Variation in Structure and Metabolism Results in Different Plant Nutrient Requirements

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It’s 2009!

We’ve learned a lot about plants.

What we’ve learned may help us better understand plant nutrient needs.

Why do plants need macronutrient and micronutrient elements?

- Some are in structures – P in membrane phospholipids, Ca in cell walls
- Some are in important molecules – P in ATP, DNA, RNA
- Some are buried in proteins – Cu in plastocyanin
- Some are buried in enzymes – many Zn metalloenzymes
- Some are required in high concentrations to activate enzymes – proper bathing solution

Plants

- Gymnosperms
- Angiosperms
- Dicots
- Monocots
- C3, C4 and CAM plants
- Cool season, warm season and desert plants

First question:

Are all plant cell walls the same?

No!

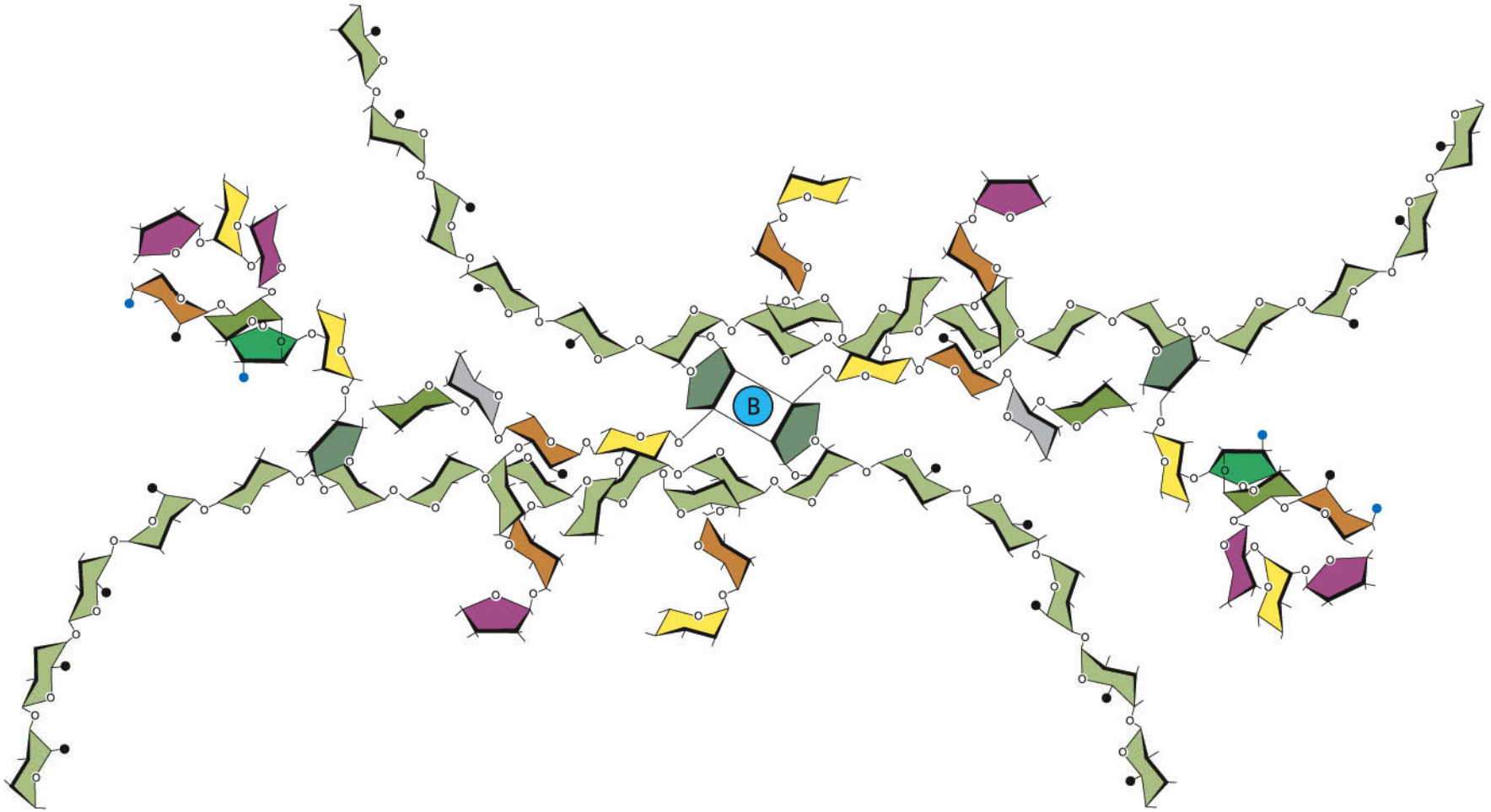
Does this affect their nutritional needs?

Graminaceous plants and dicots have very different cell walls.

Cell walls of dicots contain more pectin than cell walls of grasses.

CELL WALL PECTIN

(E) **Rhamnogalacturonan II (RG II)** dimer cross-linked by borate diester bonds



PLANT PHYSIOLOGY, Fourth Edition, **Figure 15.11 (Part 4)**

Plants may be grouped according to their B content:

- **Lactifers - highest (70 to 100 ppm)**
- **Cole (*Brassica*) crops - second highest**
- **Legumes, other dicots and lily family of monocots - third highest**
- **Graminaceous plants - lowest, hardly require B until flowering (2 to 5 ppm)**

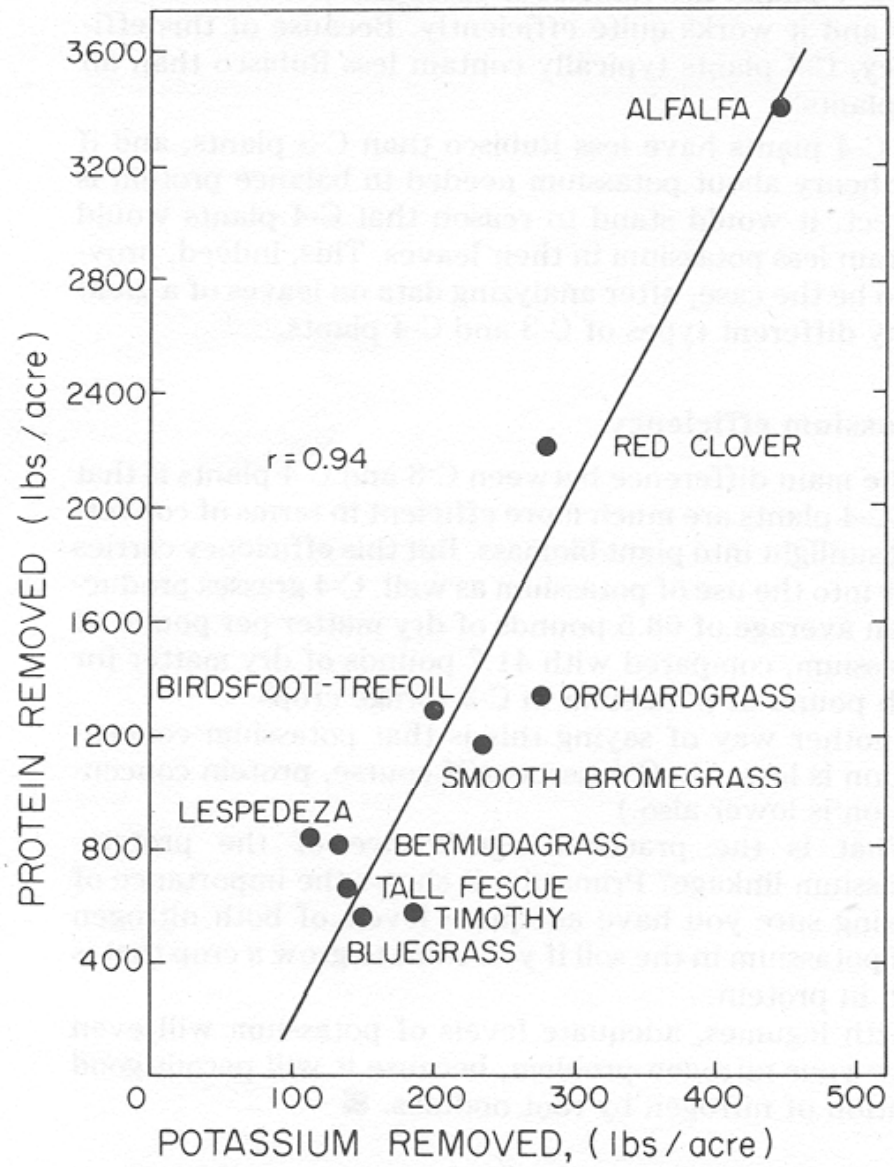
Species variability in boron requirement is correlated with cell wall pectin

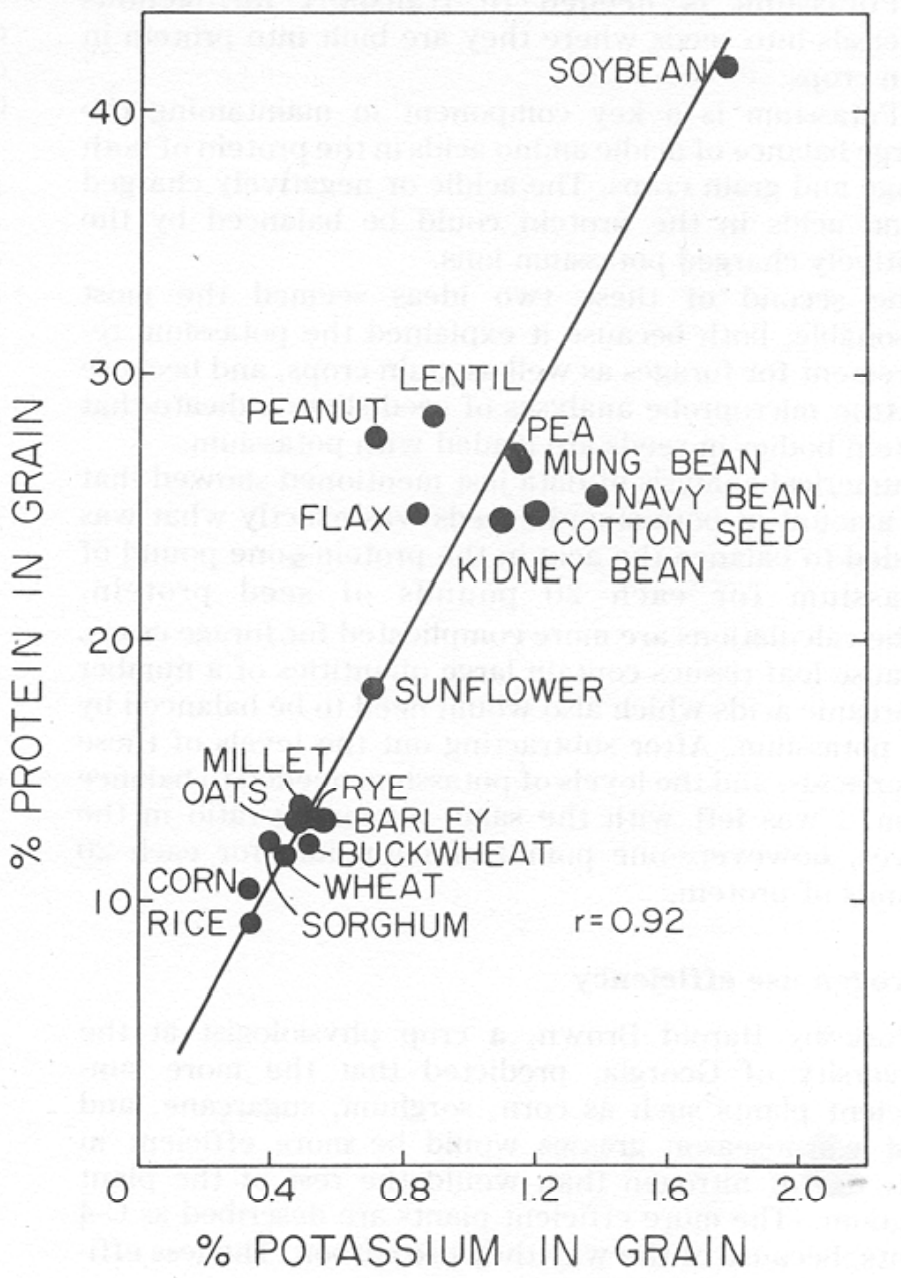
Hening Hu, Patrick H. Brown and John M. Labavitch

1996. J. Exp. Botany 47:227-232

Why do some plants need so much potassium?

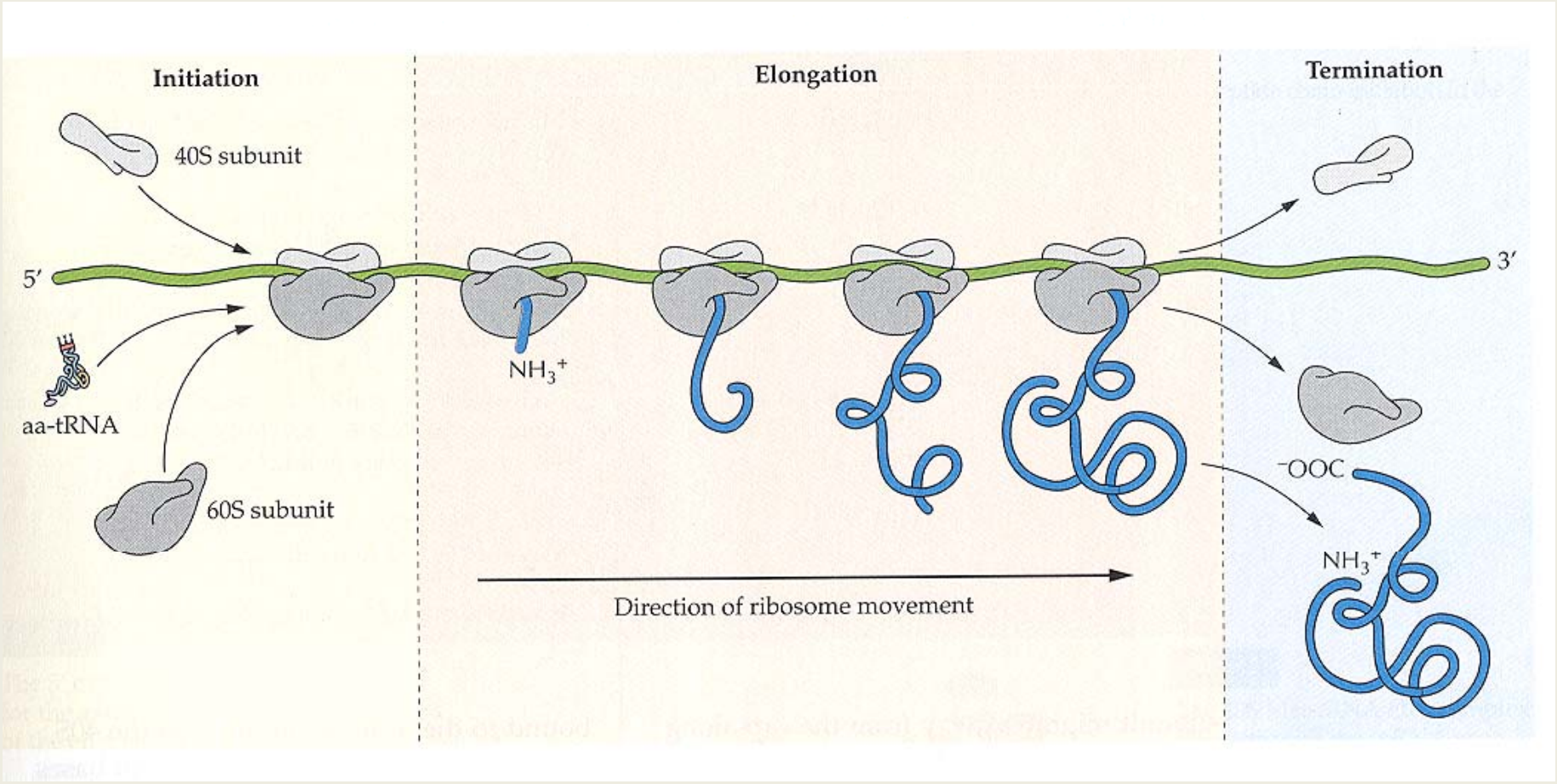
Alfalfa removes 50 lbs of K^+ with every ton of hay removed.





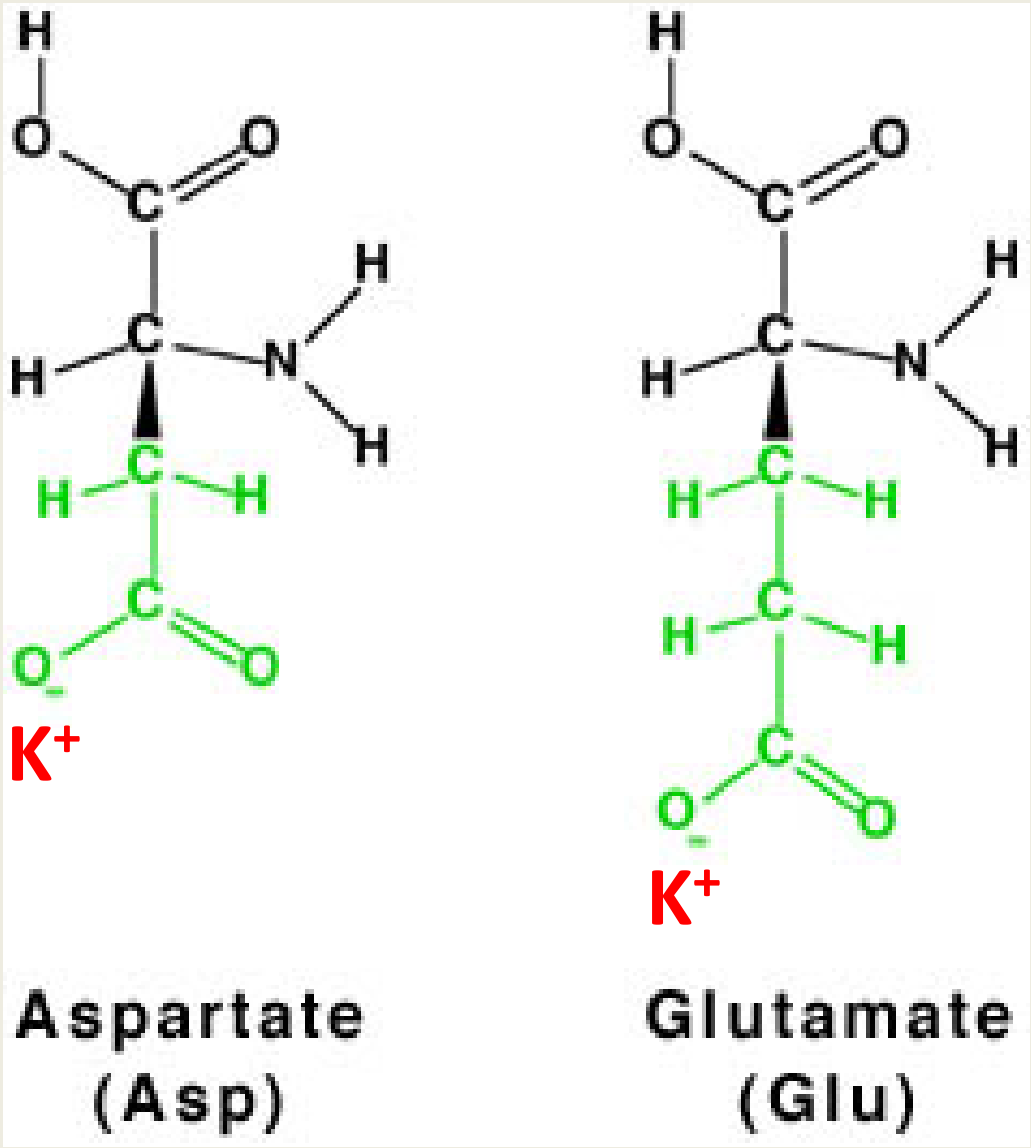
Blevins 1985

Potassium is involved in every step of protein synthesis.



Buchanan et al 2000

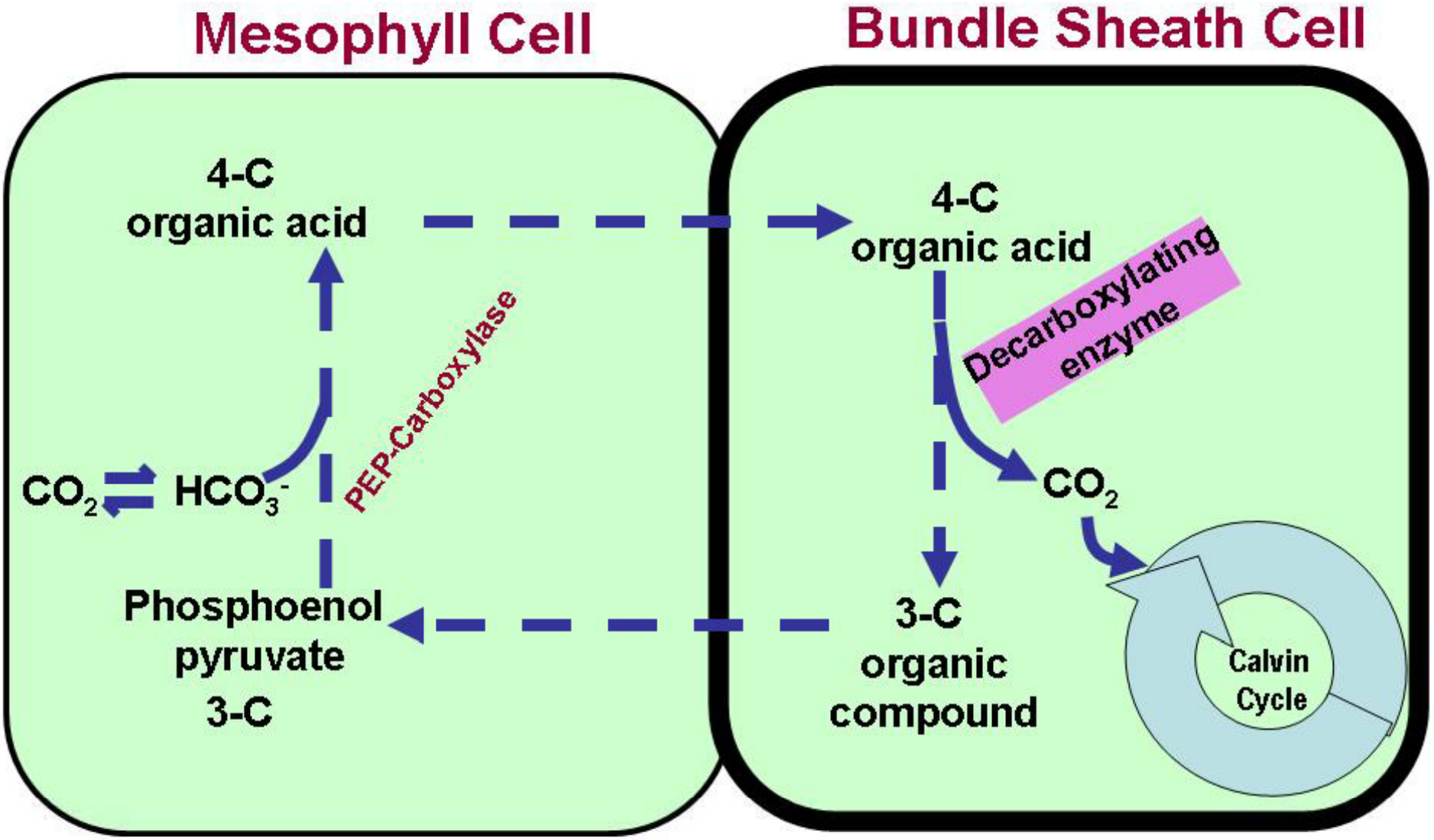
How is K^+ associated with proteins?



Manganese and C4 Plants

There are three major types of C4 plants.

C-4 Photosynthesis

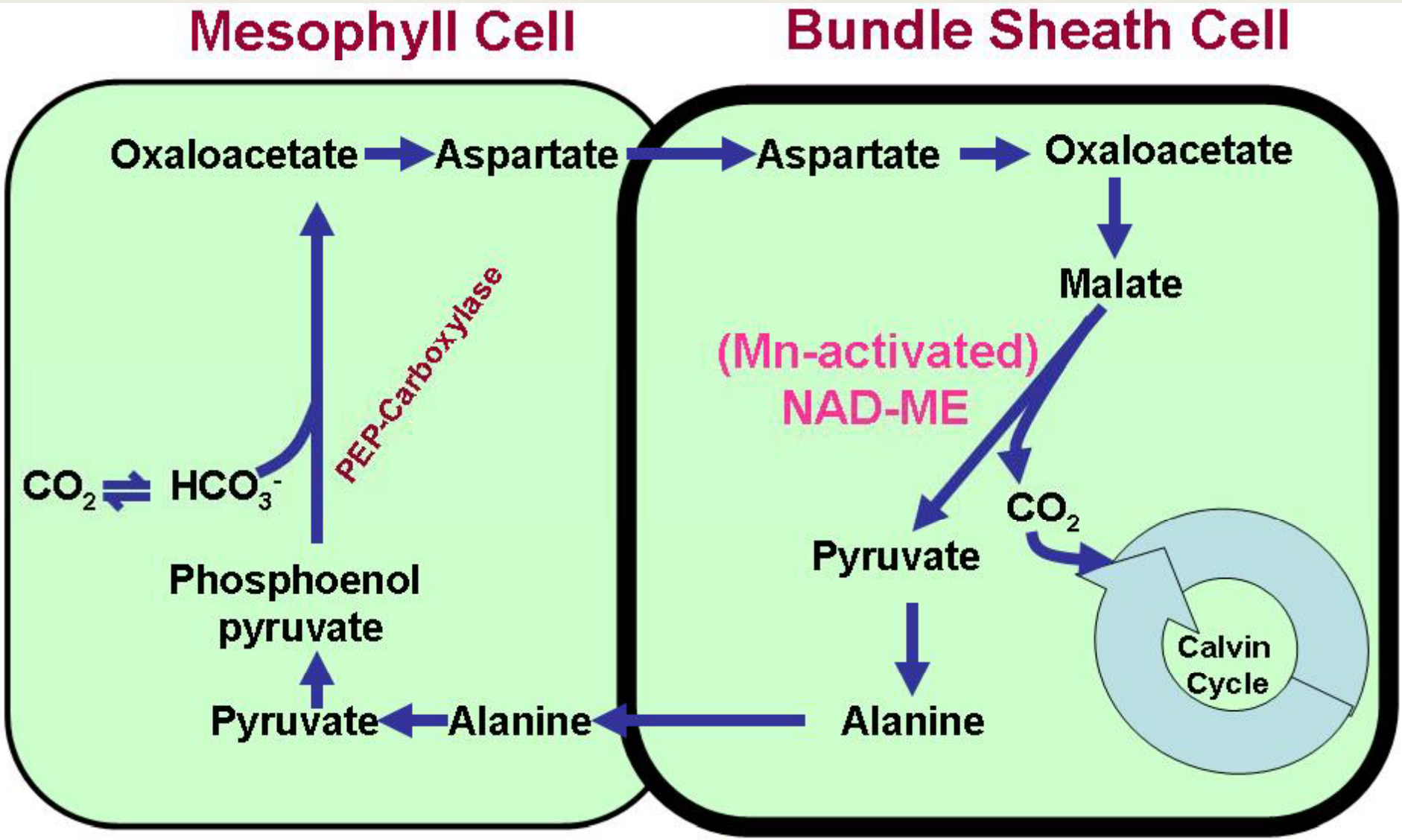


The three major sub-types of C4 plants:

- NADP-malic enzyme (NADP-ME) (Mg activated)
- Phosphoenol pyruvate carboxykinase (PEP-CK) (mainly Mn, Mg)
- NAD-malic enzyme (NAD-ME) (Mn activated)

Species within each of the C4 subtypes:

NADP-ME	NAD-ME ★	PEP-CK
Big bluestem	Pearl millet	Guinea grass
Indian grass	Amaranth	Rhode grass
Little bluestem	Bermuda grass	Side oats grama
Crab grass	Switch grass	
Corn	Buffalo grass	
Sorghum	Blue gamma	
Sugar cane		

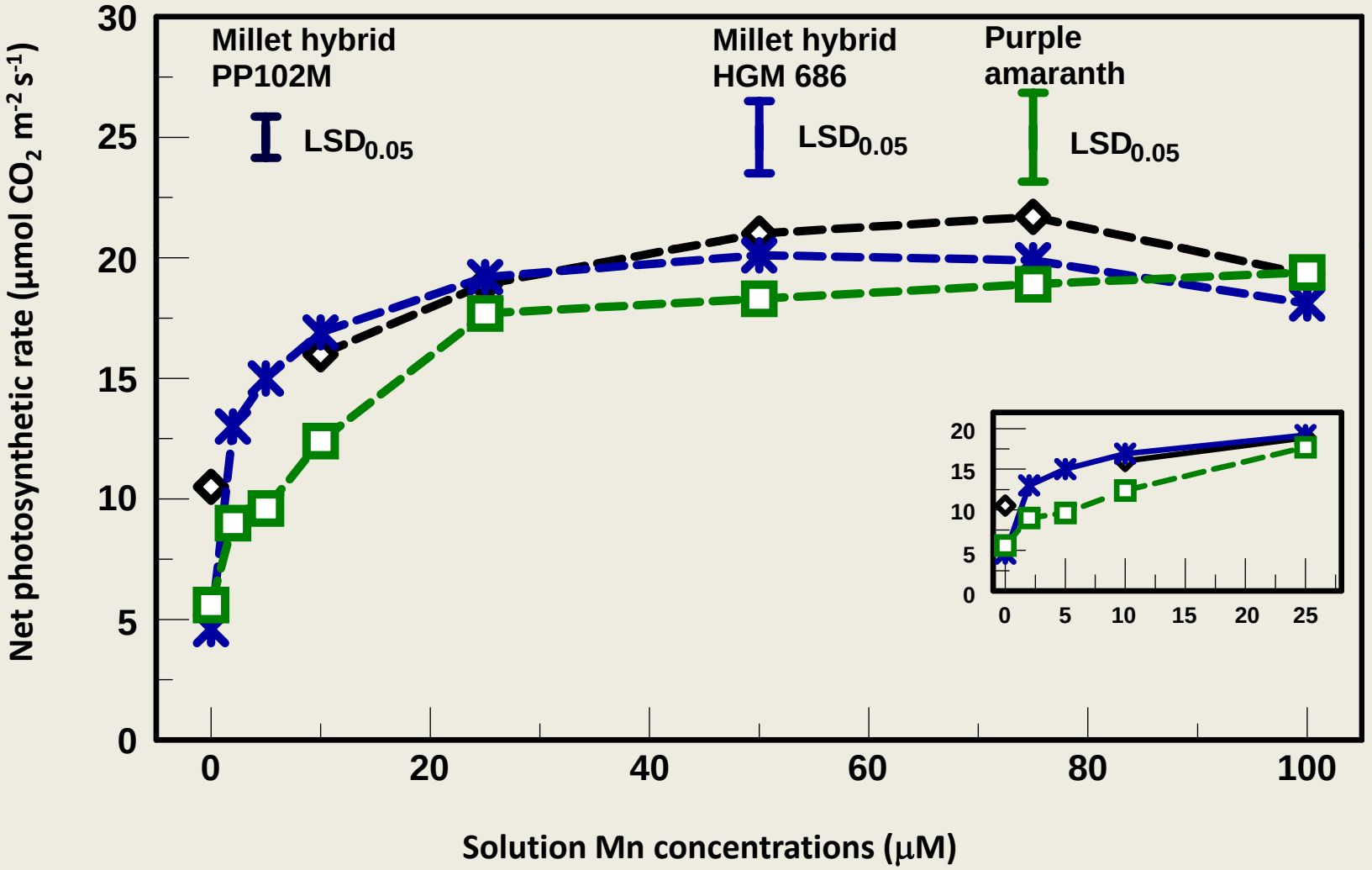

Mesophyll Cell
Bundle Sheath Cell
Oxaloacetate
Aspartate
Aspartate
Oxaloacetate
Malate
(Mn-activated)
NAD-ME
PEP-Carboxylase
CO_2 ⇌ HCO_3^-
CO_2
Pyruvate
Phosphoenol
pyruvate
Calvin
Cycle
Pyruvate
Alanine
Alanine

Hydroponically Grown
Pearl Millet and Purple Amaranth

(µM Mn)

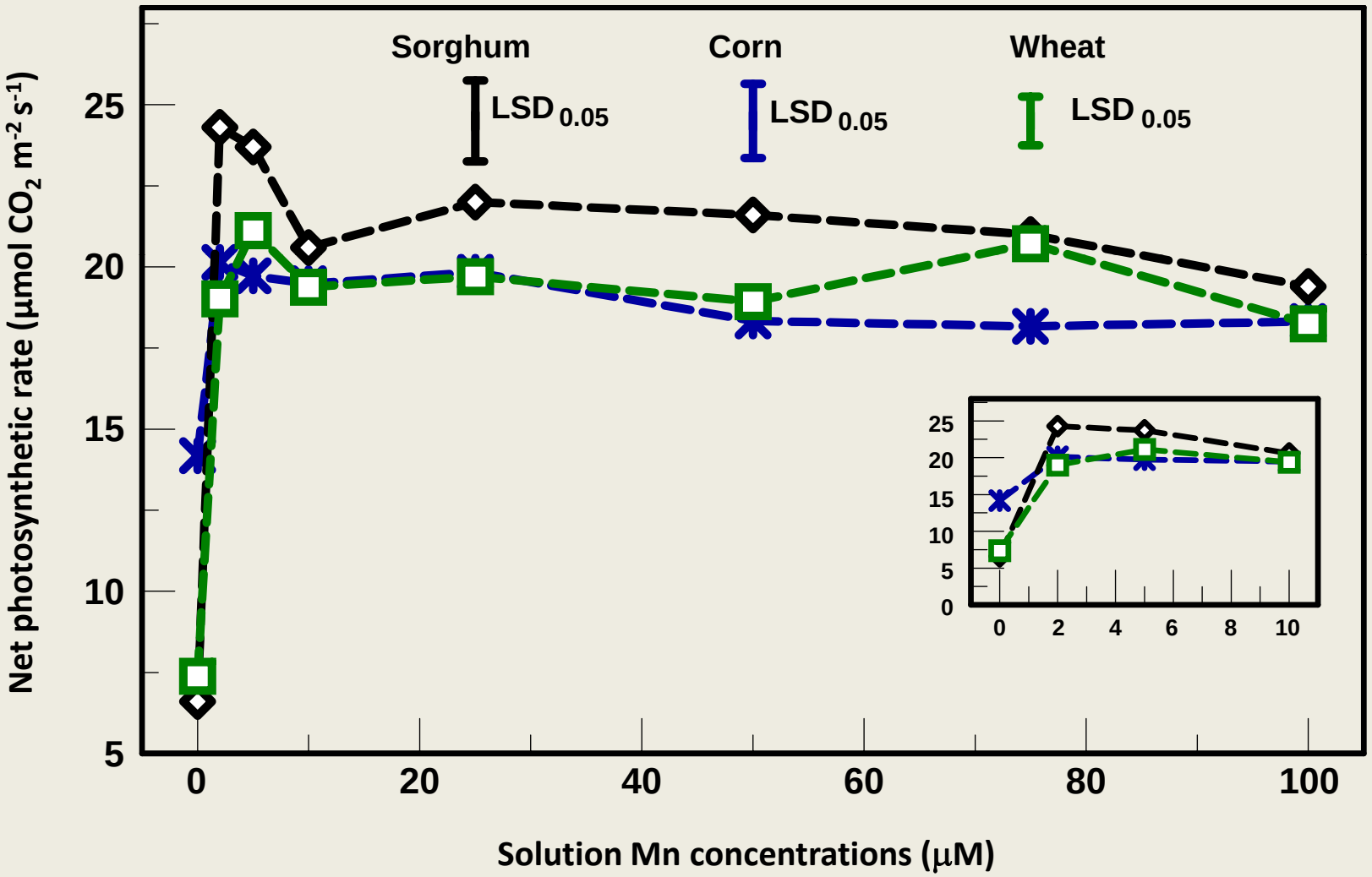
Kering & Blevins 2009

Mn & Photosynthesis

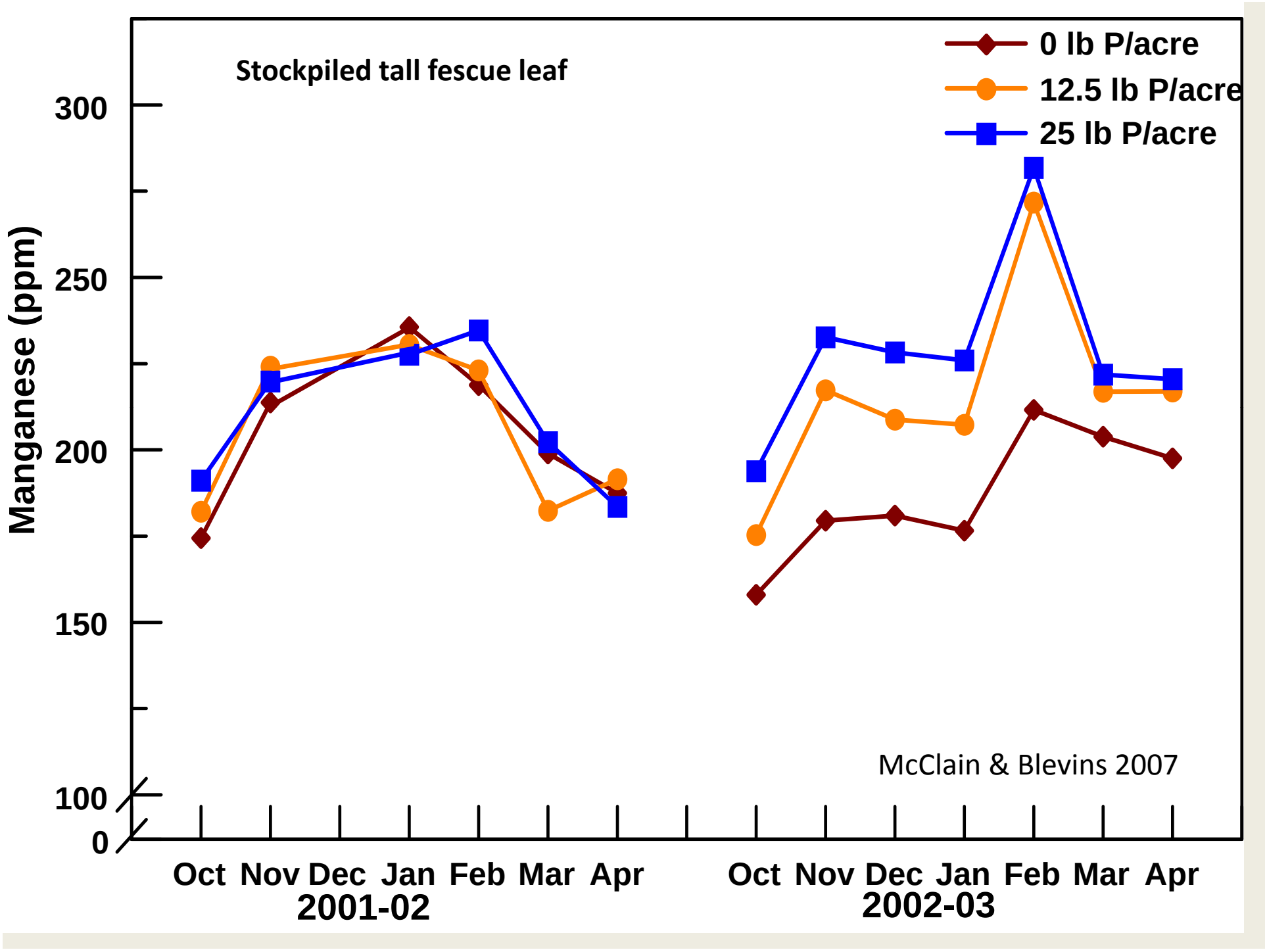


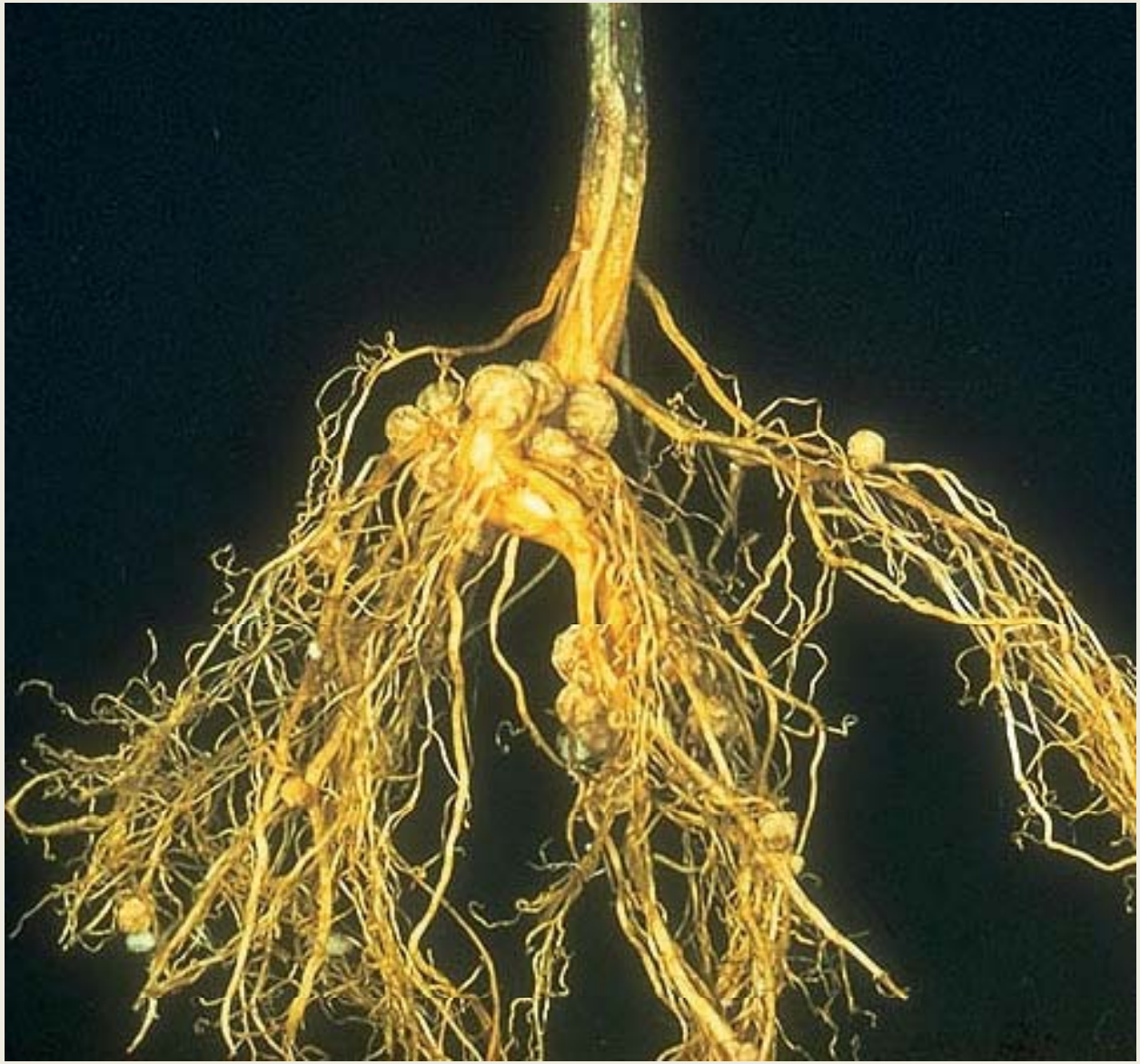
Kering & Blevins 2009

Mn & Photosynthesis



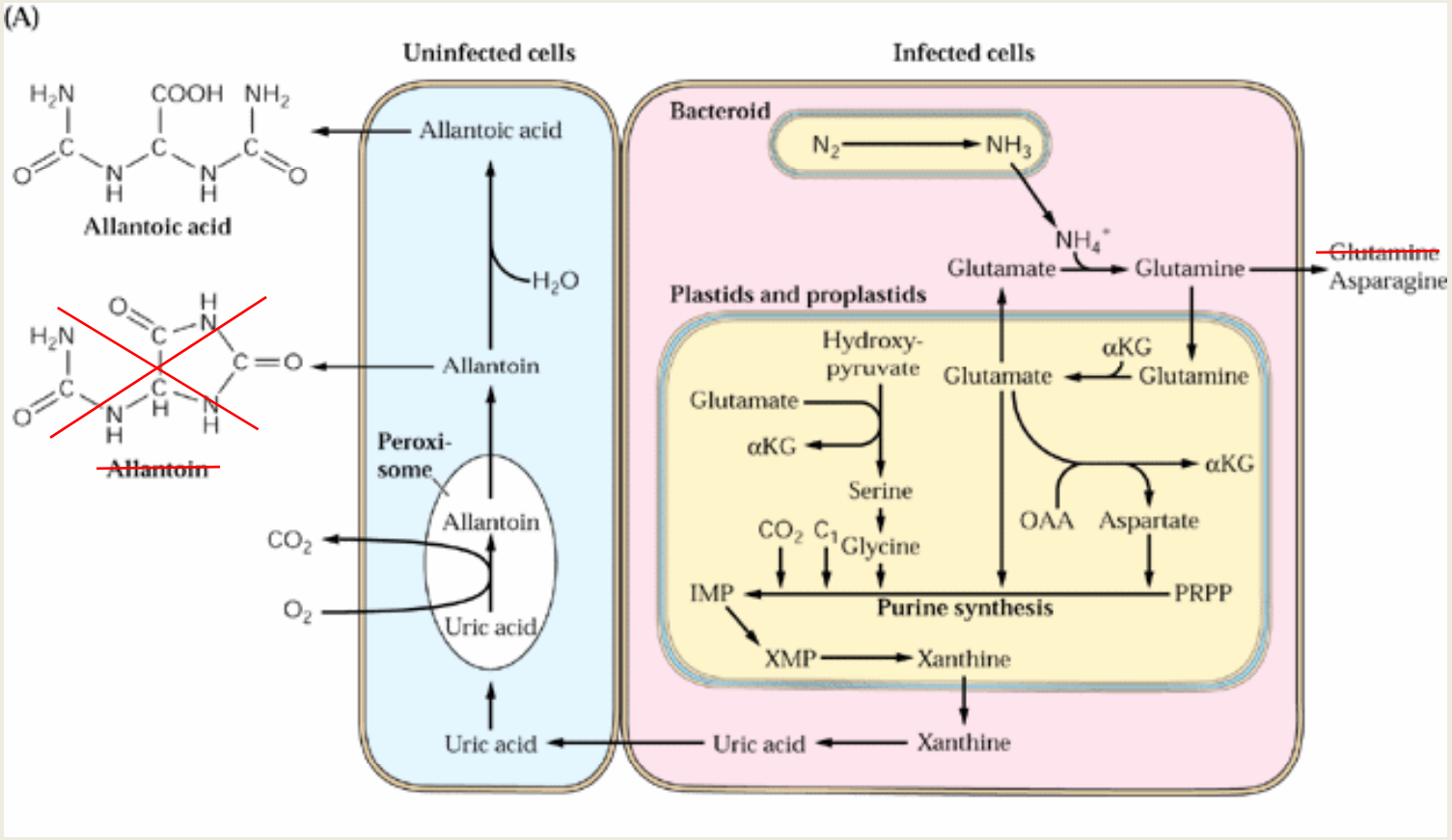
Kering & Blevins 2009


Stockpiled tall fescue leaf
0 lb P/acre
12.5 lb P/acre
25 lb P/acre
Manganese (ppm)
300
250
200
150
100
0
Oct Nov Dec Jan Feb Mar Apr
2001-02
Oct Nov Dec Jan Feb Mar Apr
2002-03
McClain & Blevins 2007

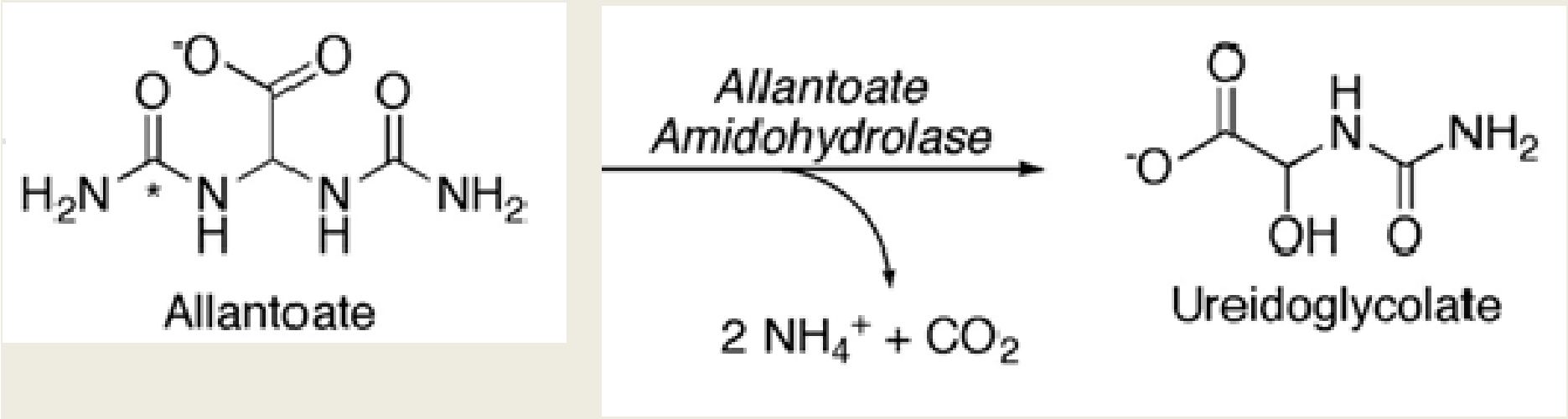


Nitrogen Fixation in Soybean

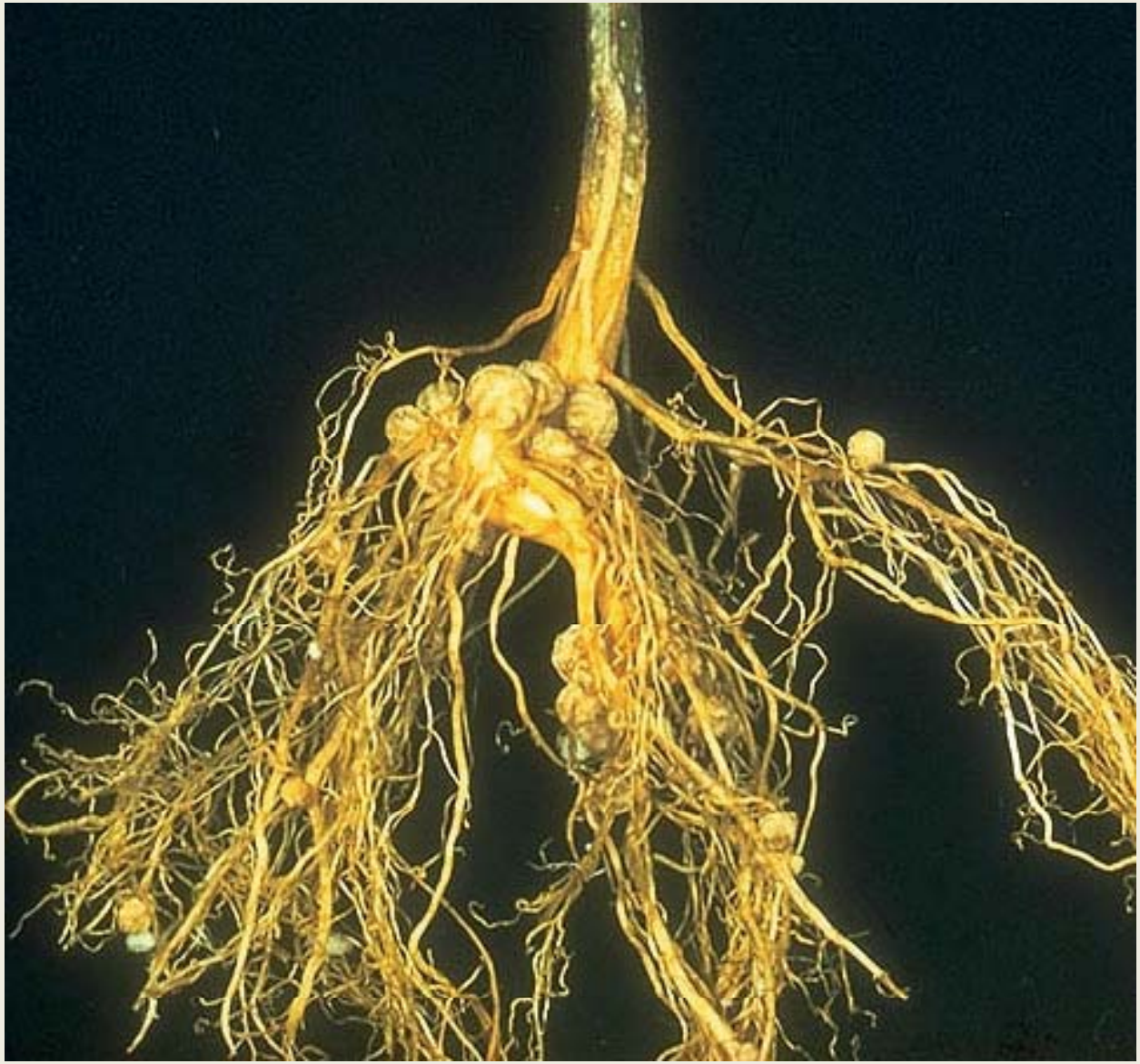
Do nitrogen-fixing soybeans have a high manganese requirement?



Buchanan et al 2000



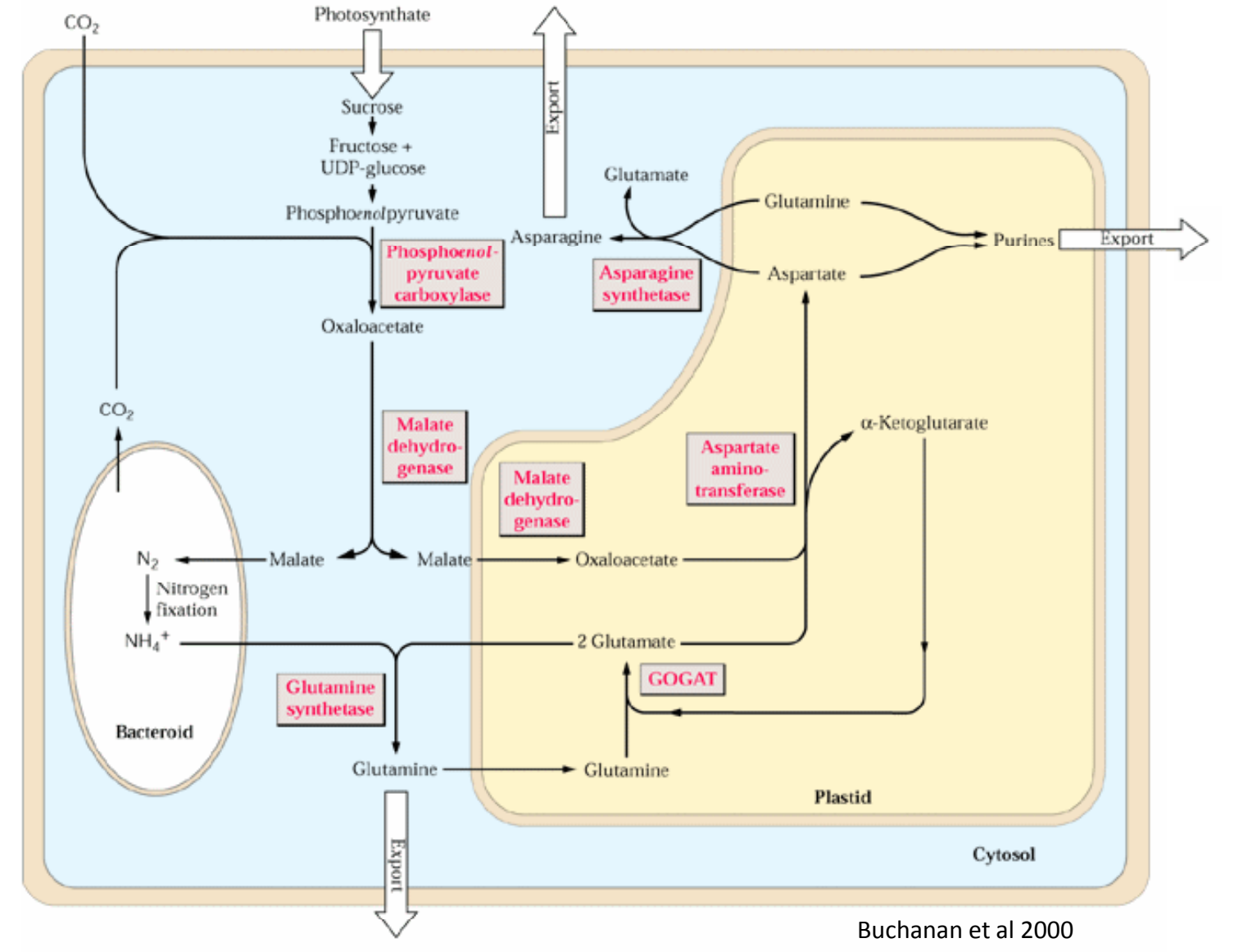
Allantoate amidohydrolase is a Mn-activated enzyme.



Do soybean root nodule bacteroids have a high Mn requirement?

Legumes feed the root nodule bacteria organic acids, like malate.

Inside a soybean root nodule cell



Buchanan et al 2000

Mn-activated NAD-malic enzyme in bacteroids

malate + NAD^+ → pyruvate + CO_2 + NADH

There are at least two reasons why soybeans may have a high Mn requirement.

- Ureide-N metabolism in leaves and developing pods
- Malate utilization in root nodule bacteroids
- There may be a third reason for high Mn: Roundup Ready soybeans?

Summary

Learning about plant structure and function helps us understand their specific nutrient needs.

- **Pectin in cell walls indicates B requirement**
- **High protein crops need more K**
- **NAD-malic enzyme C4 plants require more Mn**
- **Soybeans may need more Mn**

Questions