POTASSIUM IN PLANT GROWTH AND YIELD

by
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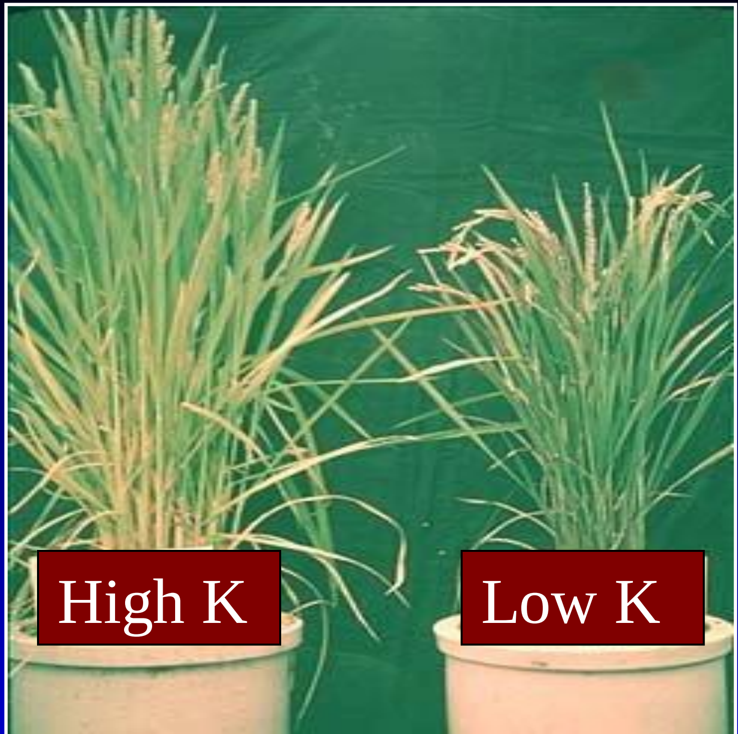
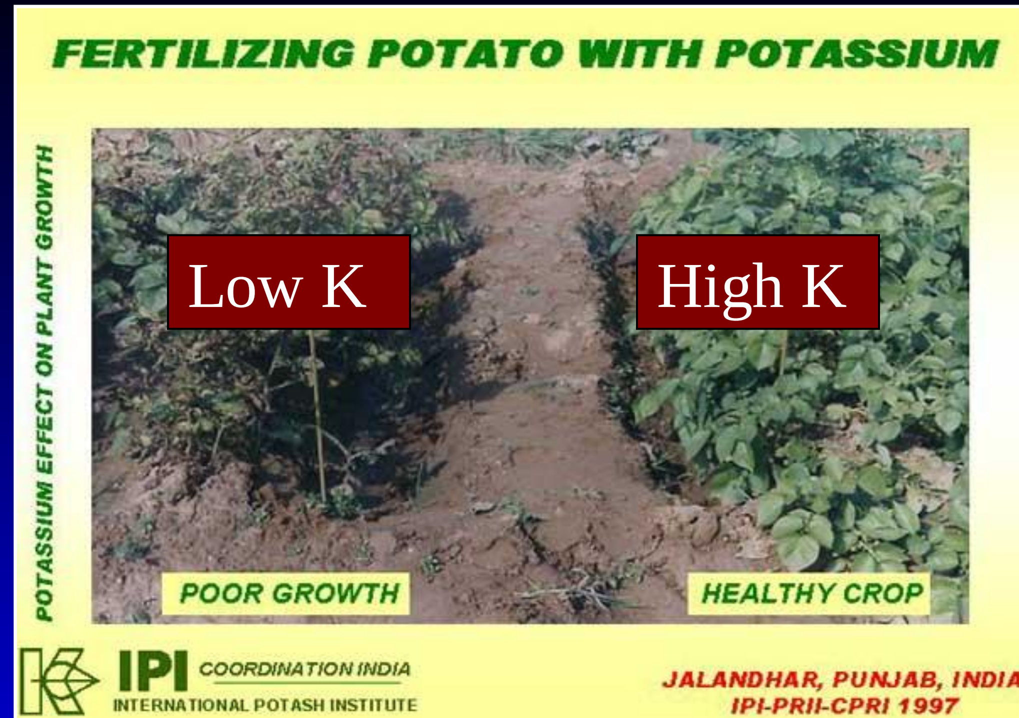
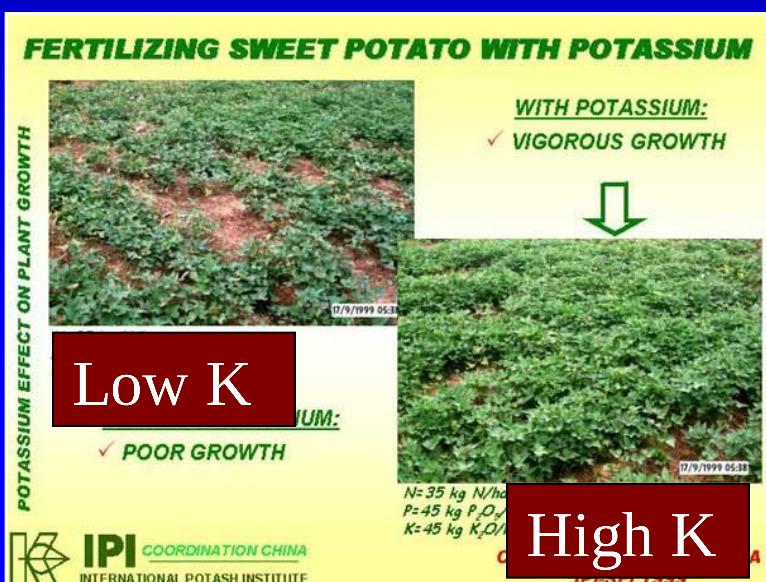
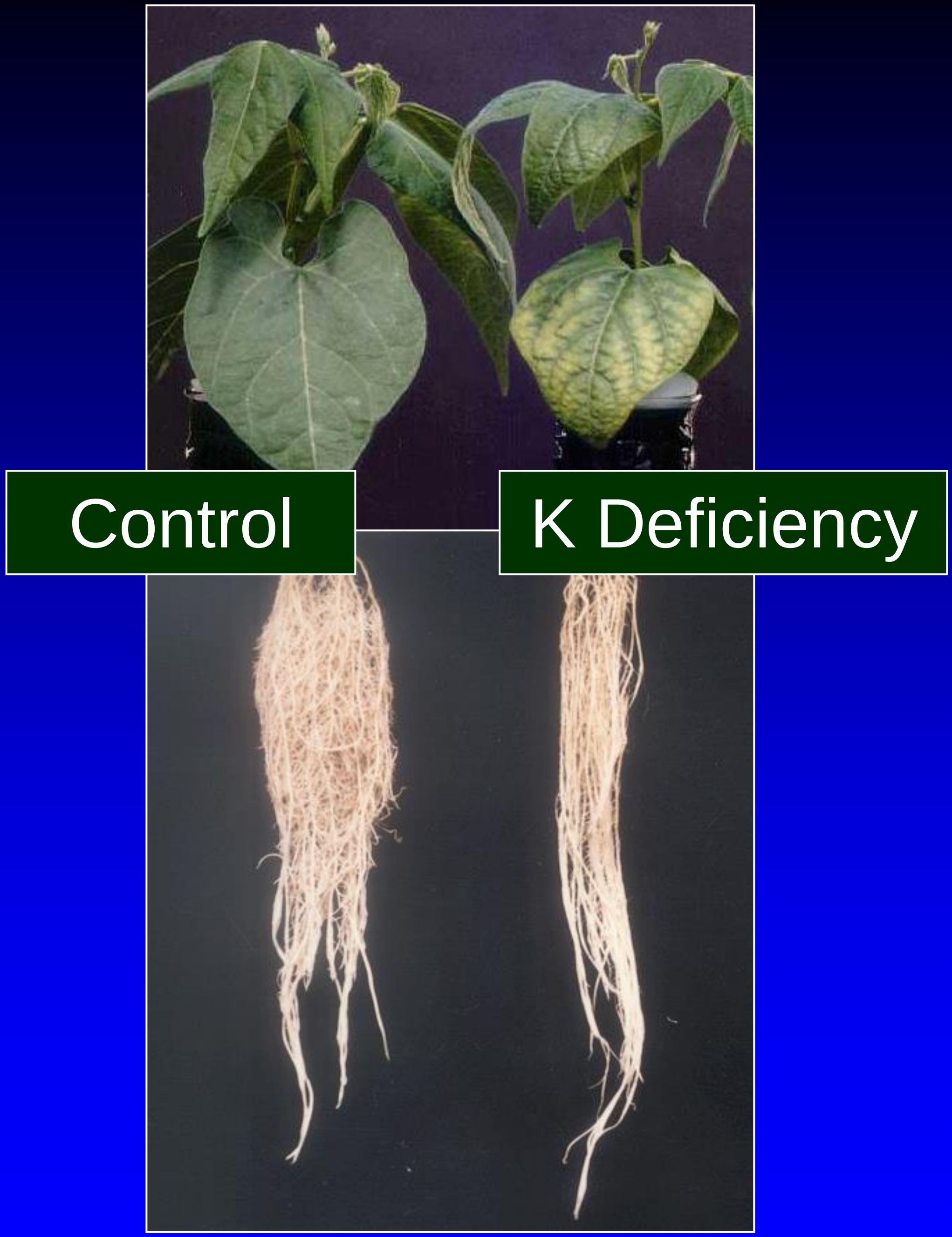
SIMPÓSIO SOBRE
POTÁSSIO NA AGRICULTURA BRASILEIRA
SÃO PEDRO-SP, 22 a 24 de Setembro de 2004


High K
Low K


FERTILIZING POTATO WITH POTASSIUM
POTASSIUM EFFECT ON PLANT GROWTH
Low K
High K
POOR GROWTH
HEALTHY CROP
IPI COORDINATION INDIA
INTERNATIONAL POTASH INSTITUTE
JALANDHAR, PUNJAB, INDIA
IPI-PRII-CPRI 1997

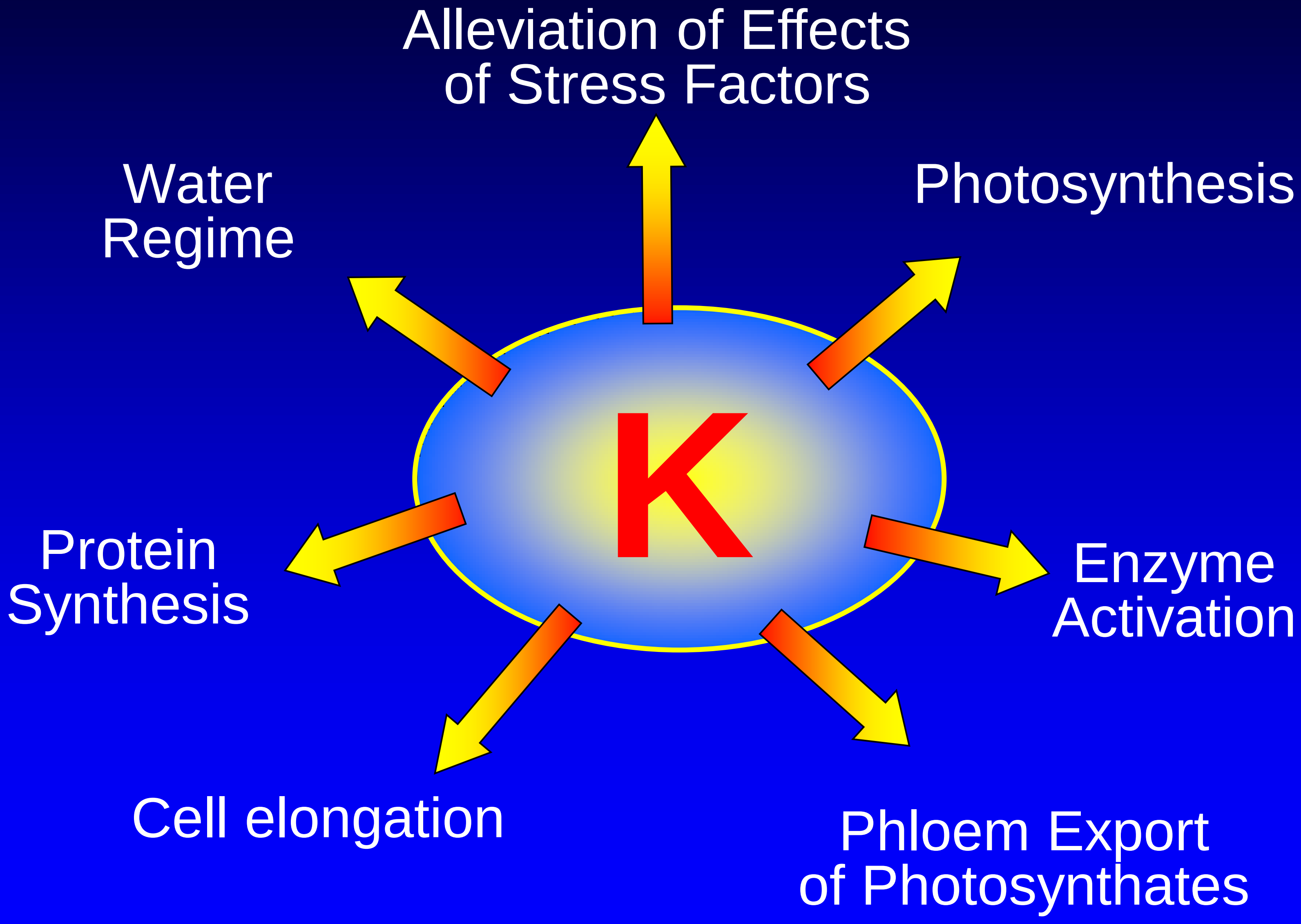

FERTILIZING SWEET POTATO WITH POTASSIUM
POTASSIUM EFFECT ON PLANT GROWTH
WITH POTASSIUM:
✓ VIGOROUS GROWTH
Low K
✓ POOR GROWTH
High K
IPI COORDINATION CHINA
INTERNATIONAL POTASH INSTITUTE


High K
Low K



Cakmak et al., 1994, J. Experimental Bot.

POTASSIUM IN CROP PRODUCTION

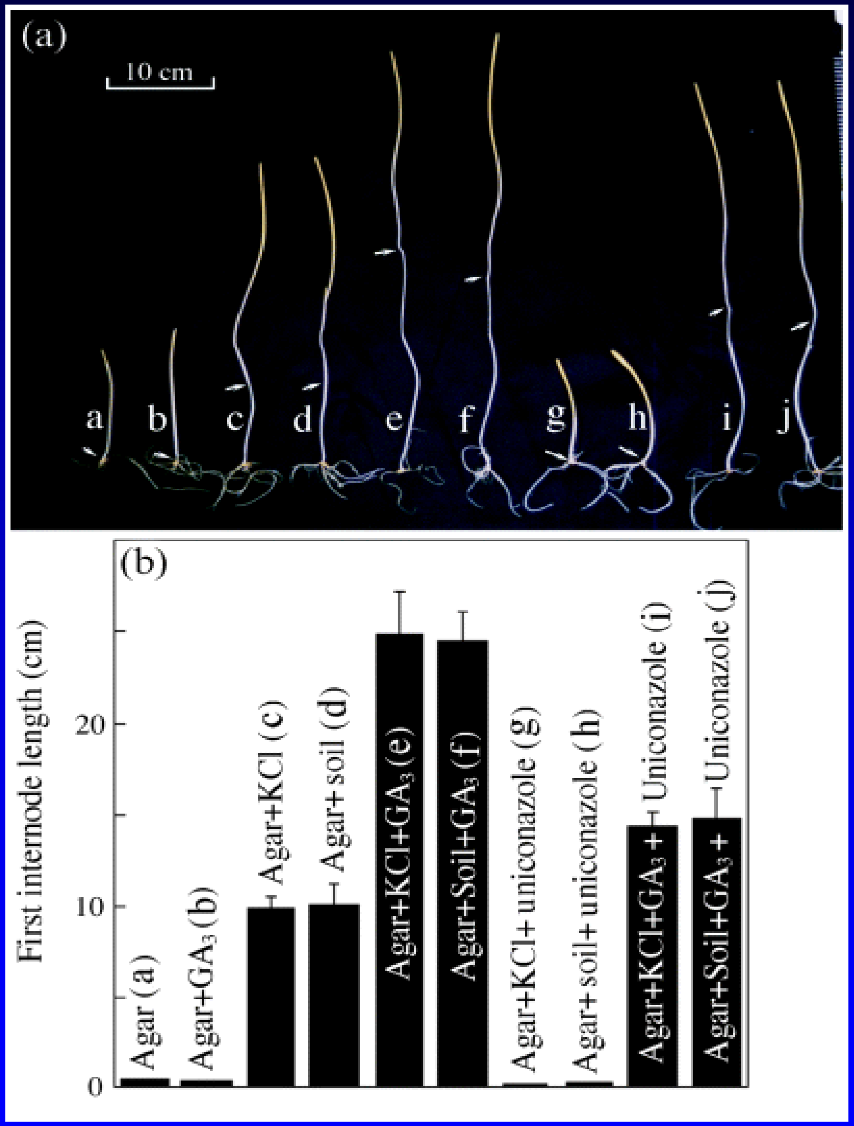


K and Cell Elongation/Extension

In most cases, cell extension is the consequence of the accumulation of K in the cells that is required for both stabilizing the pH of the cytoplasm and increasing the osmotic potential in vacuoles.

Cell elongation by GA is dependent on K supply

Potassium is essentially needed for cell elongation

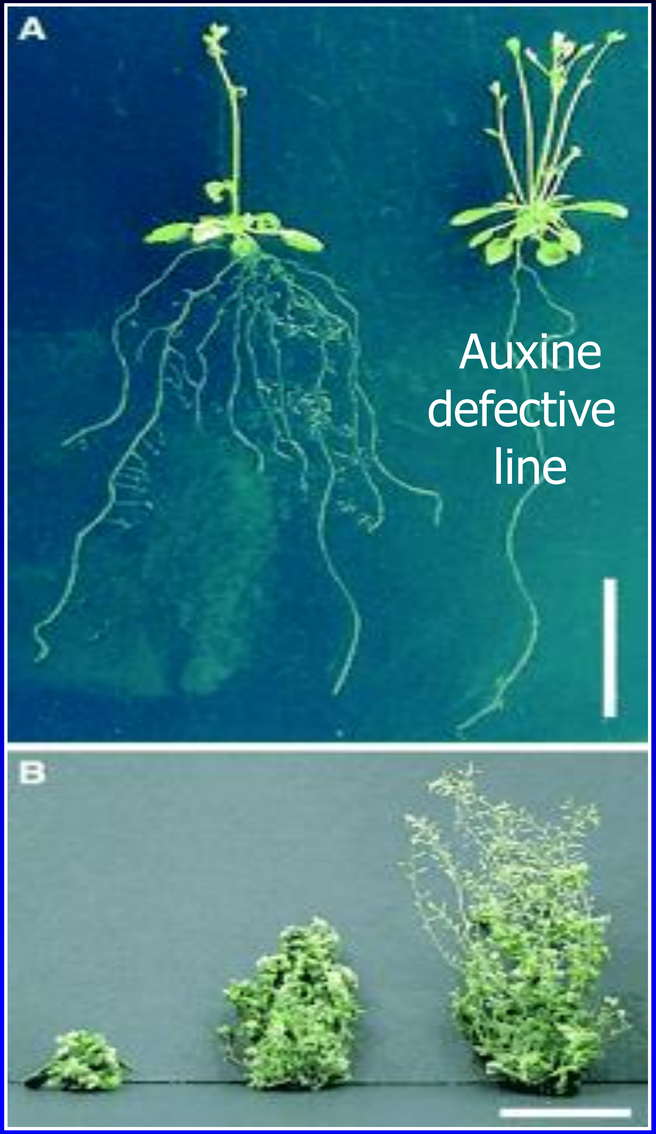


Potassium is essential for GA3 (gibberellin)-induced cell elongation/extension, especially under deep-seeding conditions (seedling establishment!!!)

Potassium is needed for turgor potential to avoid drought stress in arid environment

Potassium and GA act synergistically in elongating cells

(Chen et al., 2001;
Plant Cell Environ. 24: 469-476)



Rogg et al., 2001, Plant Cell

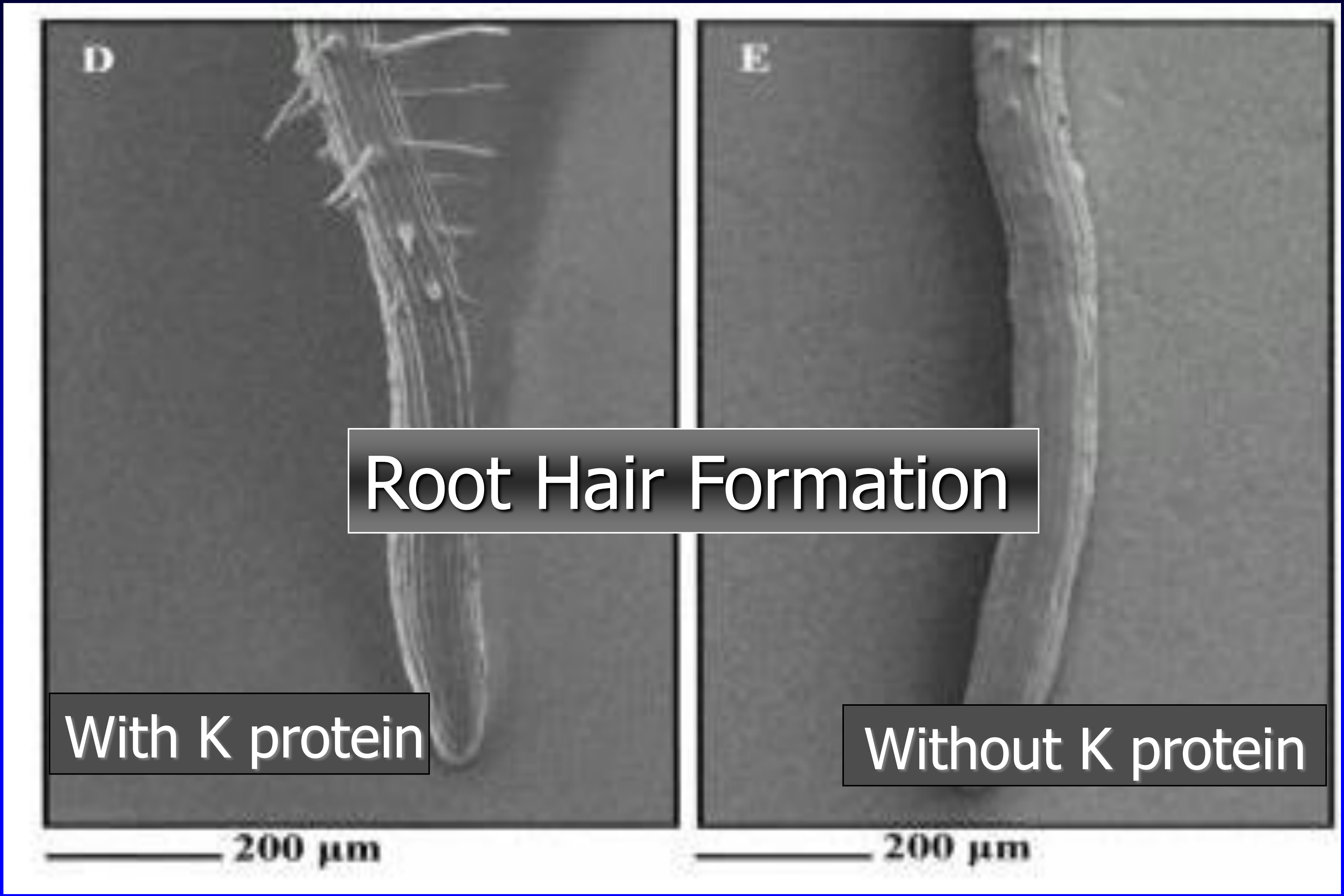
Auxin-stimulated cell elongation is also dependent on presence of potassium.

There is a strong correlation between expression of K-channel proteins and cell elongation following application of auxin

TRH1 encoding a potassium transporter protein: essential for root tip growth. As cell elongation is driven by turgor pressure, the operation of K translocators is crucial for growth.

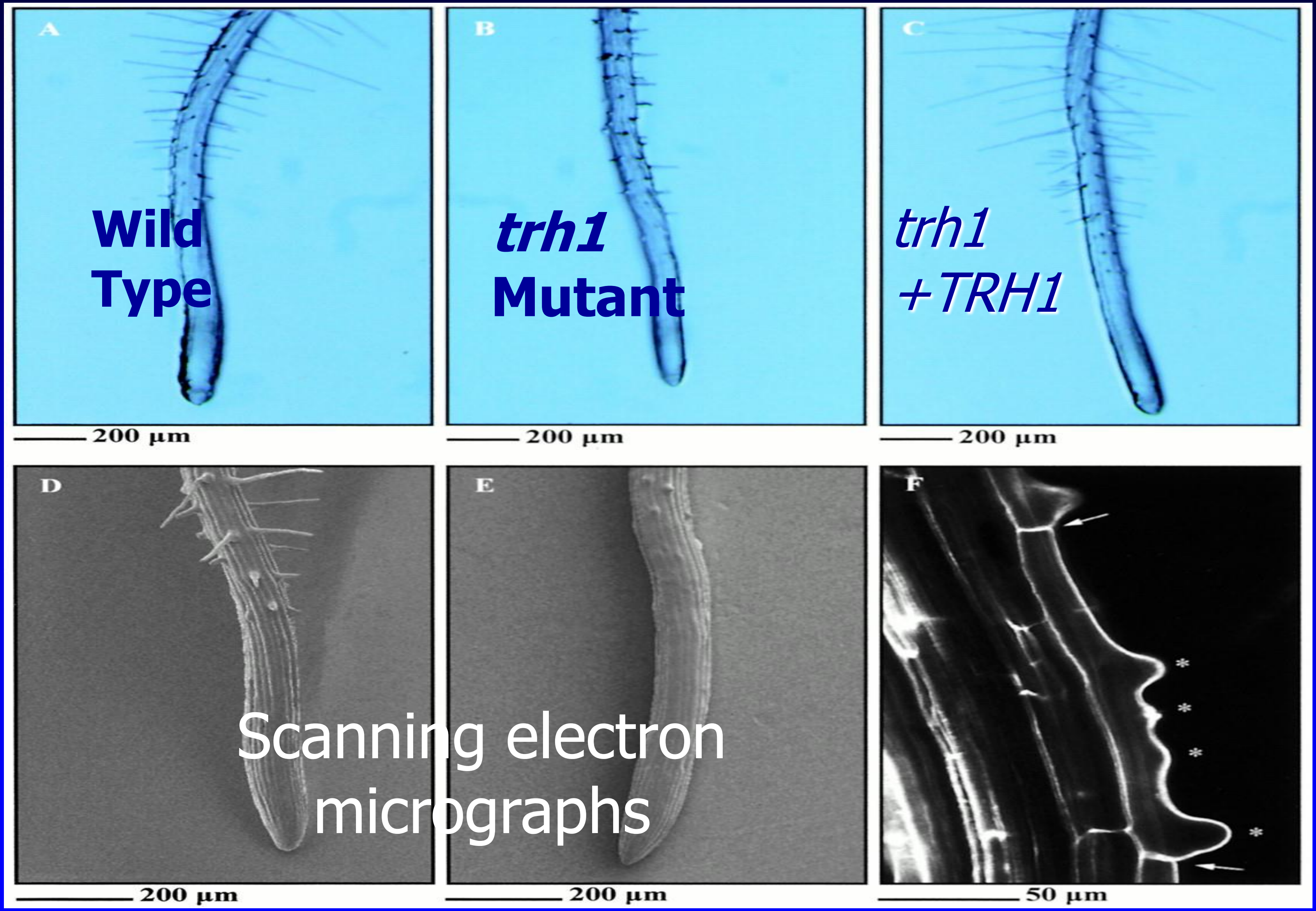
In the mutant lines without TRH1 protein root hair formation was totally blocked.

Root Hair Formation

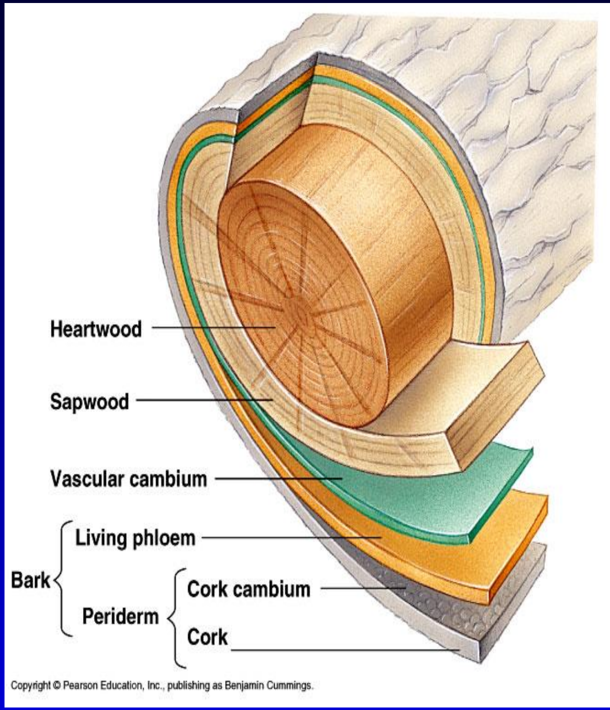


Rigas et al., 2001, Plant Cell, 13: 139-151

TRH mediating K transport essential for root hair formation



Rigas et al., 2001, Plant Cell, 13: 139-151



Potassium is a critical mineral nutrient in tree growth and wood formation.

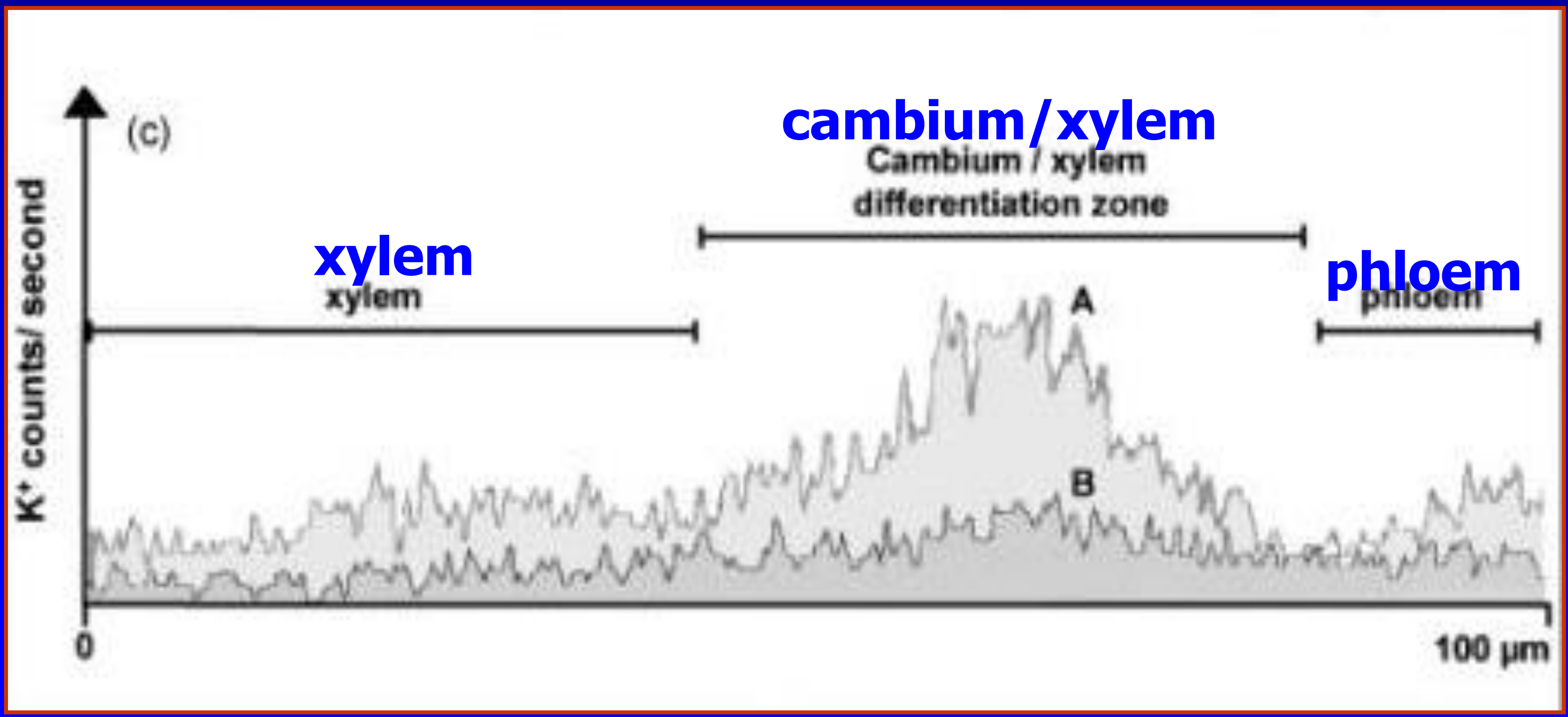
In cambial region and xylem differention zone a strong potassium demand has been shown.

Differentiating xylem cells involved in wood formation represent a strong sink for potassium that provides the driving force for cell expansion

Langer et al., 2002; Plant Journal, 32: 997-1009

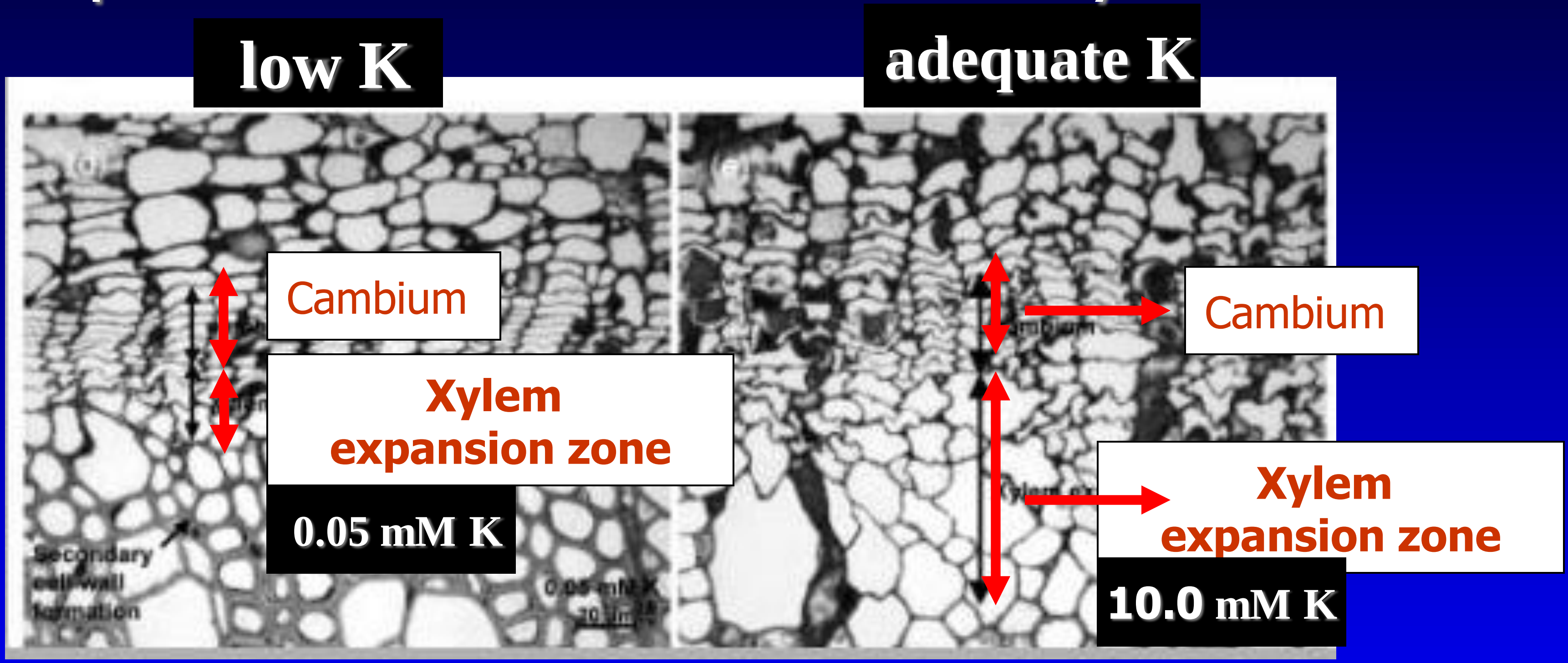
K nutritional status strongly affects development of wood producing cells

Potassium concentration in xylem tissue, cambium/xylem differention zone and phloem tissue



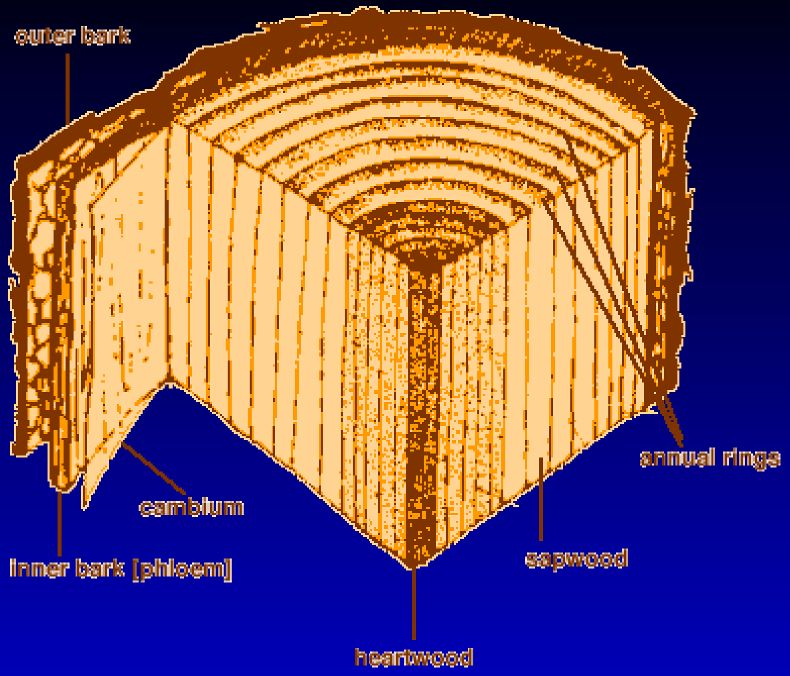
Langer et al., 2002; Plant Journal, 32: 997-1009

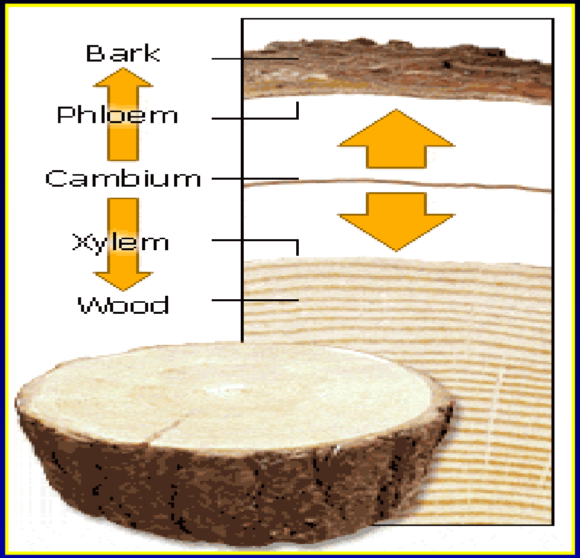
Under K deficiency cambial and cell-expansion zones lack 2-3 cell layers each



Langer et al., 2002; Plant Journal, 32: 997-1009

Lack of cell divisions in the vessel development region results in reduced wood production





The cambium cells divide and make new <u>wood</u> on the inside and new <u>inner bark</u> on the outside. In this way, a tree gets bigger around as it grows!

Potassium is highly needed for wood production.

Potassium is driving force for expansion of wood producing cells

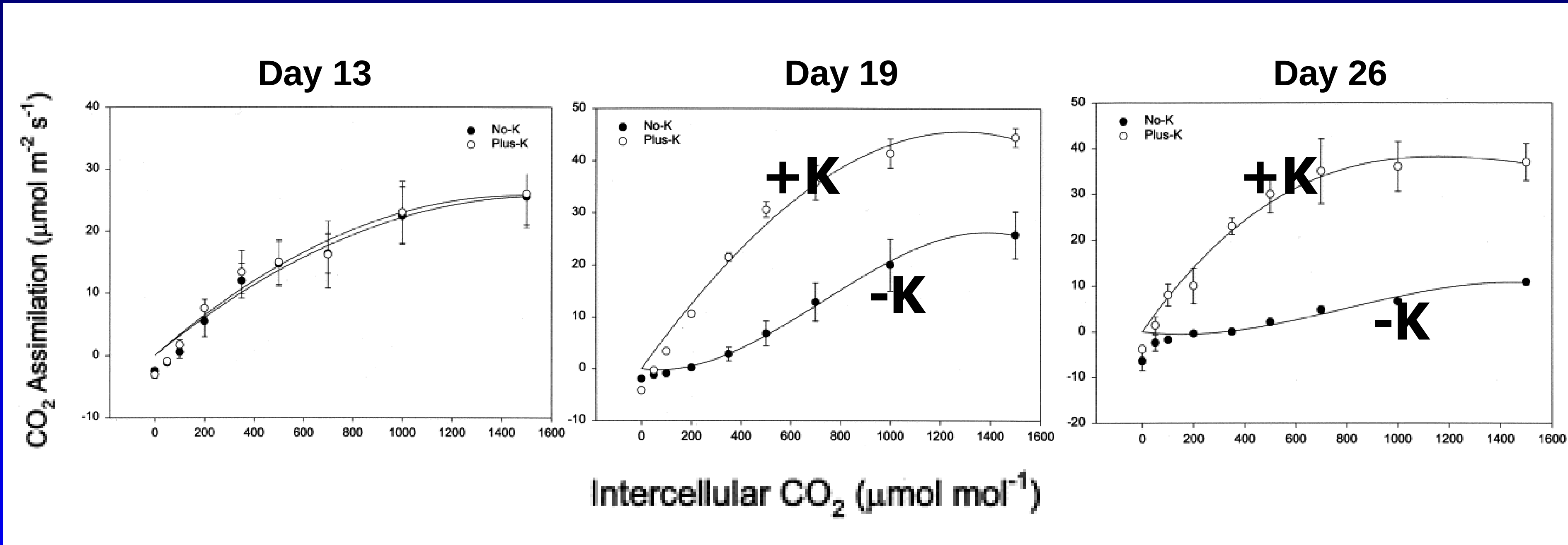
Photosynthesis and Potassium

In K-deficient leaves photosynthesis is impaired at different levels

- stomatal CO_2 flux into chloroplasts
- conversion of light energy into chemical energy
- rubisco activity/CO_2 reduction
- phloem export of photosynthates and,
- detoxification of toxic O_2 species

Photosynthesis and Potassium

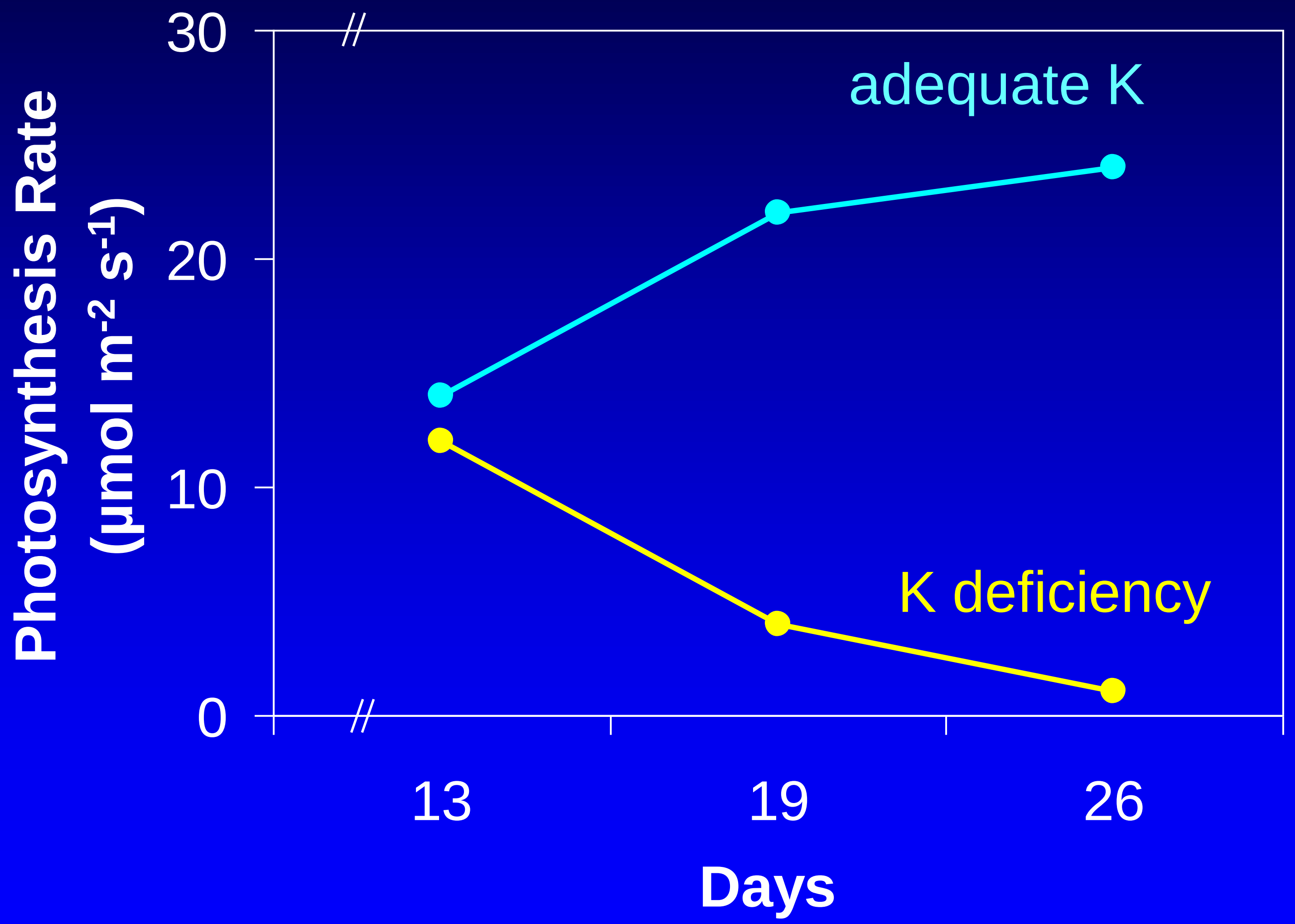
During a mild K deficiency in cotton, increased stomatal resistance is first to result in a decrease in net photosynthesis and, as the deficiency becomes more acute, biochemical factors contribute.



Severity of K deficiency

Bednarz, et al. 1998, Environ. Exp. Bot. 39: 131-139

Effect of Varied K Supply on Photosynthesis in Cotton

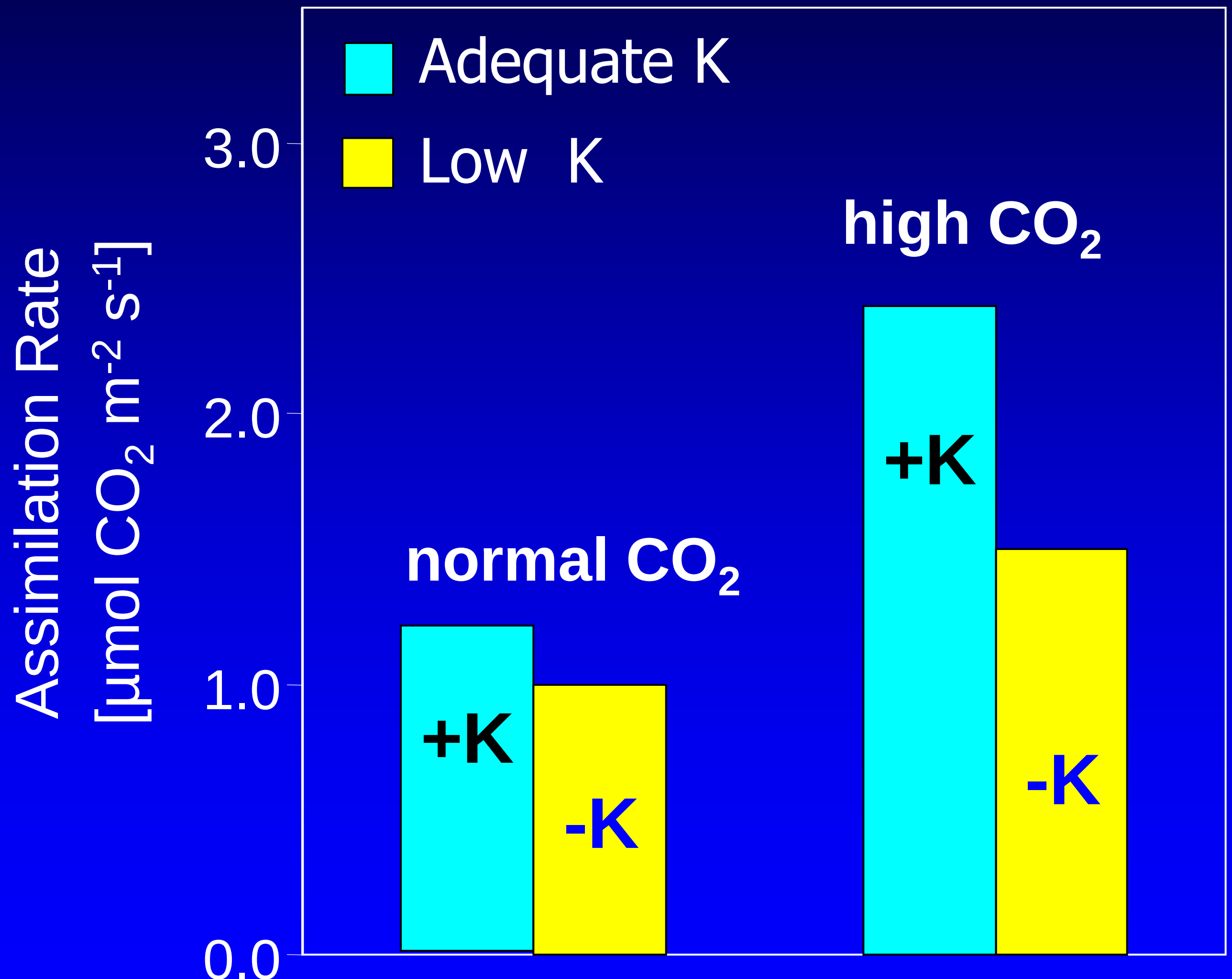


Bednarz and Oosterhuis, 1999 ; J. Plant Nutr.

Decrease in photosynthesis with K deficiency becomes more distinct when plants are exposed to elevated CO_2 concentrations

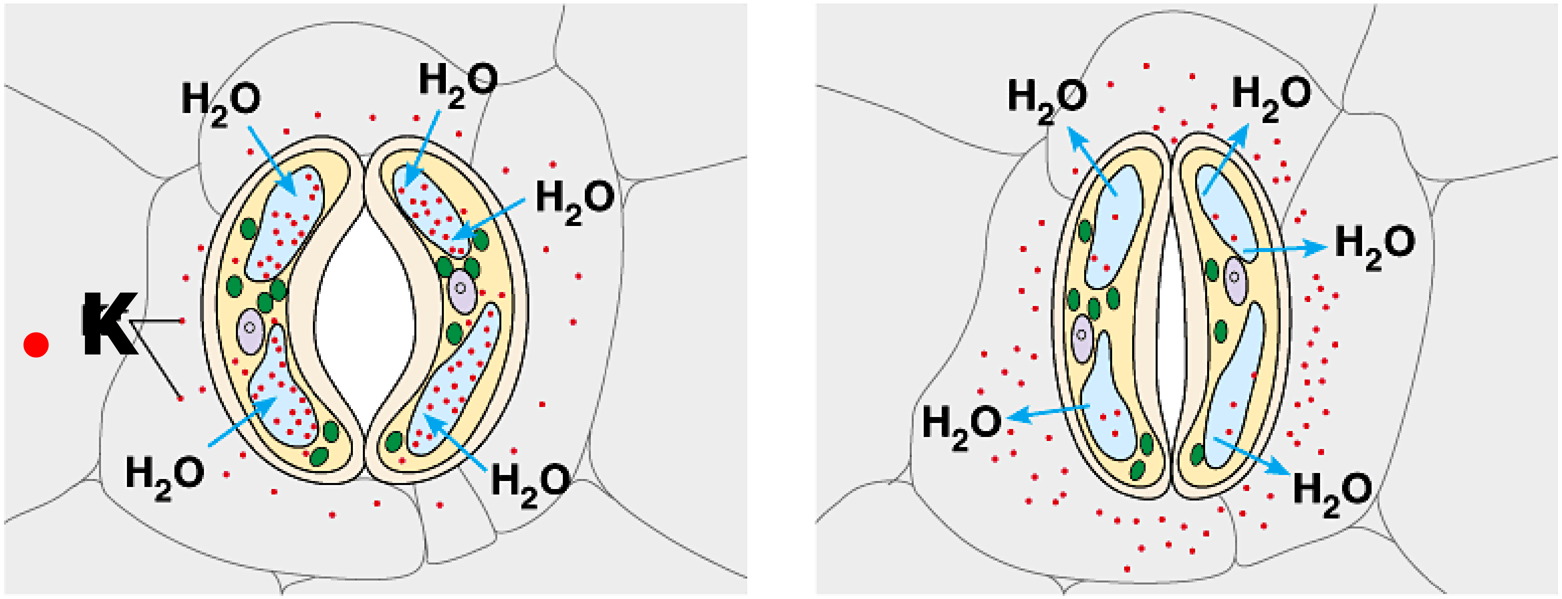
Enhanced K requirement of plants when exposed to increasing CO_2 concentration in atmosphere

Effect of Elevated CO_2 on Photosynthesis at Varied K Supply



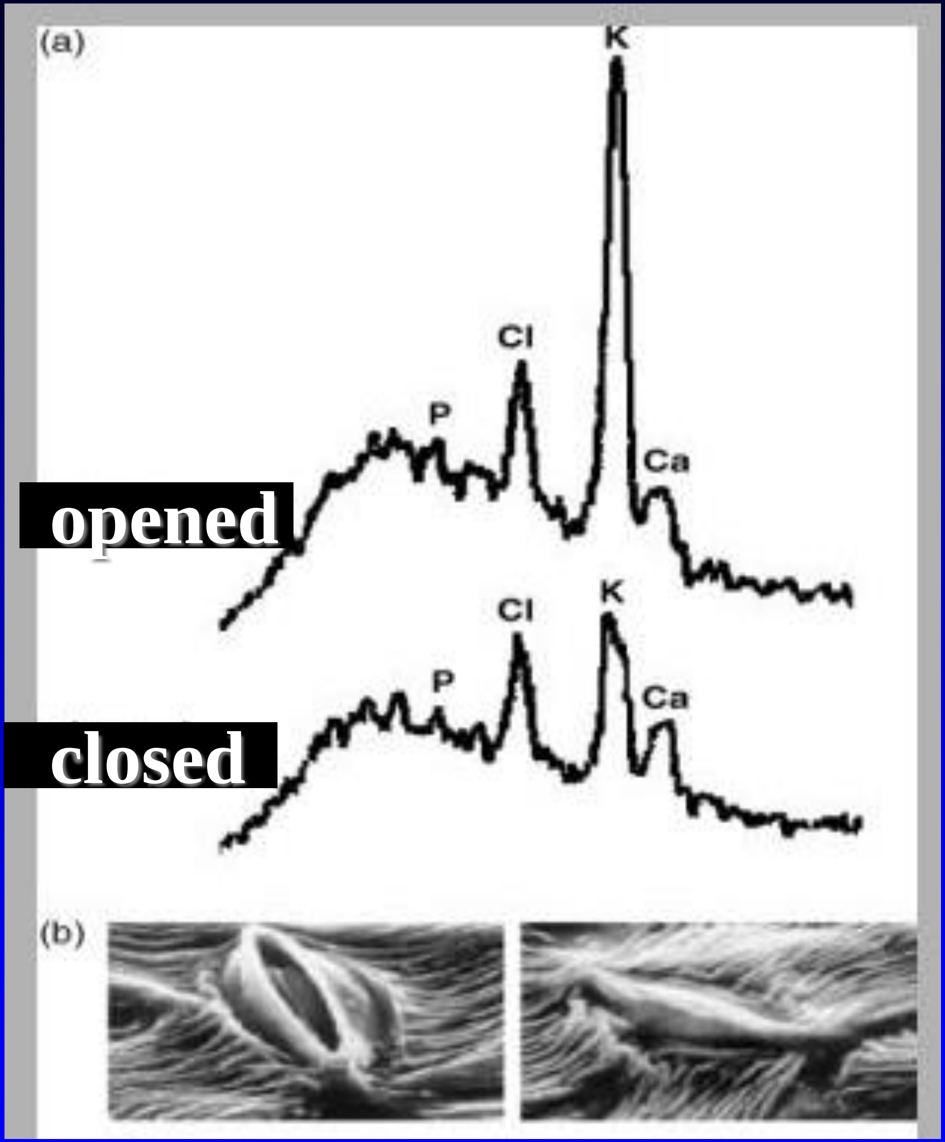
Barnes et al., 1995, Plant Cell Environ.

Stomata regulating transpiration and CO_2 uptake



(b) Role of potassium in stomatal opening and closing

The transport of K^+ across the plasma membrane and tonoplast causes the turgor changes of guard cells. Stomata open when guard cells accumulate potassium (red dots), which lowers the cells' water potential and causes them to take up water by osmosis. The cells become turgid.



Langer et al., 2004; Plant Journal, 37: 828-838

Role potassium in stomatal action

When stomata opened, the K content of guard cells increased by factor 2, indicating a very rapid stomatal opening by K uptake

PHLOEM TRANSPORT

K plays a critical role in phloem transport

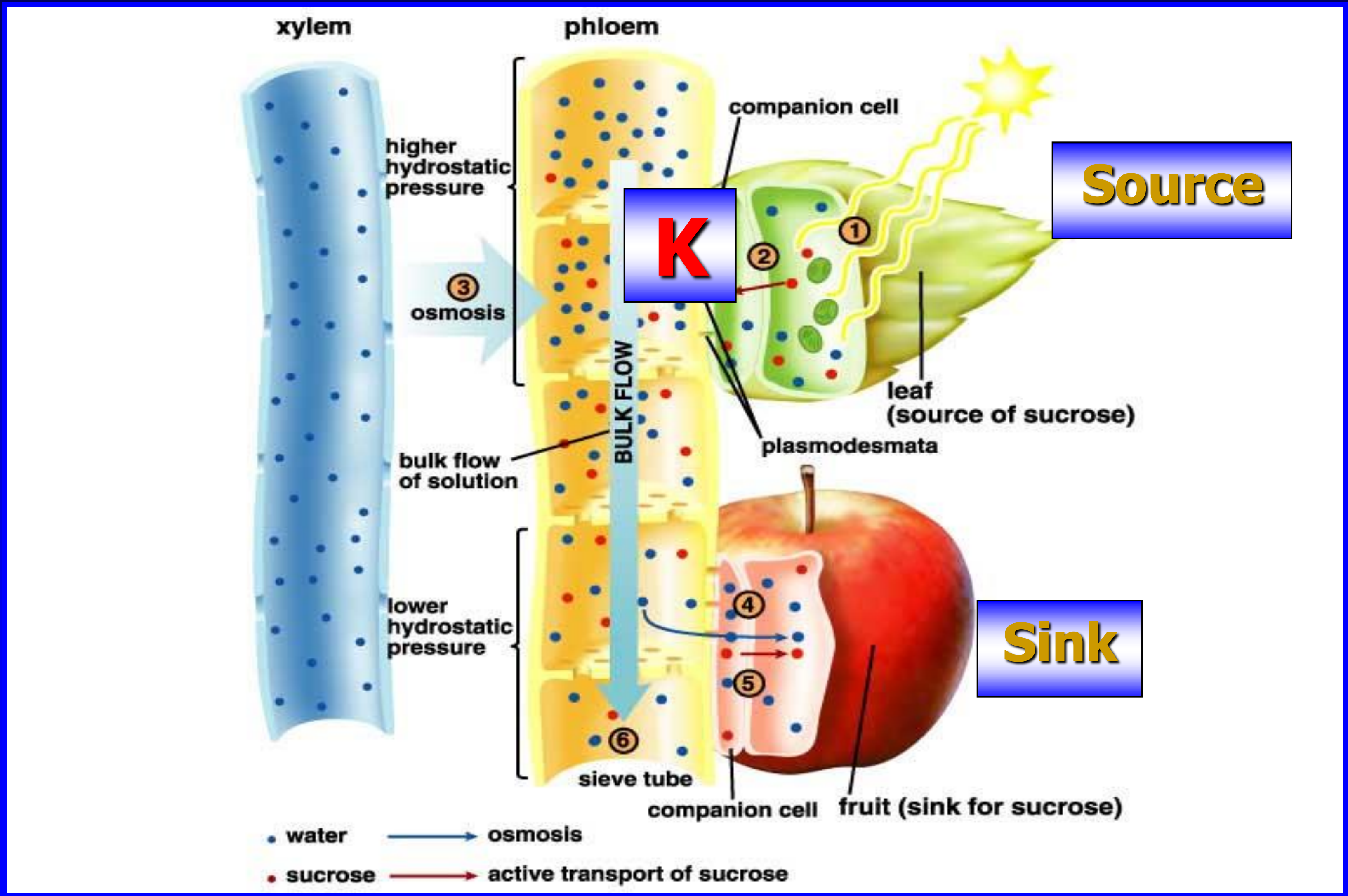
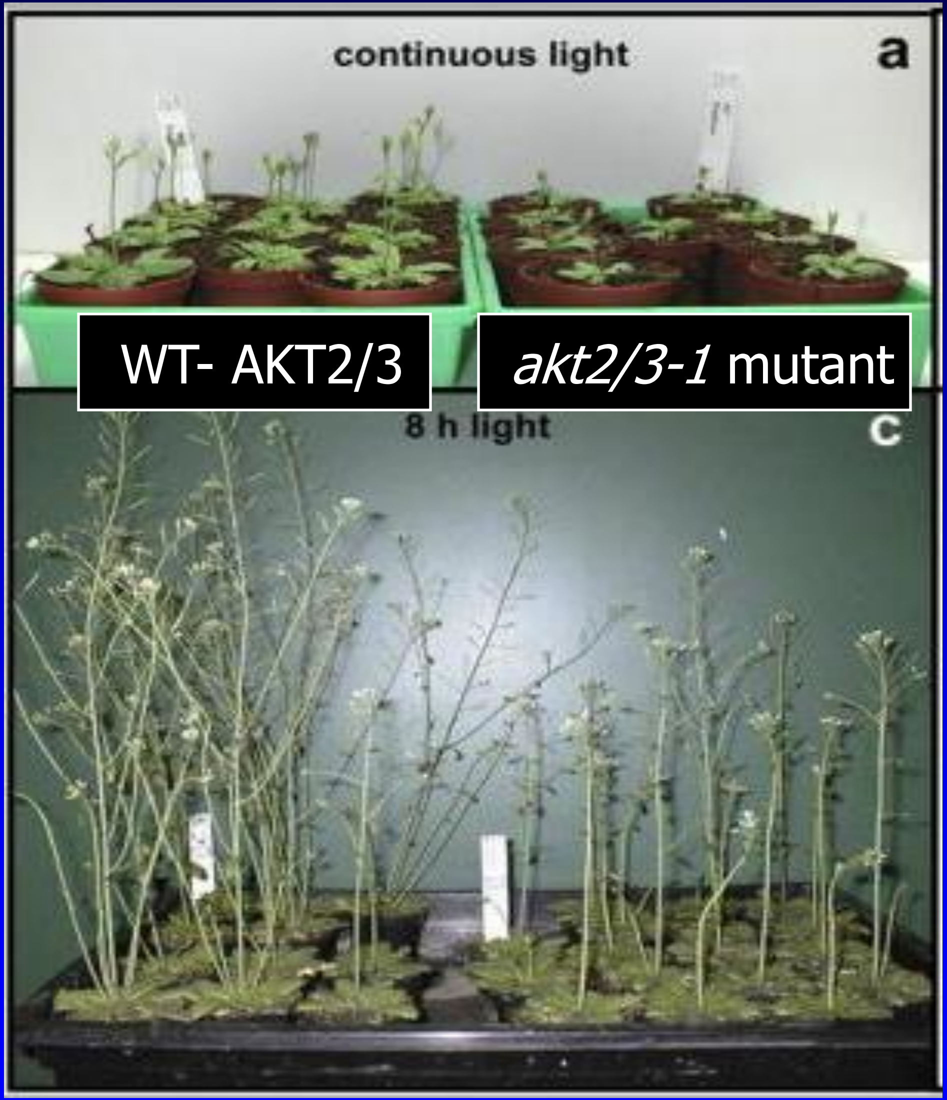


TABLE 10.2
The composition of phloem sap from castor bean (*Ricinus communis*), collected as an exudate from cuts in the phloem

Component	Concentration (mg mL^{-1})
Sugars	80.0–106.0
Amino acids	5.2
Organic acids	2.0–3.2
Protein	1.45–2.20
Potassium	2.3–4.4
Chloride	0.355–0.675
Phosphate	0.350–0.550
Magnesium	0.109–0.122

Source: Hall and Baker 1972.

Potassium is essential for transport of photosynthates into growing organs

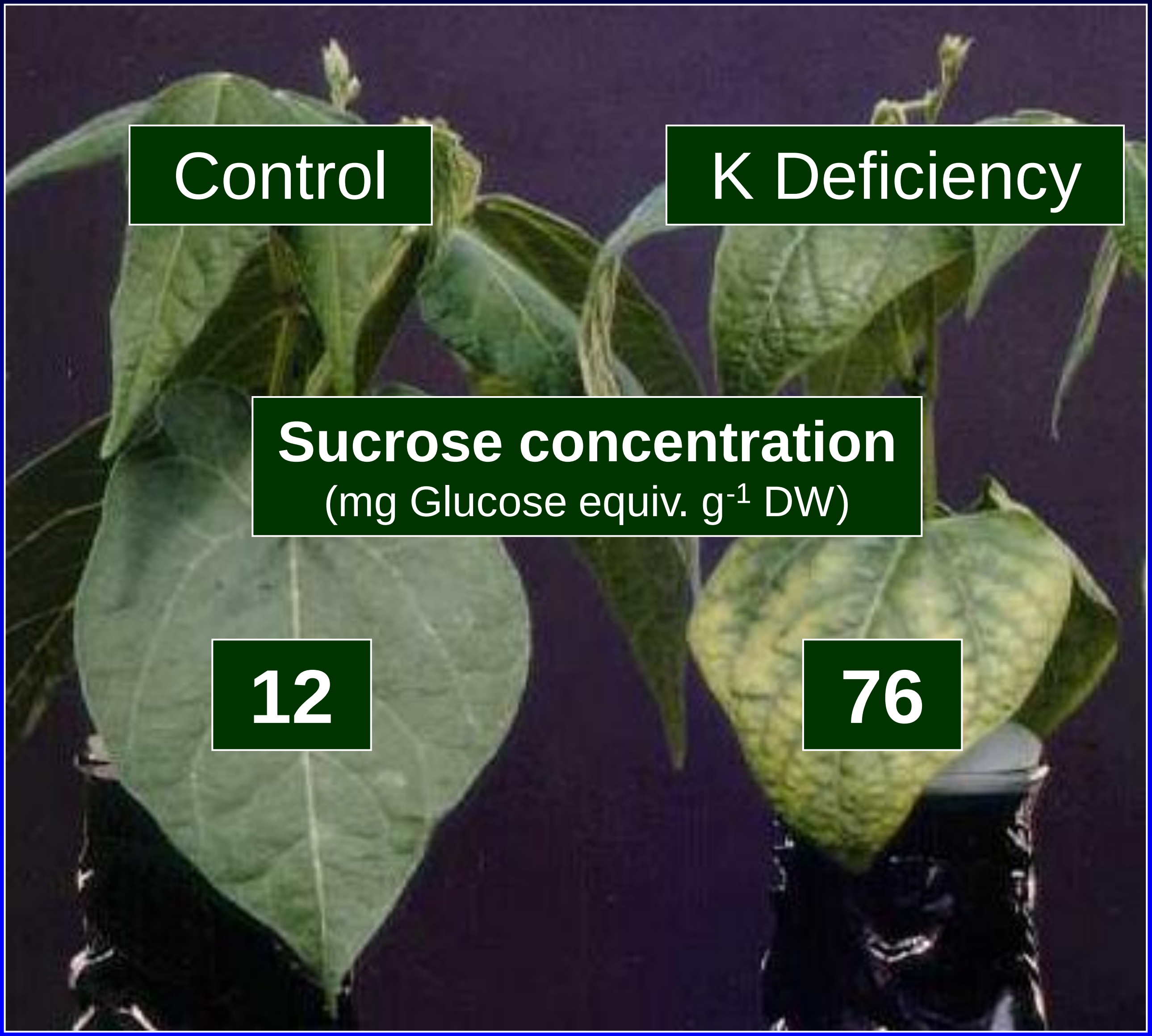


AKT2/3: a potassium channel protein and identified as photosynthate-induced phloem K channel.

Flower induction and rosette development of the *Arabidopsis* with loss of AKT2/3 function (*akt2/3-1* mutant) is delayed

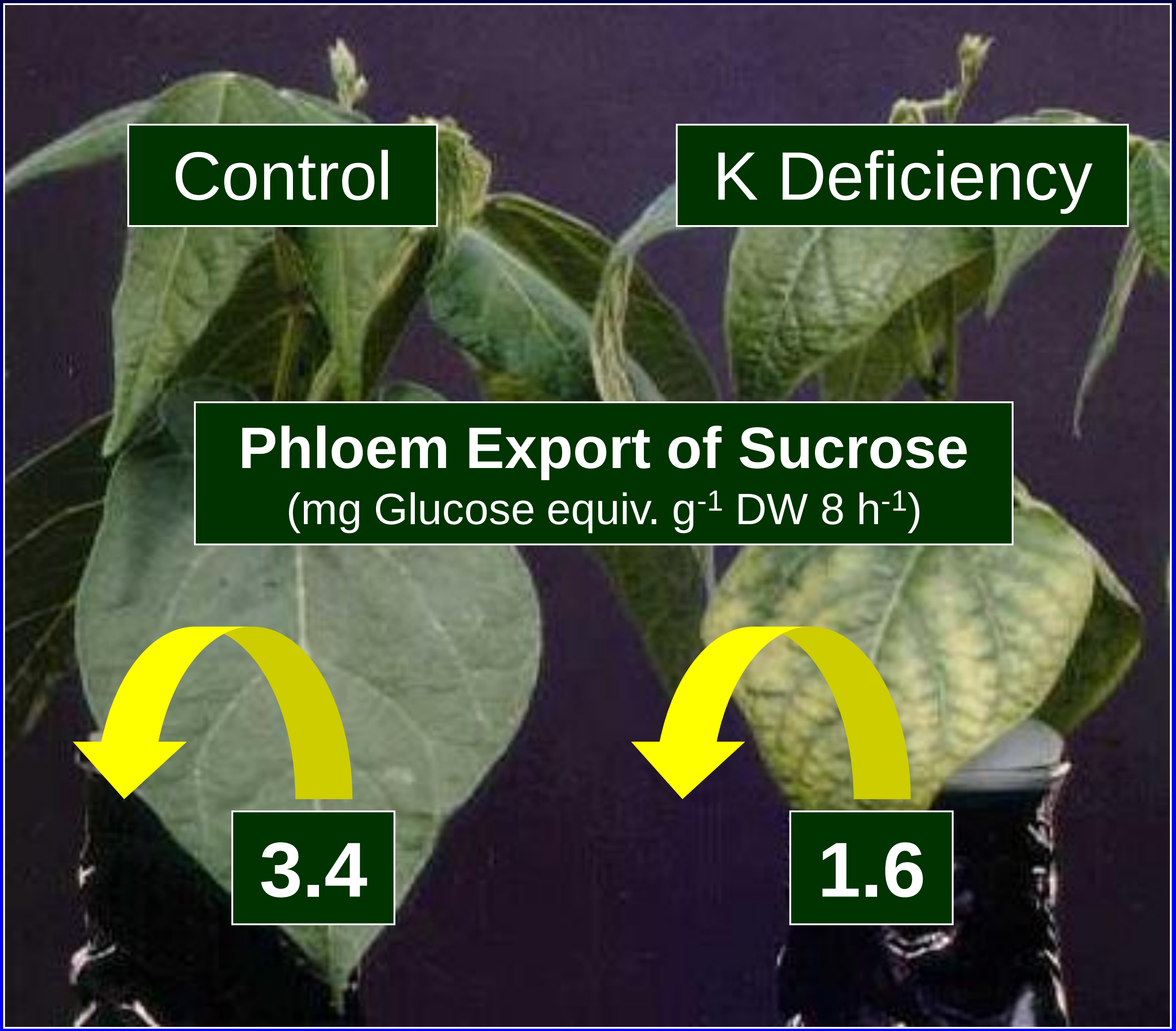
Deeken et al., 2002, Planta, 216: 334-344

Accumulation of Phosynthates in K-Deficient Source Leaves



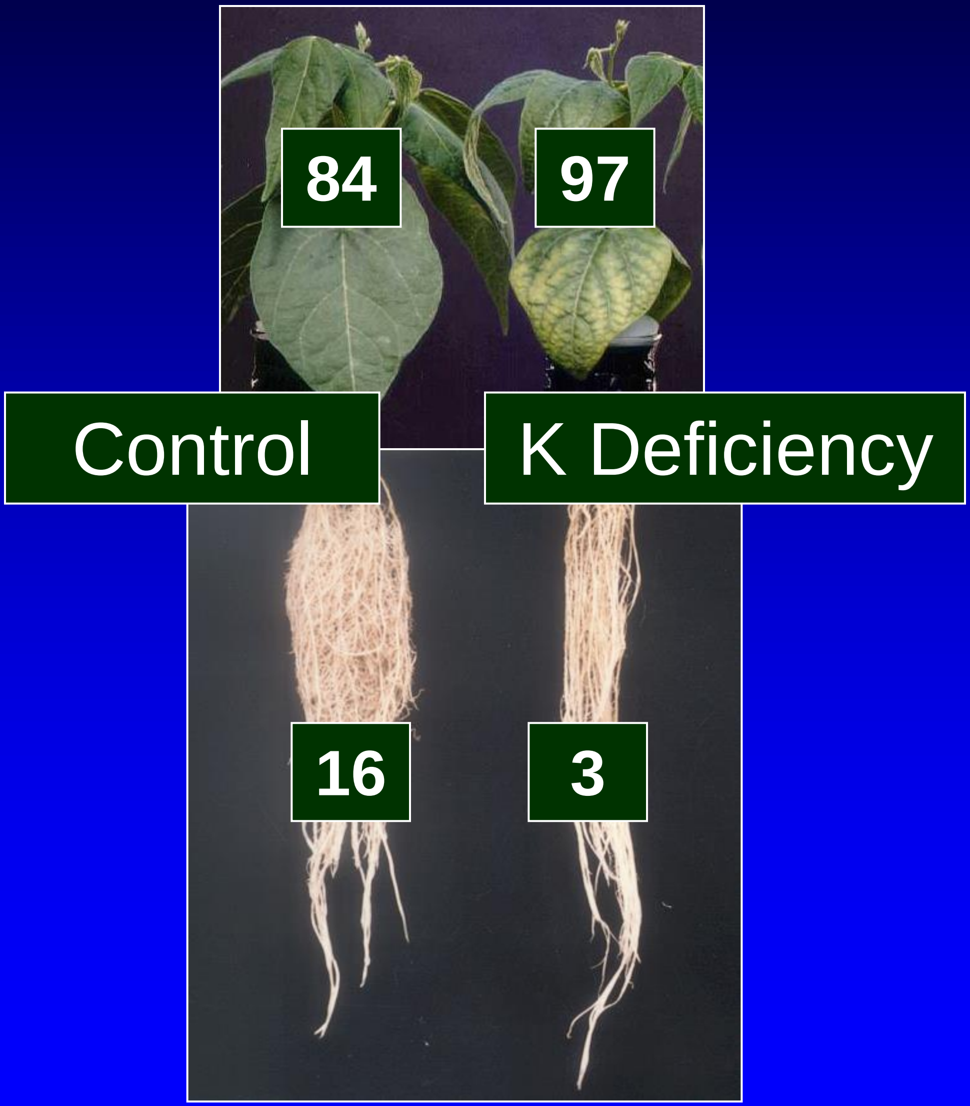
Cakmak et al., 1994b, J. Experimental Bot.

Decrease in Phloem Export of Sucrose by K-Deficiency



Cakmak et al., 1994b, J. Experimental Bot.

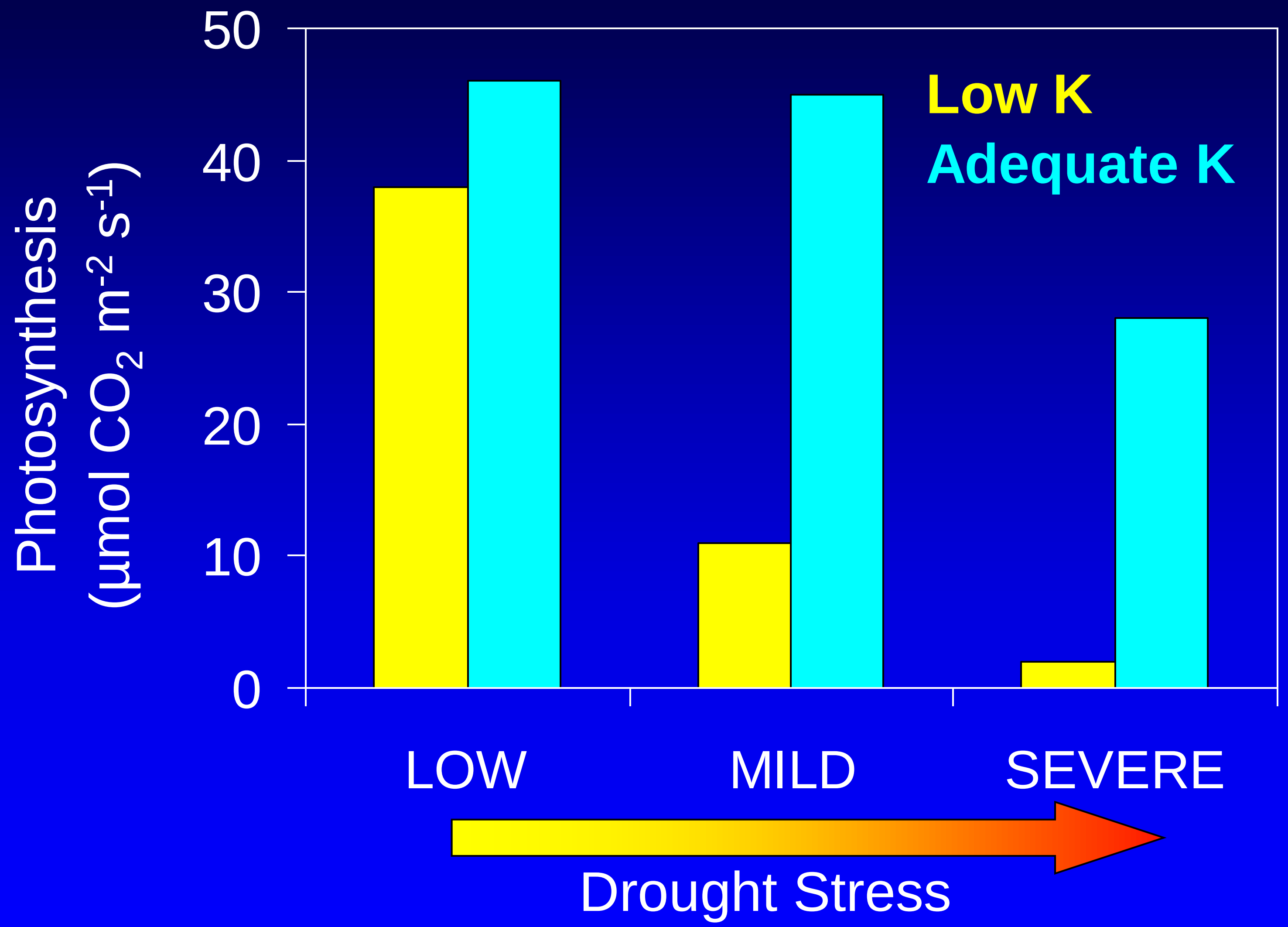
Relative distribution of total carbohydrates between shoot and roots (%)



Cakmak et al., 1994a, J. Experimental Bot.

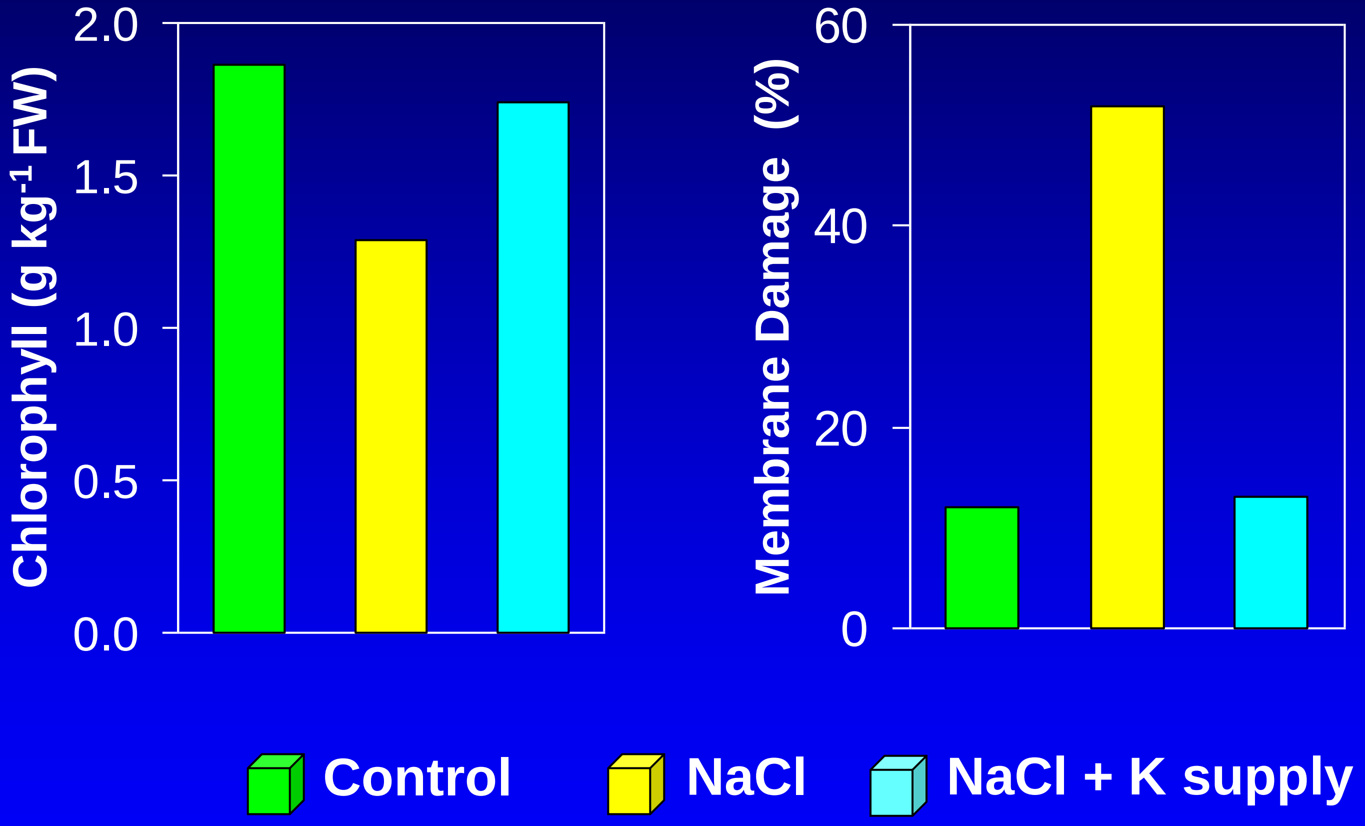
Plants suffering from environmental stress factors such as drought, high light intensity and salinity have larger requirement for potassium

Potassium Improved Photosynthesis Under Drought Stress



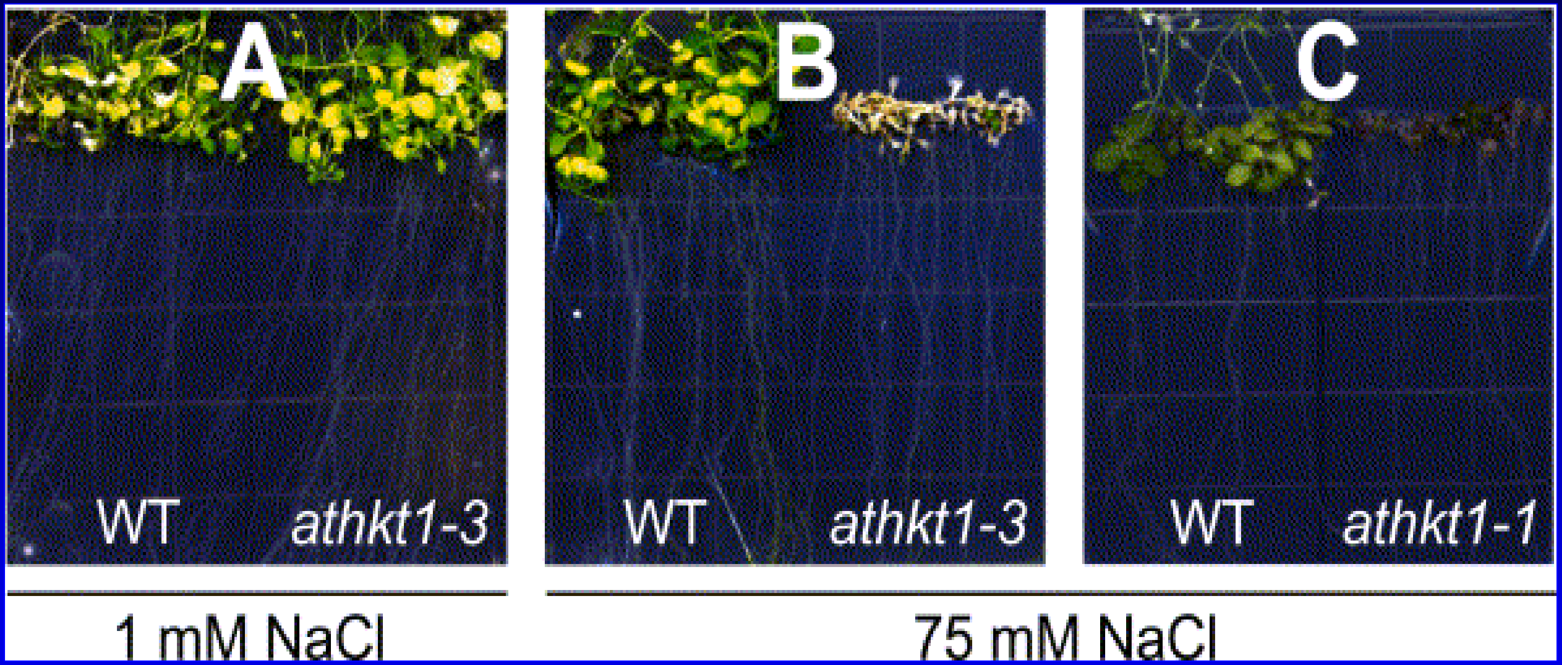
Sen Gupta et al., 1988, Plant Physiol.

Alleviation of Salt Stress by K Supply



Kaya et al., 2001, J. Plant Nutr.

Increased salt sensitivity in the absence of K transporter protein.



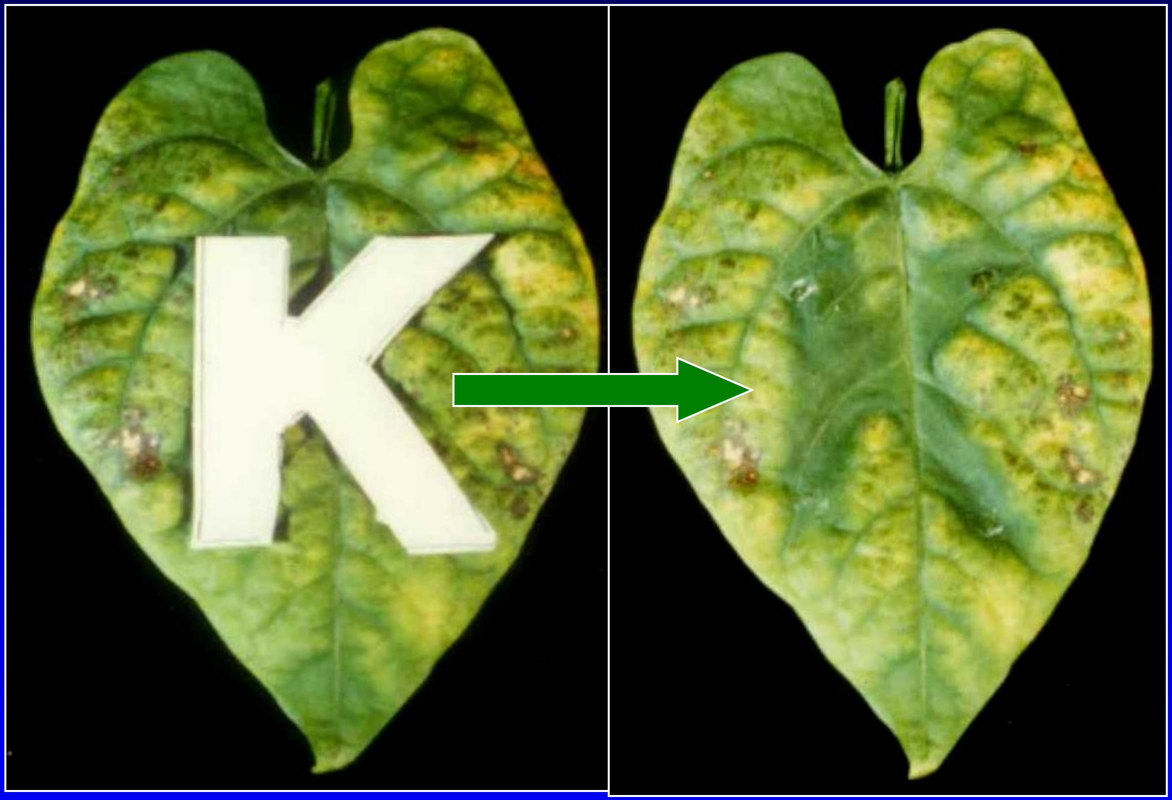
AtHKT1 controls root/shoot Na^+ distribution and counteracts salt stress in leaves by reducing leaf Na^+ accumulation.

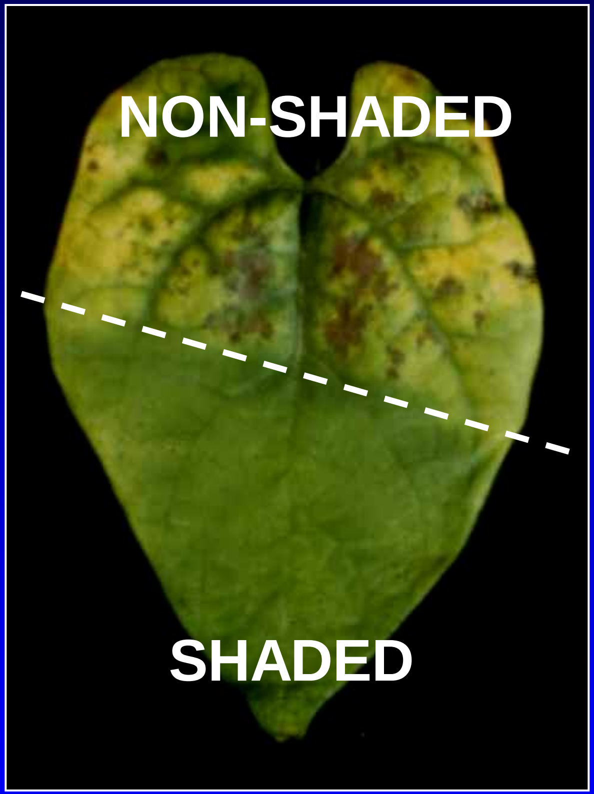
Maser et al., 2002; FEBS Letters;531: 157-161

Growth of bean plants with low K supply under low and high light intensity

Plants grown under high light intensity require more K than plants grown under low light

Enhancement of leaf symptoms of K-deficieny by high light

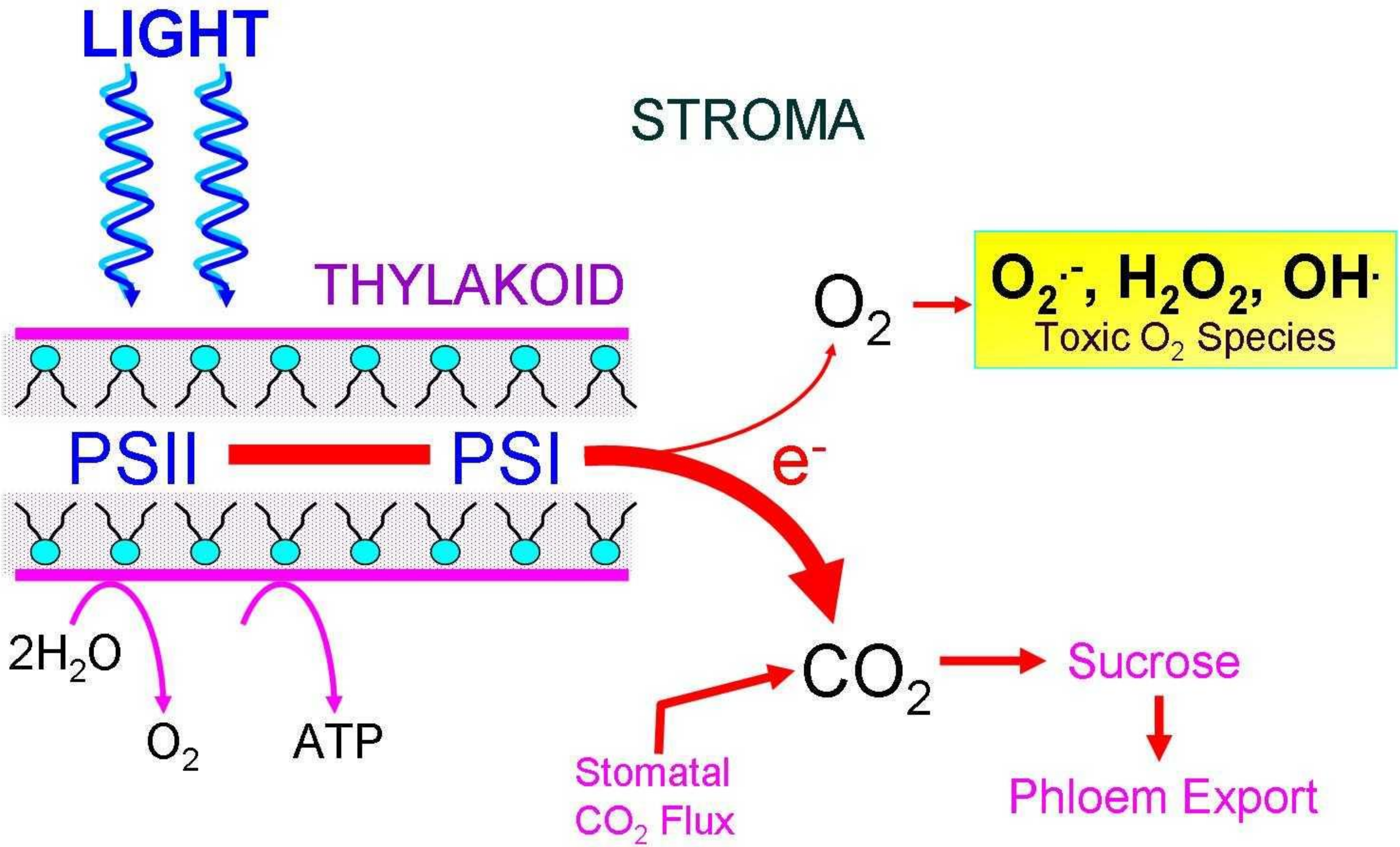




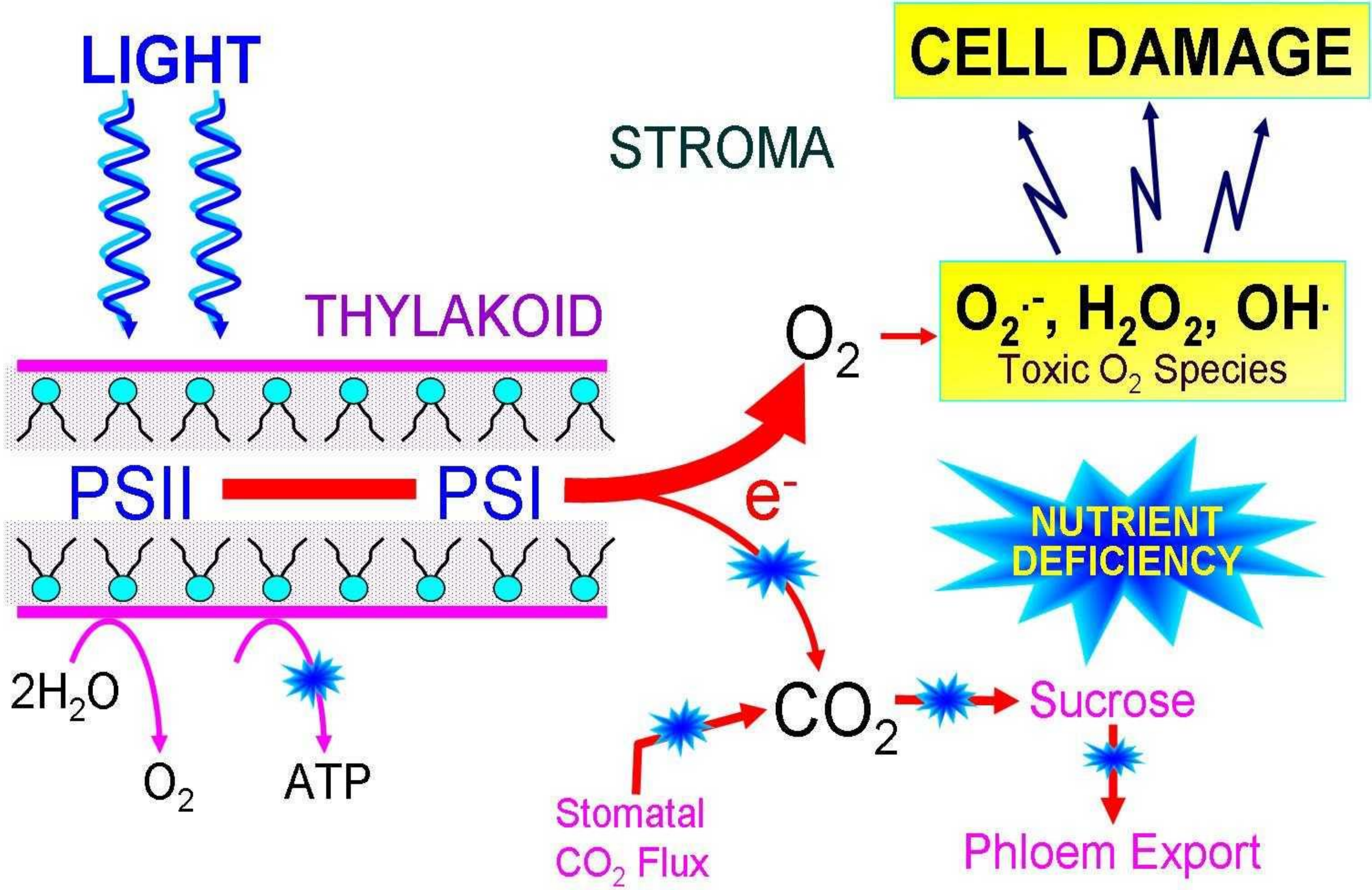
Partially shaded K-deficient bean leaves

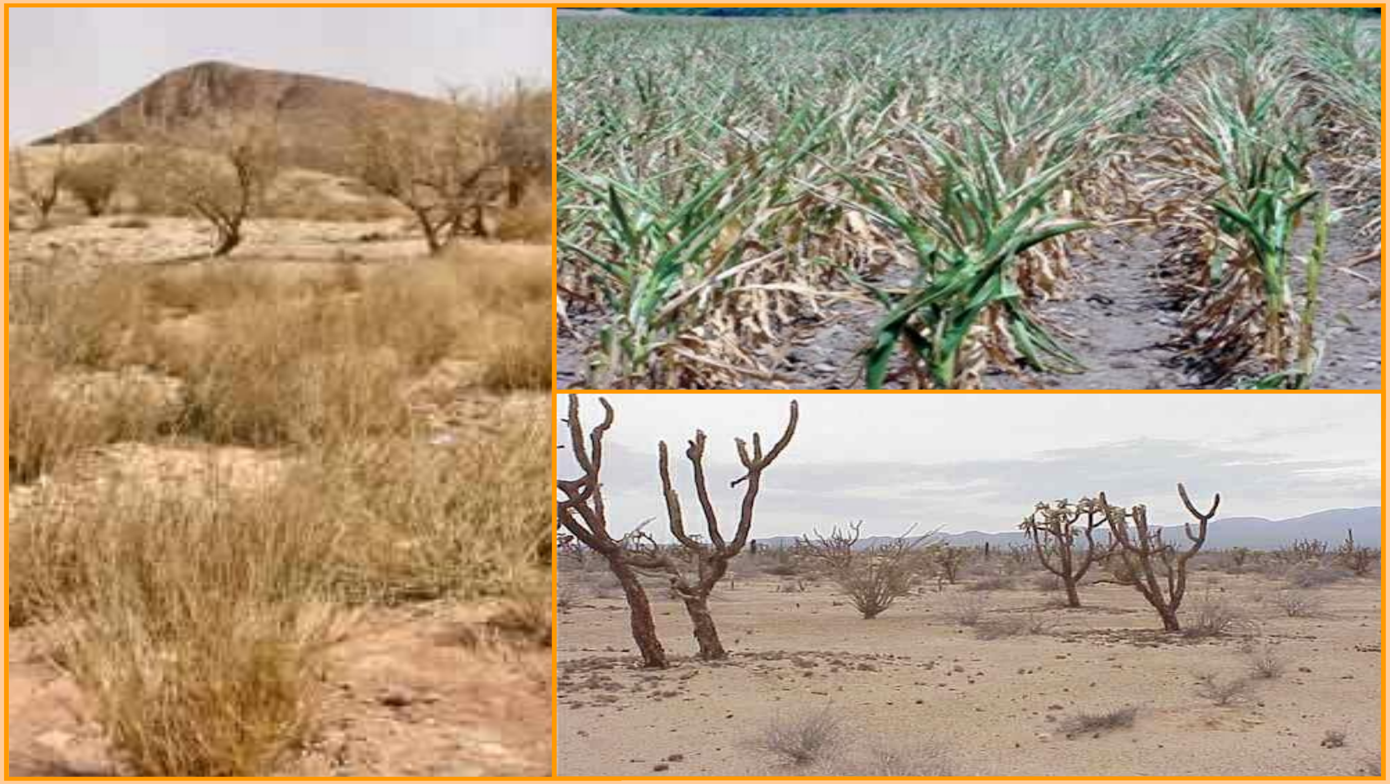
REMEMBER:

Photosynthetic Electron Transport and Superoxide Radical Generation



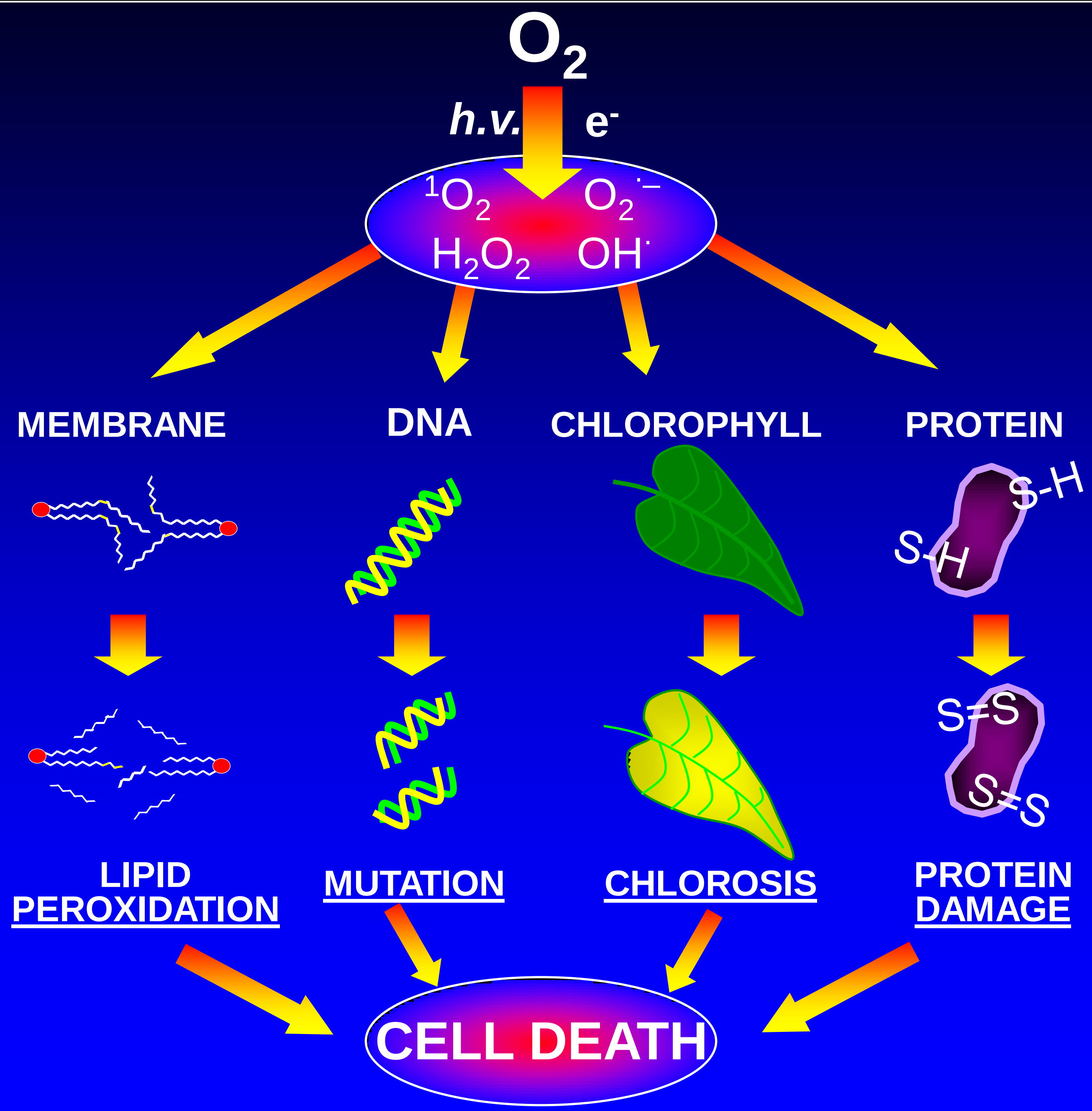
Photosynthetic Electron Transport and Superoxide Radical Generation





- Potassium deficiency makes plants sensitive to environmental stress factors.
- Plants under environmental stress factors need additional potassium

FREE RADICAL DAMAGE TO CRITICAL CELL CONSTITUENTS



Conclusions

- Potassium has several critical roles in plant growth and yield formation including cell elongation, maintenance of turgor pressure and photosynthesis, stomatal closure, protein synthesis and photoassimilate transport.

- Potassium transporter proteins play critical role in K uptake and translocation (contributing to cell elongation) and tolerance to Na toxicity

- Plants exposed to high light intensity or grown under long-term sunlight conditions like in southern countries in Northern Hemisphere have much larger K requirement

- Improving K nutritional status of plants is a major contributing factor to the protection of plants from environmental stress factors under marginal conditions

Remark: During the late growth stage (generative phase) plants can need higher amount of potassium because at this stage

- high amount of K is required for translocation of carbohydrates
- plants can be exposed to more light and
- topsoil with high root density and high K concentration can be dry (limited K uptake !)

High need for late K application to foliar !!

Obrigado...