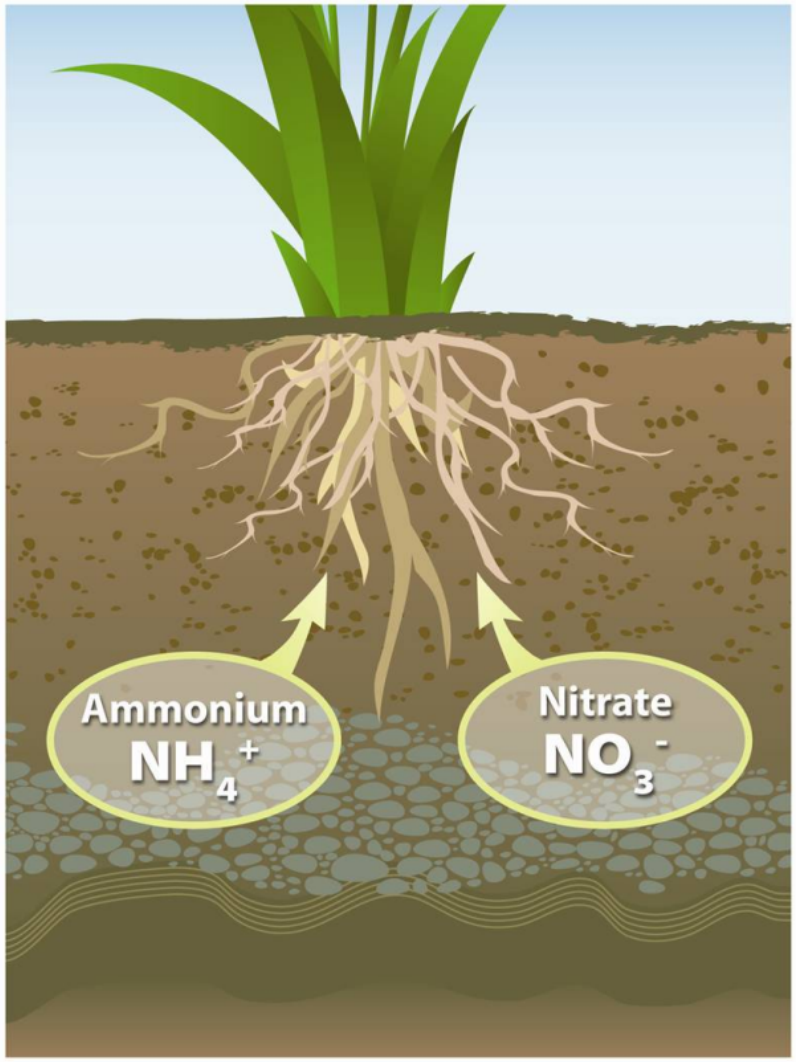
- 4 R's of N management
  - Right Rate, Right Time, Right Placement, Right Source
  - Patterns of N demand by crops
  - Nitrogen in soil and water
  - Balanced nutrition
  - Placement and fertigation

Competencies:

- What are the 4 R's
- What is relationship between plant growth and N demand
- How does nutrient balance influence NUE

Nitrogen in Plants

Plants take up N in the form of ammonium (NH_4^+) and Nitrate (NO_3^-).



(Image from http://www.nitrogenfree.com/problem/nitrogen_cycle.php.html)

Nitrogen in Plants

- Most abundant mineral element in plants (2-4% Dwt)
  - Amino acids, proteins, nucleic acids
  - Most common limiting element in natural and man-made environments.
- Uptake as nitrate and ammonium (also limited uptake of organic N sources)
  - Species have distinct preferences (Nitrate is significantly more ‘expensive’ to assimilate than ammonium)
  - Nitrate dominates in warm, neutral-alkaline soils
  - Ammonium dominates in cool, wet, and acid soils
  - Uptake and assimilation are highly regulated

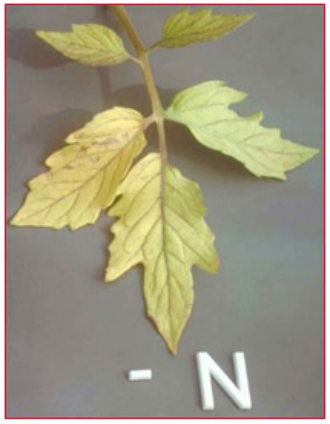
Nitrogen in Plants: Chlorosis

Growth and symptoms

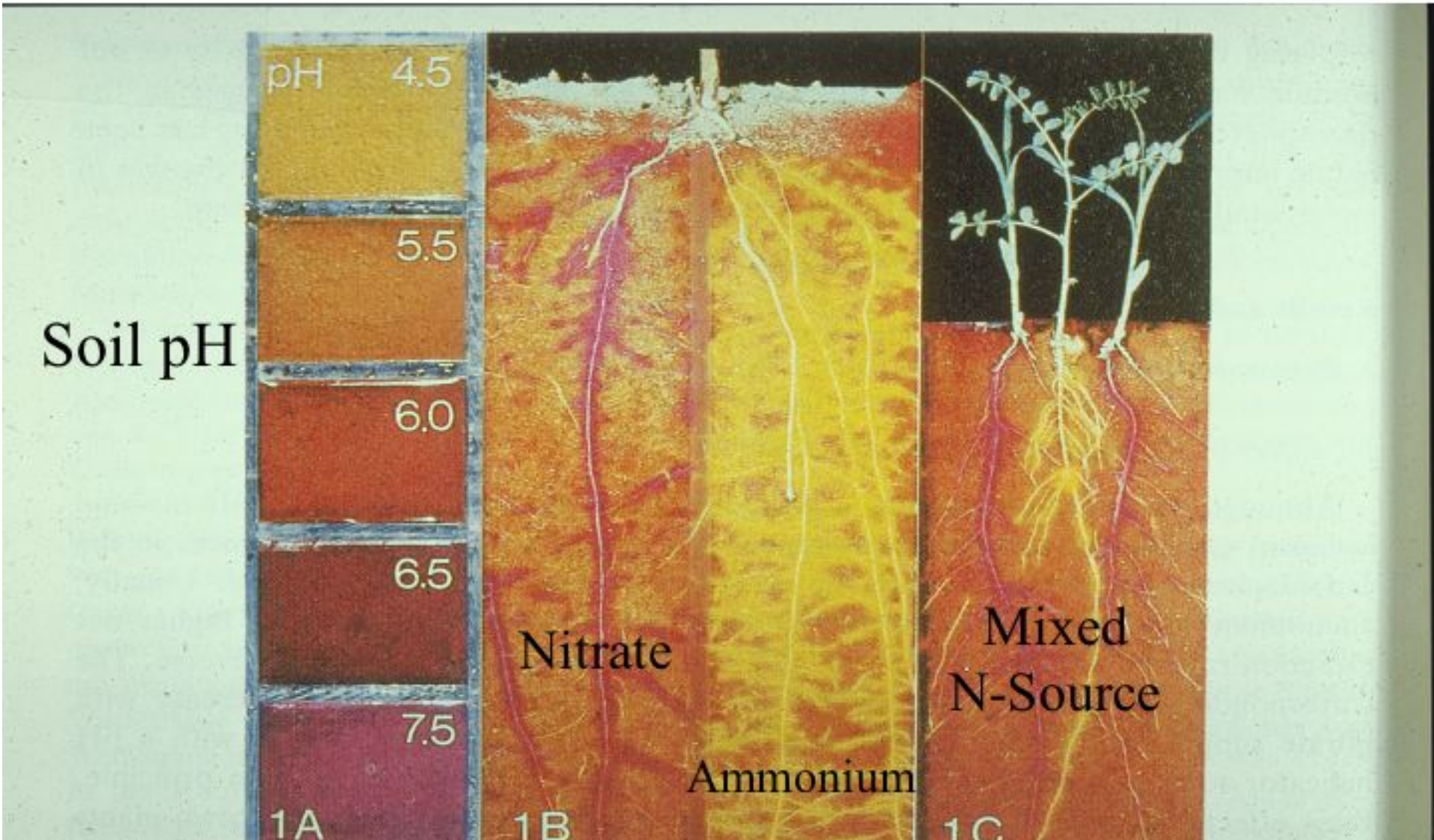
- N availability alters root allocation (root weight ratio) and shoot branching.

- High N enhances vegetative growth ('lushness'), delays senescence, increases disease susceptibility (chemical and phenological causes).

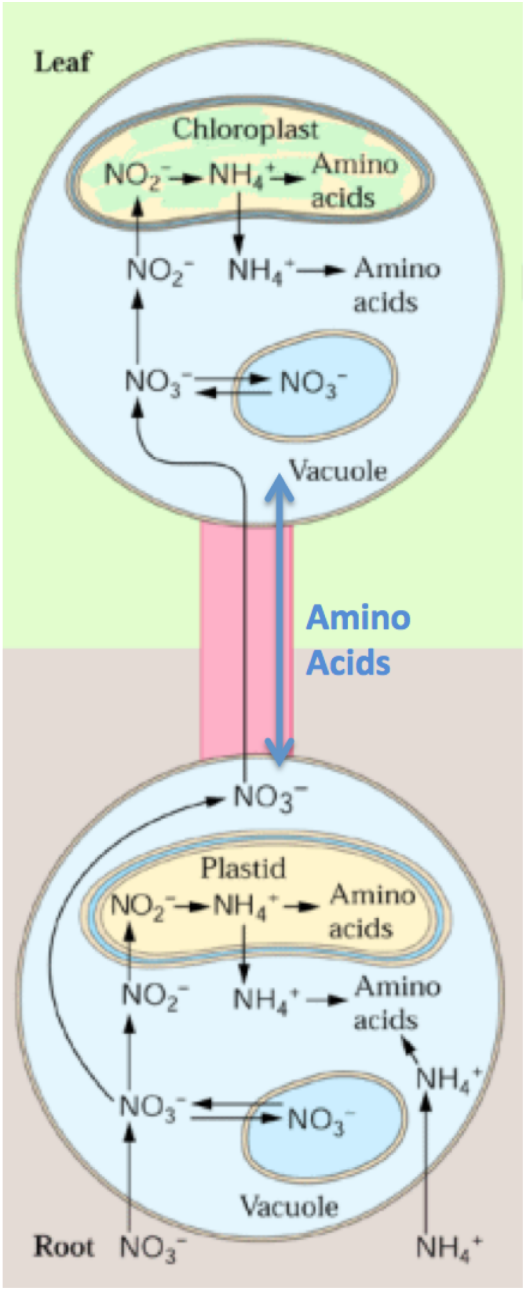
- Deficiency symptoms: growth inhibition/chlorosis appearing on older leaves; progresses to young leaves if severe.



Nitrogen in Plants: N Uptake and Rhizosphere Changes



Nitrogen in Plants: Biology of Nitrate Uptake



Some species transport nitrate to the **shoot** prior to reduction to ammonium and assimilation into amino acids. In these species petiole nitrate levels are high (1,000's ppm Nitrate).

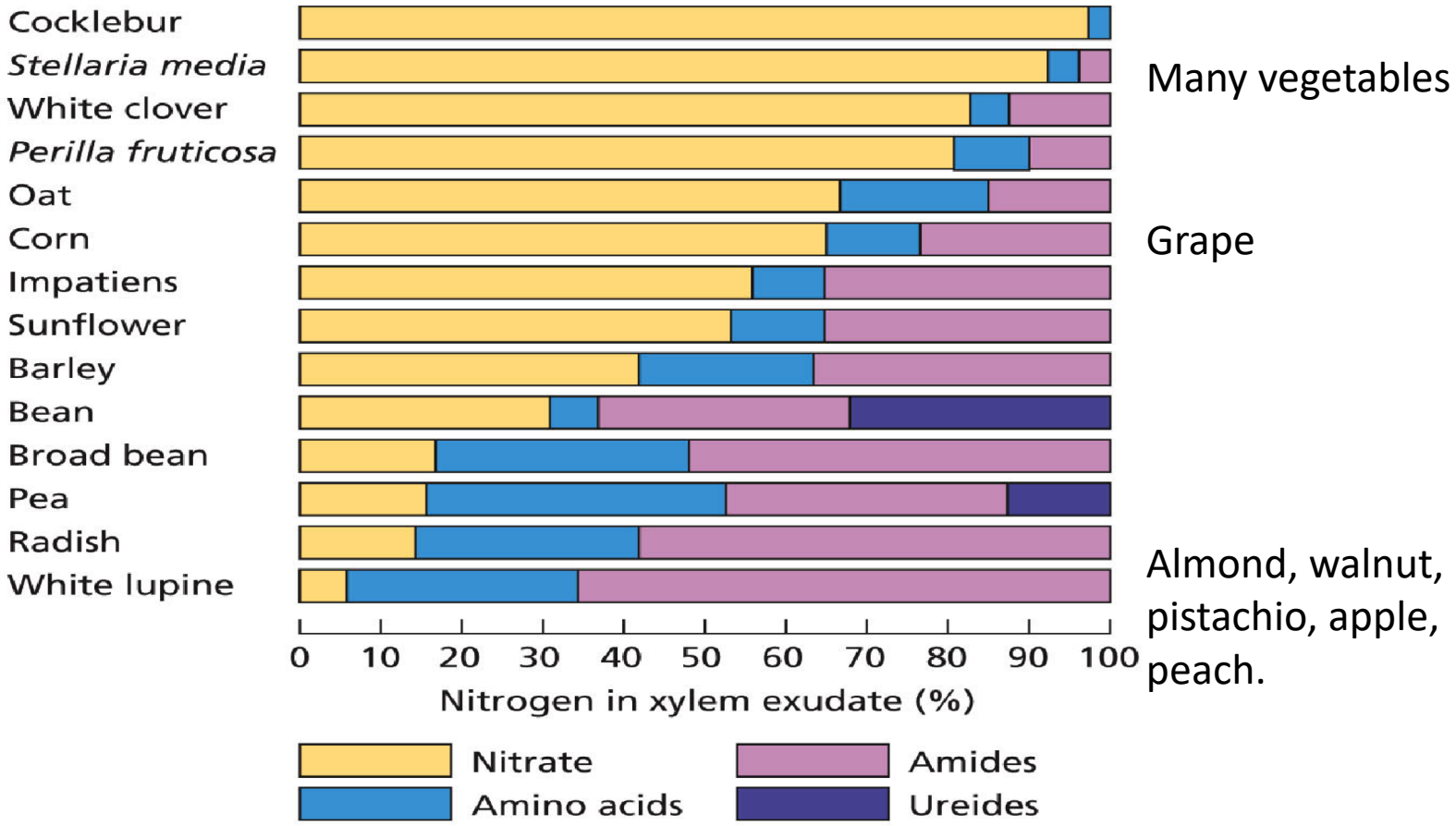
Other species reduce nitrate in the **root**, and petiole nitrate remains low (10's ppm Nitrate).

In all species nitrate uptake is a regulated process determined by internal nitrate concentrations and concentrations of amino acids transported from the shoot to root. The concentrations of nitrate and amino acids are determined by the rate at which protein synthesis is occurring in the plant and hence is strictly tied to growth rates.

(Plant Physiology, 4th Ed 2006 Sinnauer)

Nitrogen in Plants: N Concentration in Sap

Concentration of nitrate in sap differs between species. In most tree species, nitrate in sap is too low to detect reliably. In most crops nitrate is too variable to be of value as an N diagnostic method.

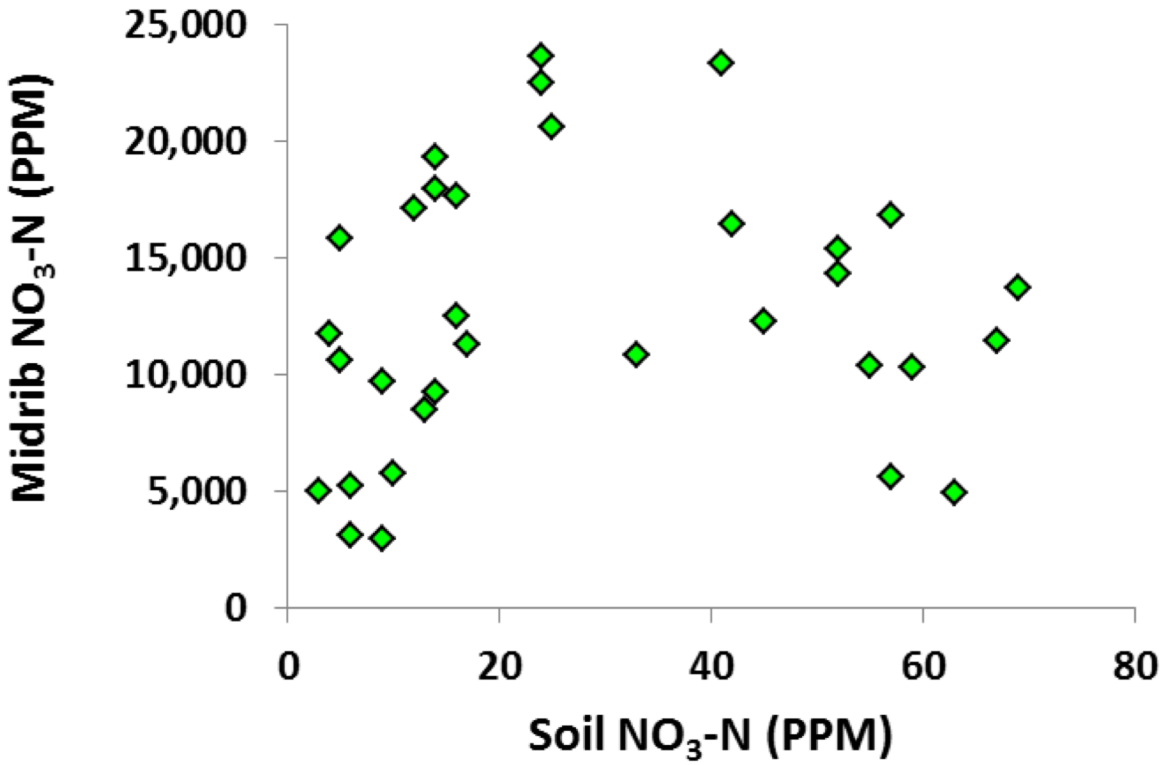


PLANT PHYSIOLOGY, Fourth Edition, Figure 12.6 © 2006 Sinauer Associates, Inc.

Limitations of petiole NO_3-N :

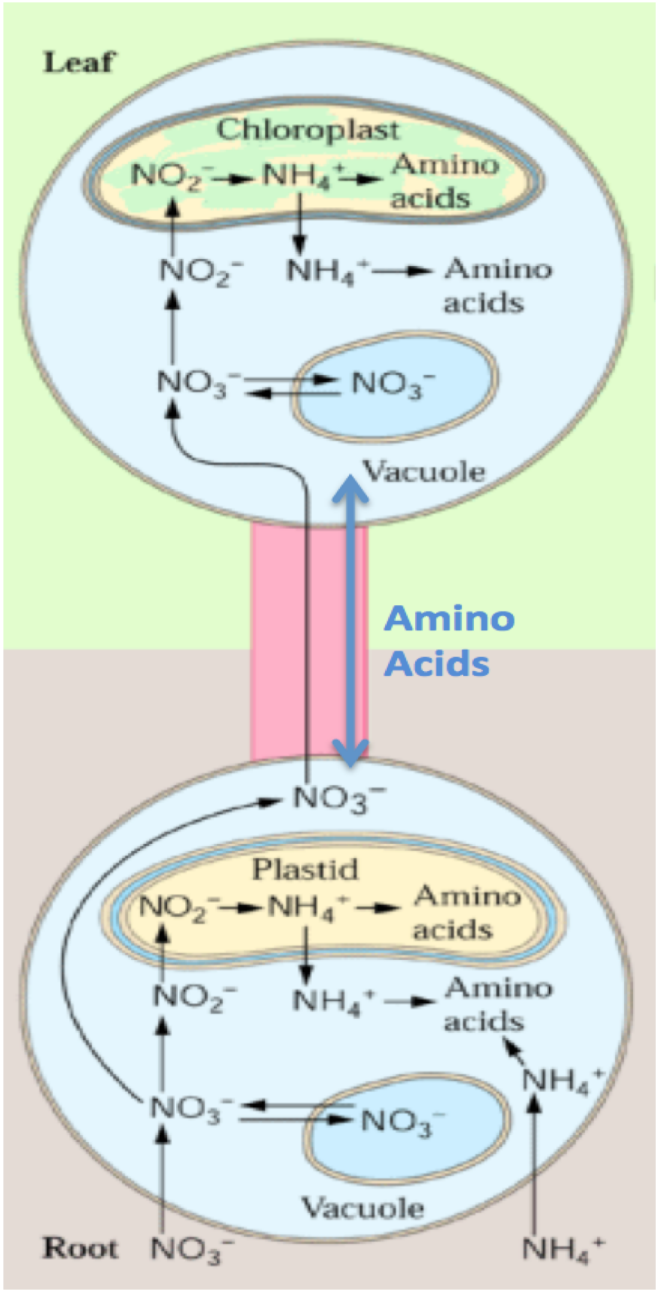
- petiole NO_3-N not well correlated with early-season soil NO_3-N, *so it is a flawed guide to early season N fertilizer need*

Lettuce midrib NO_3-N at cupping stage, 2009 trials:



Tim Hartz

Nitrogen in Plants: Biology of Ammonium

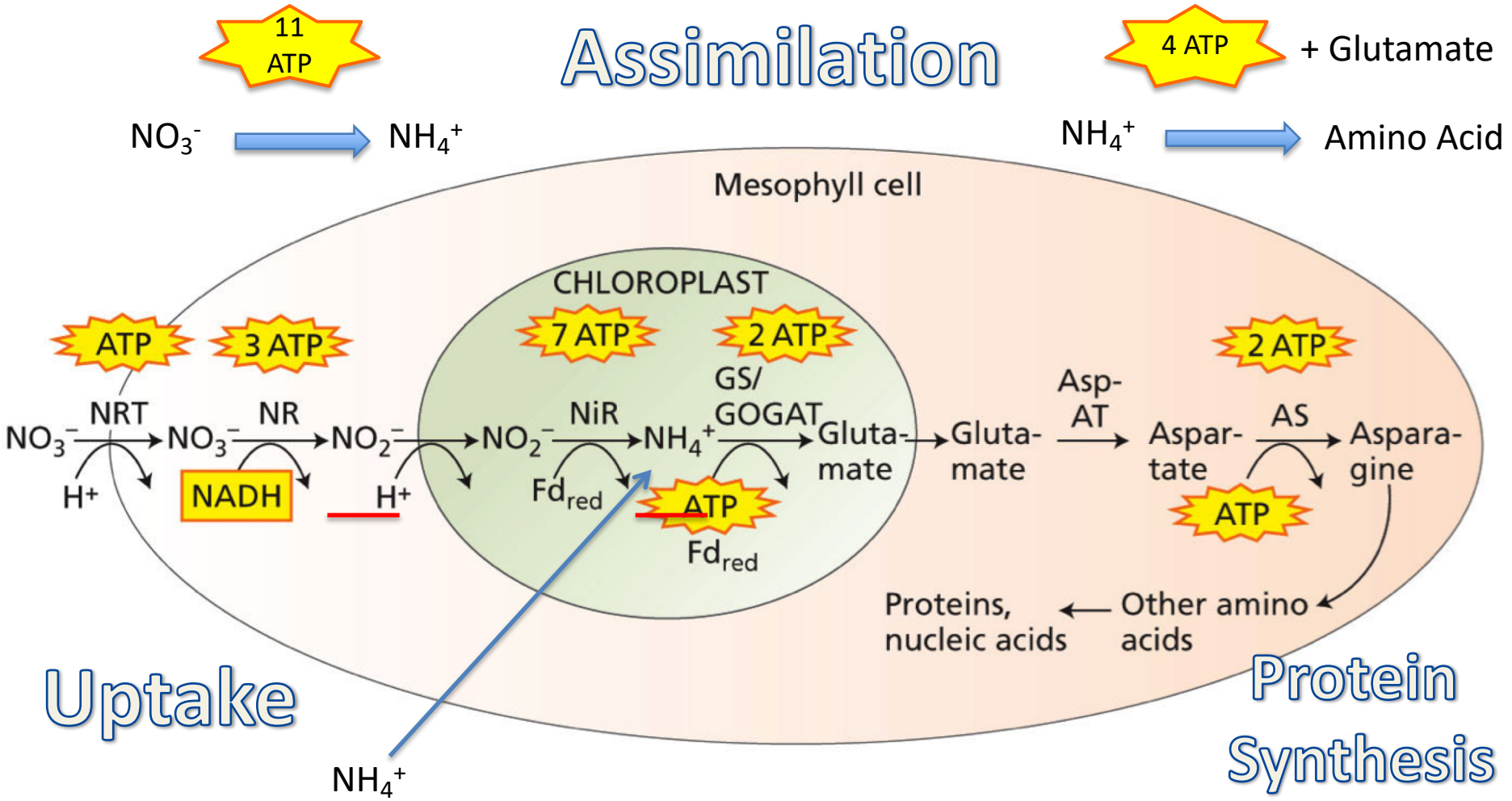


Ammonium uptake and assimilation is tightly regulated:

- NH_4^+ is toxic and hence is rapidly assimilated into amino acids and amides and is not transported.
- NH_4^+ assimilation (from NH_4^+ uptake) occurs almost exclusively in the roots, requiring a large transport of energy and carbon to the root.
- Uptake rate is feedback regulated by concentration of amino acids and protein in plant AND by availability of energy and carbohydrates.

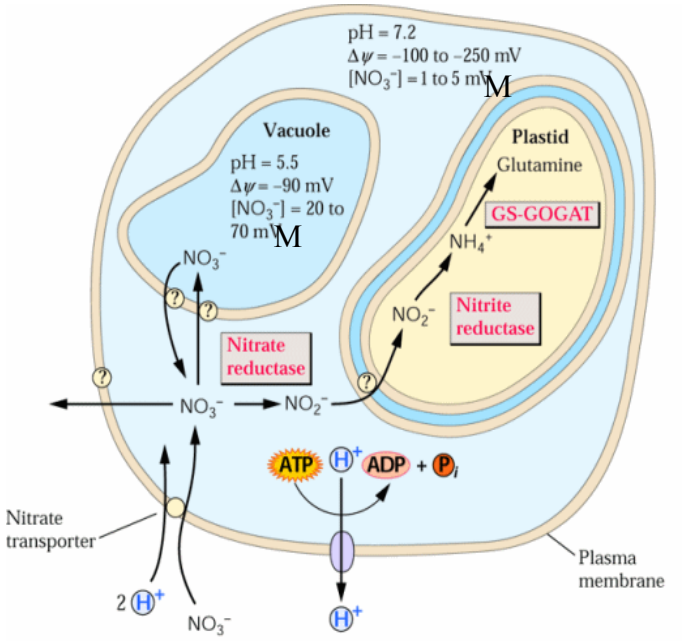
(Plant Physiology, 4th Ed 2006 Sinnauer)

Nitrogen in Plants: Energy Cost of Uptake and Assimilation



(Plant Physiology, 4th Ed 2006 Sinnauer)

Nitrogen in Plants: Nitrate Uptake and Assimilation



- Nitrate uptake, reduction, and assimilation are intricately integrated with photosynthesis and C availability.

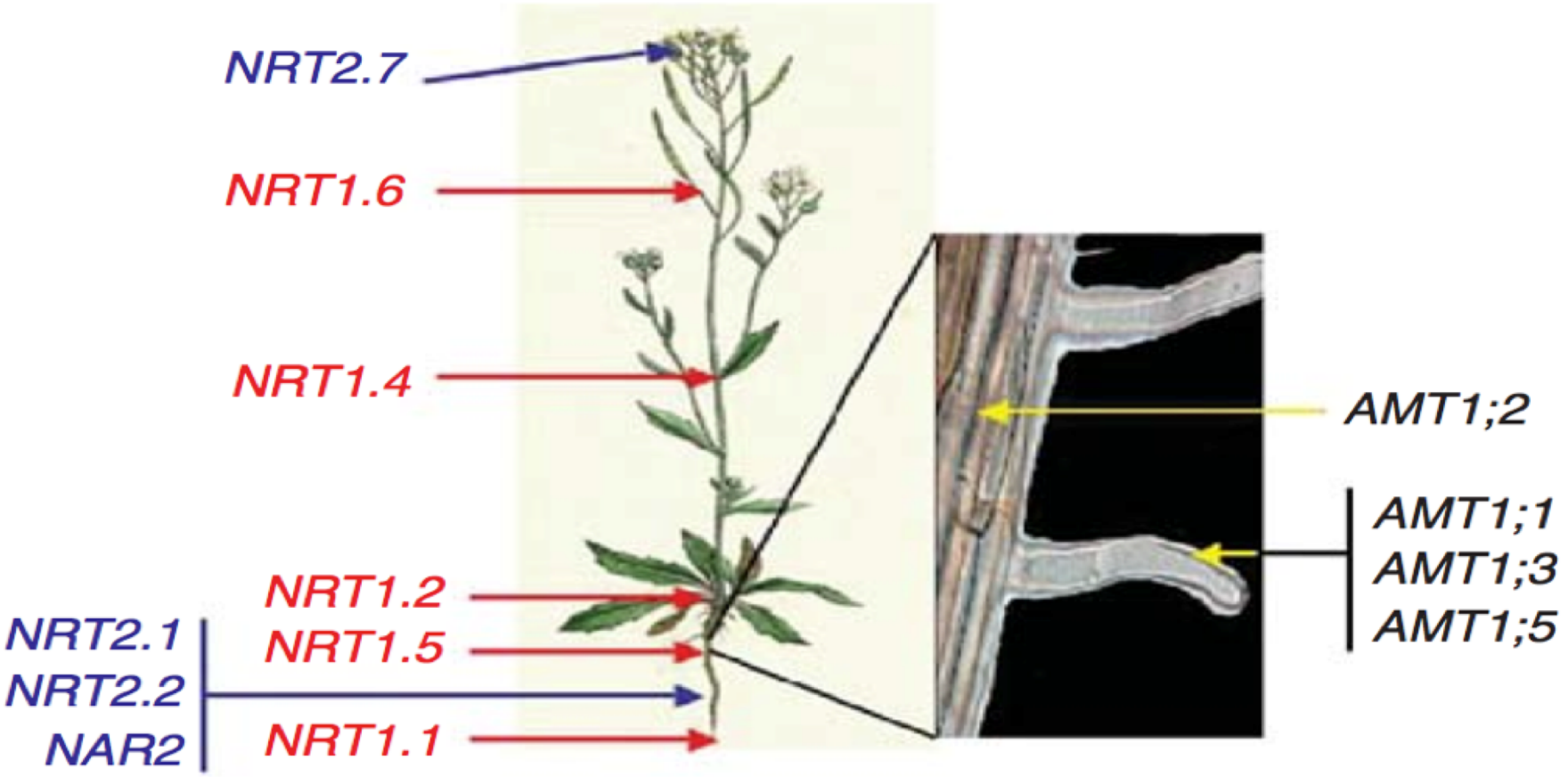
- If N demand or rate of photosynthesis is limited, uptake is reduced.

- Nitrate/nitrogen availability is a primary determinant of growth rate, root allocation, root architecture, flowering time, and fruit quality.

- Excess N in any form will result in 'excess' tissue N with no growth benefit and possible negative effects.

(Plant Physiology, 4th Ed 2006 Sinnauer)

Nitrogen in Plants: Uptake Transporters

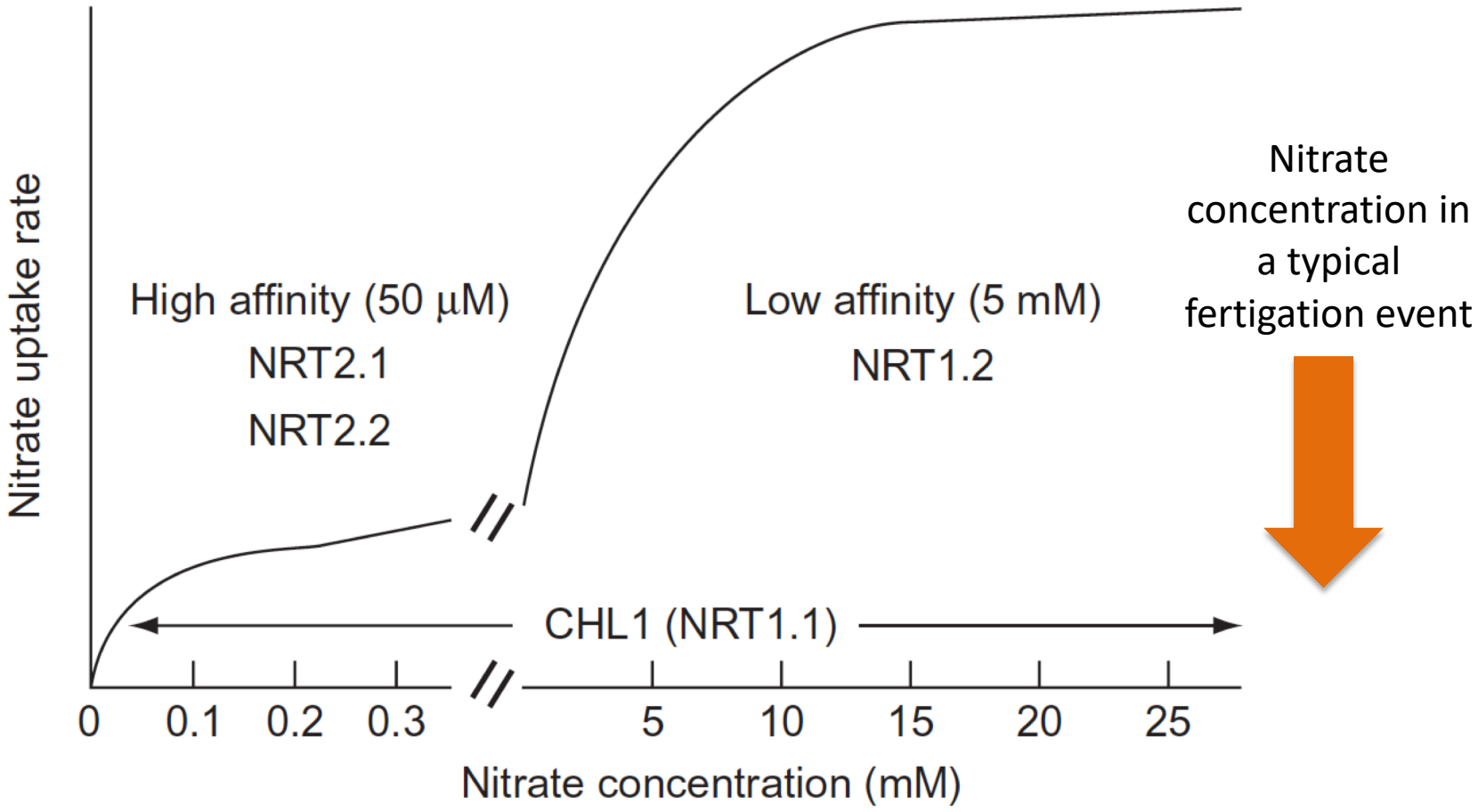


Hundreds of genes coding for dozens of nitrogen and ammonium uptake transporters (e.g. NRT2.7), located in many different organs have been identified. All are carefully regulated by demand, supply, environment and phenology.

Masclaux-Daubresse et al. — *Nitrogen in agricultural plants* *Annals of Botany* **105**: 1141–1157, 2010

Nitrogen in Plants: Nitrate Uptake Rate

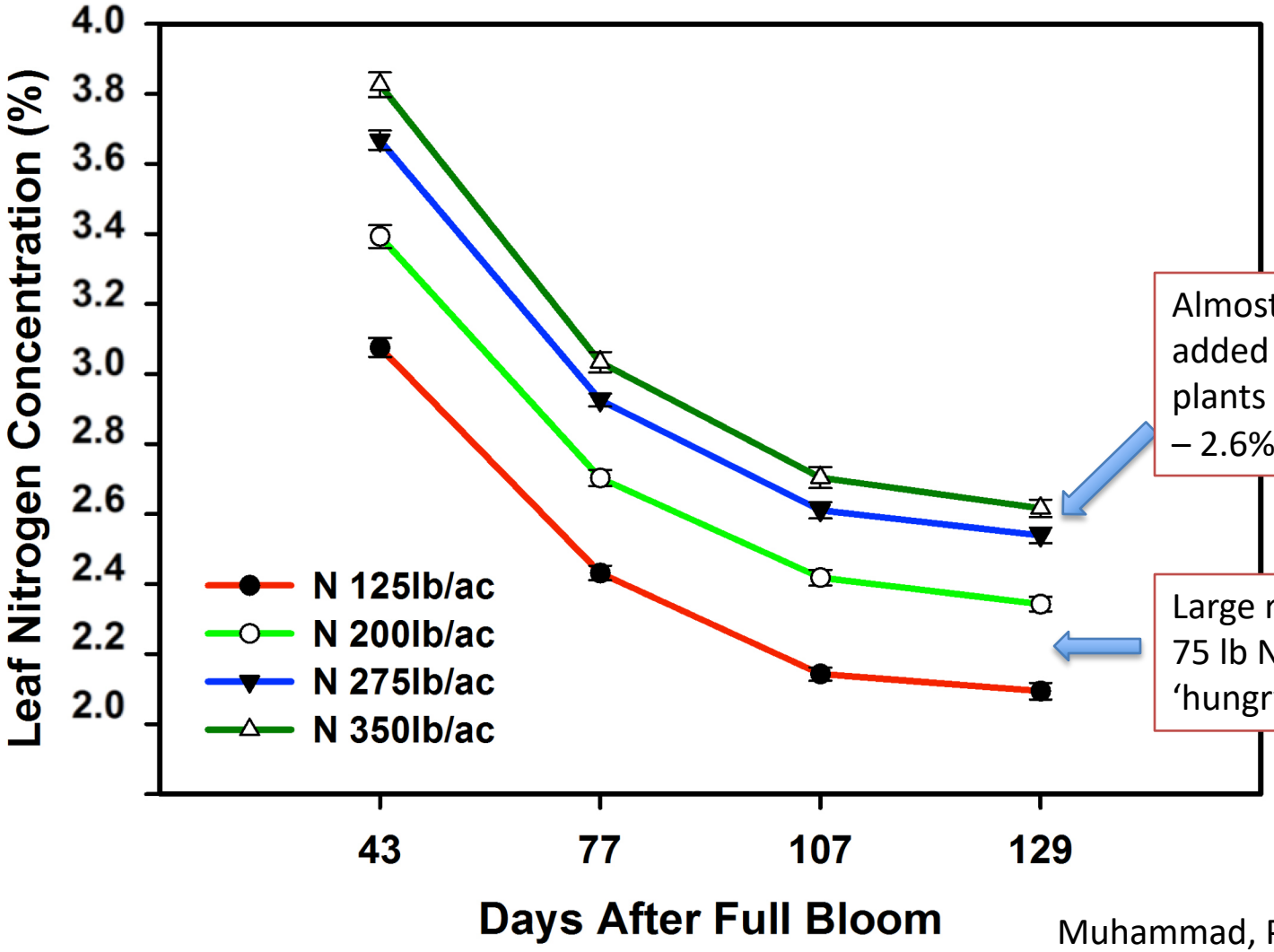
Nitrate uptake rate varies with nitrate concentration but is saturated at common fertigation concentrations.



(Marschner, P. (2012). Mineral Nutrition of Higher Plants. Academic Press. Waltham, MA, USA.)

N in excess of demand is inefficiently used.

Effect of Nitrogen Rate on Leaf Nitrogen in Almond.



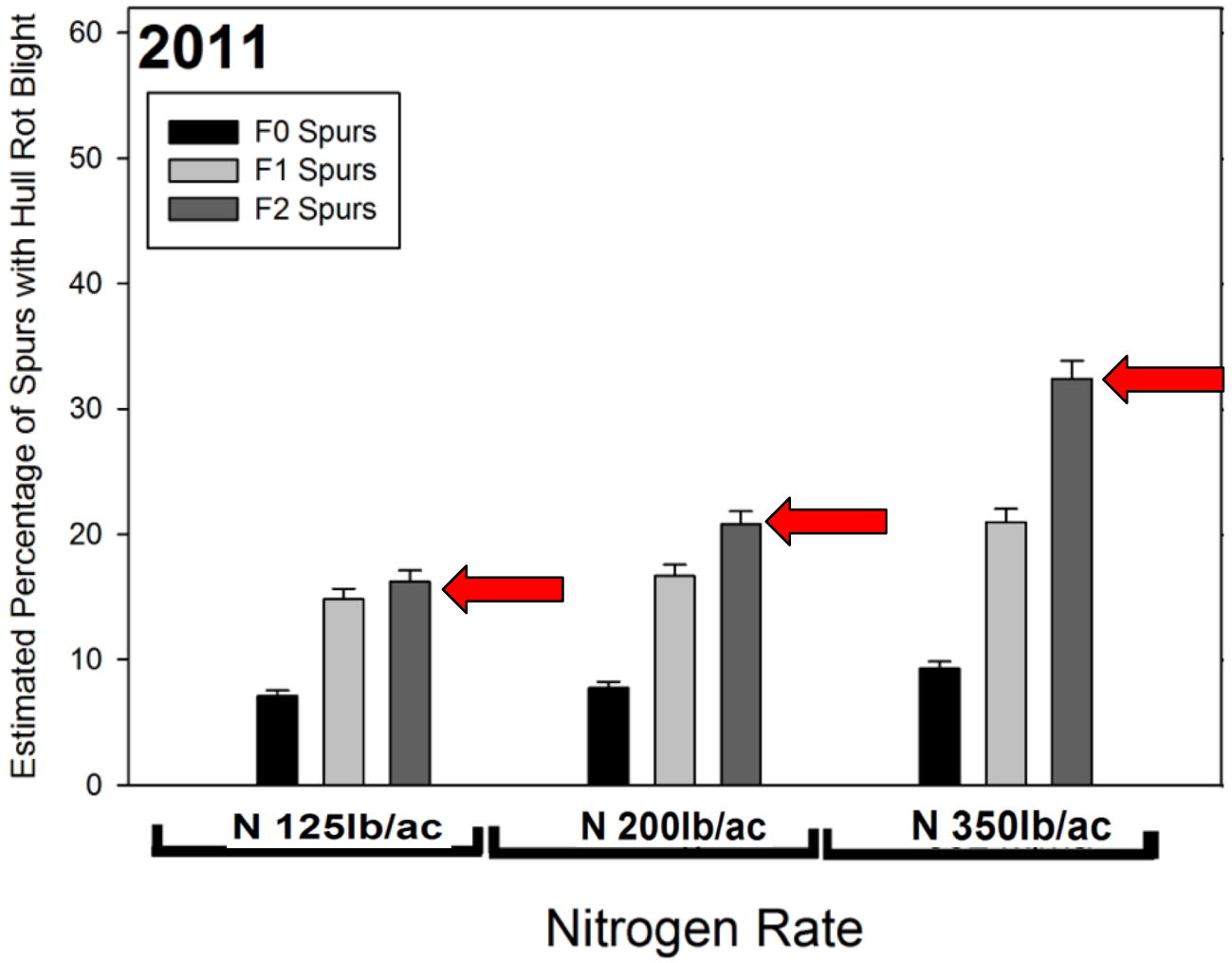
Almost no response to added 75 lb N when plants are 'satisfied'. (2.55 – 2.6%)

Large response to added 75 lb N when plants are 'hungry'. (2.0 – 2.4%)

Muhammad, PhD Dissertation. 2013

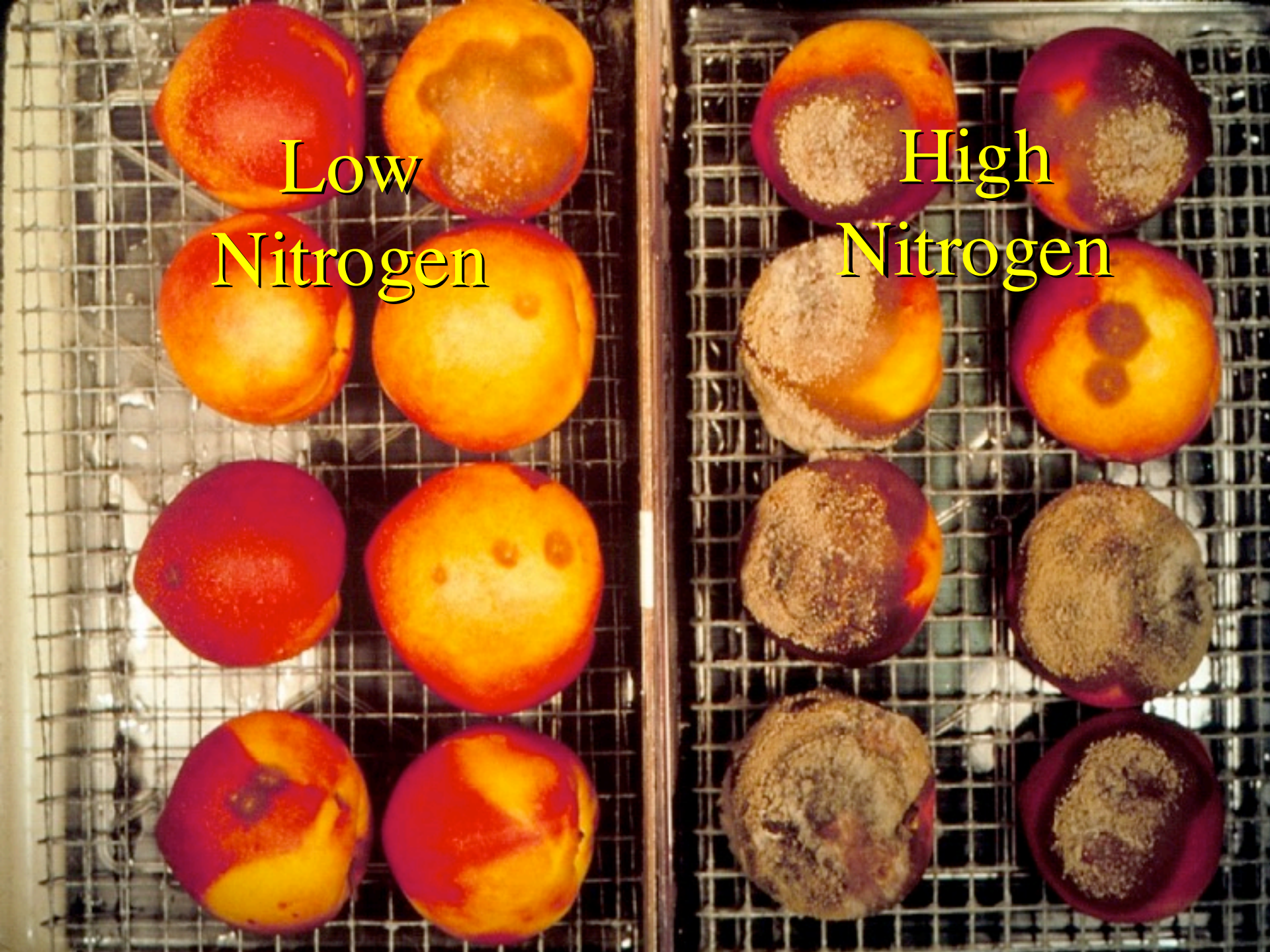
Influence of N Rate on Hull Rot in Almond

Hull Rot Incidence increased as N increased.



F0, F1, F2 = Zero, Single, and Double Fruited Spurs.

Elana Peach-Fine, MSc. 2013


Low
Nitrogen
High
Nitrogen

Above the 'critical N' requirement for growth, does additional N affect product quality ?

- **Often not, with key exceptions …**
  - **Cracked Carrots and tuber crops**
  - **Increased pest and disease damage**
  - **High nitrate greens are restricted in baby food and certain markets**

Summary N Cycle: Plant

- Most abundant mineral element in plants (2-4% dry weight)
- Uptake as nitrate and ammonium (also limited uptake of organic N sources)
- Nitrogen uptake is a tightly regulated process
- Nitrate uptake efficiency diminishes with increasing N and is regulated by demand (growth and fruit development).
- N in excess of demand is inefficiently used.
- Excess N can negatively influence crop quality and disease incidence

University of California

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Course materials available at:

ciwr.ucanr.edu/NitrogenManagement

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