Institute of Applied Plant Nutrition
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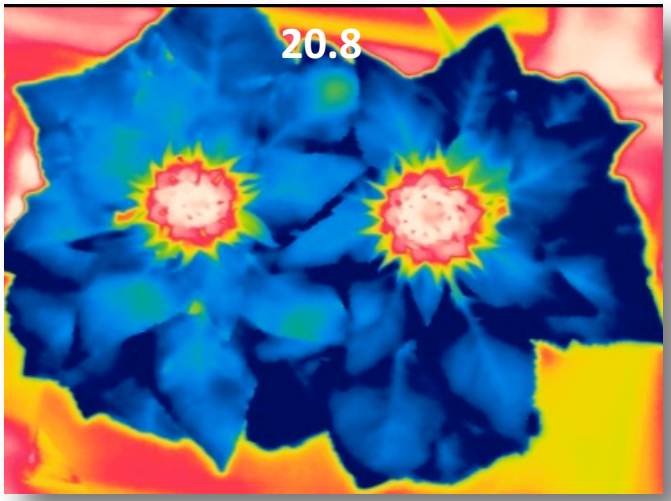
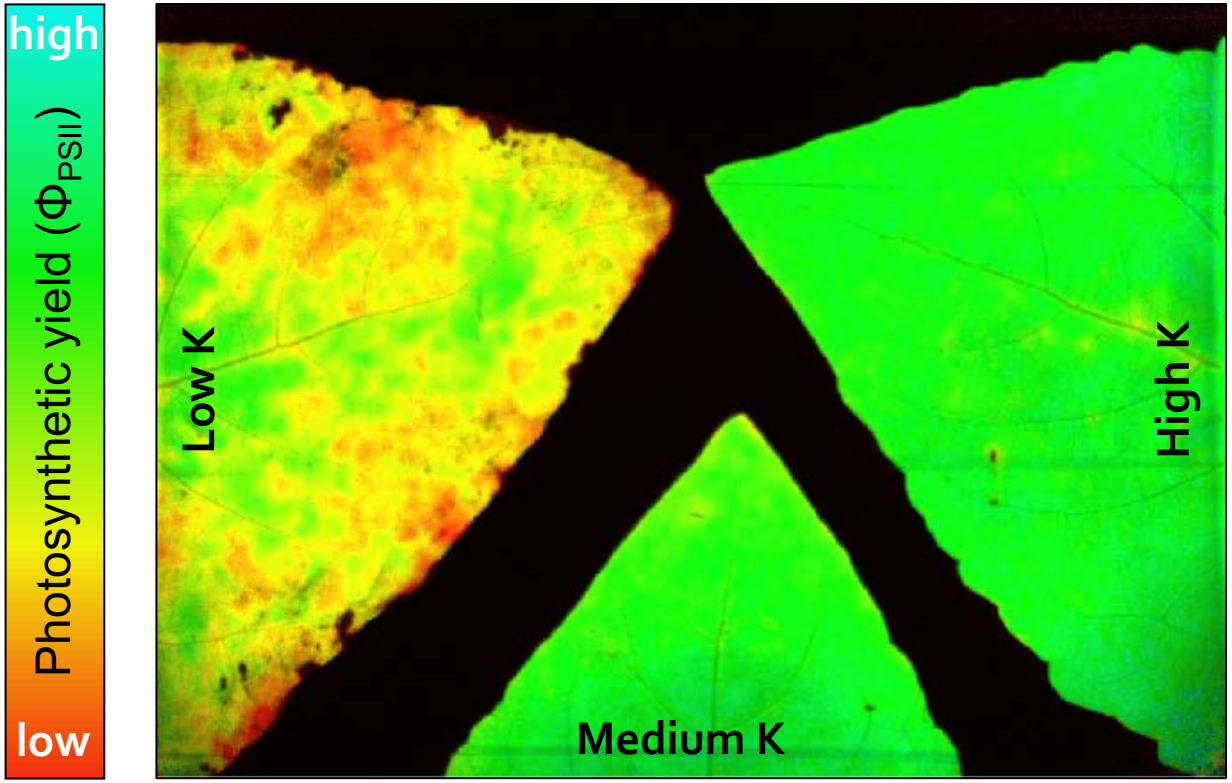
Restricted CO2 diffusion through the leaf mesophyll and not stomatal regulation limits photosynthesis in K deficient crop plants

Bálint Jákli



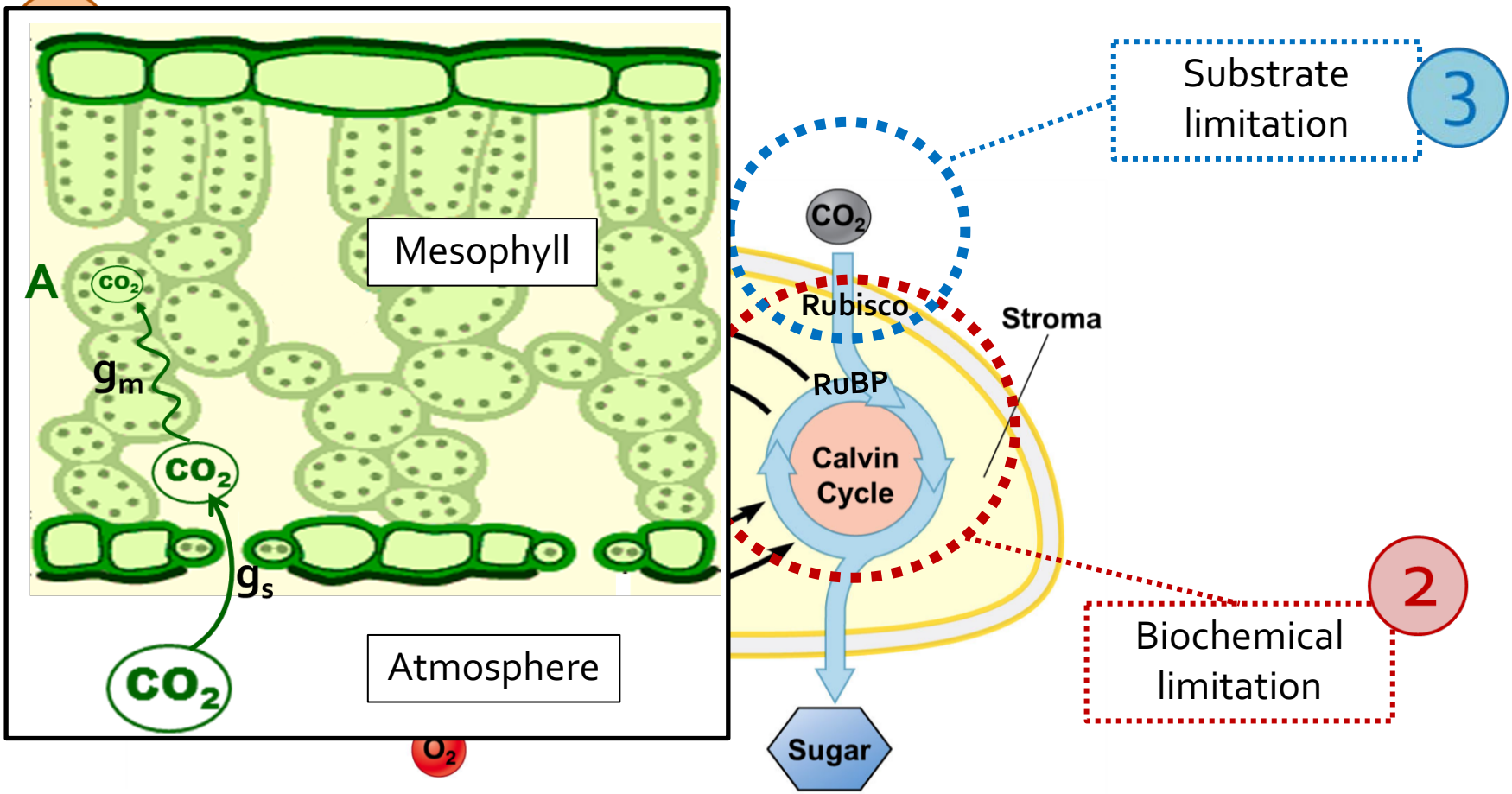
Potassium nutrition affects plant growth

Photosynthesis is reduced in K deficient plants



False color image of leaves of sunflower, 17 days after K concentration was reduced in nutrient solutions, JÀKLI et al., J. Plant Phys., 2017

Which physiological processes can limit photosynthesis?



Which of the three major limitations dominate under K deficiency?

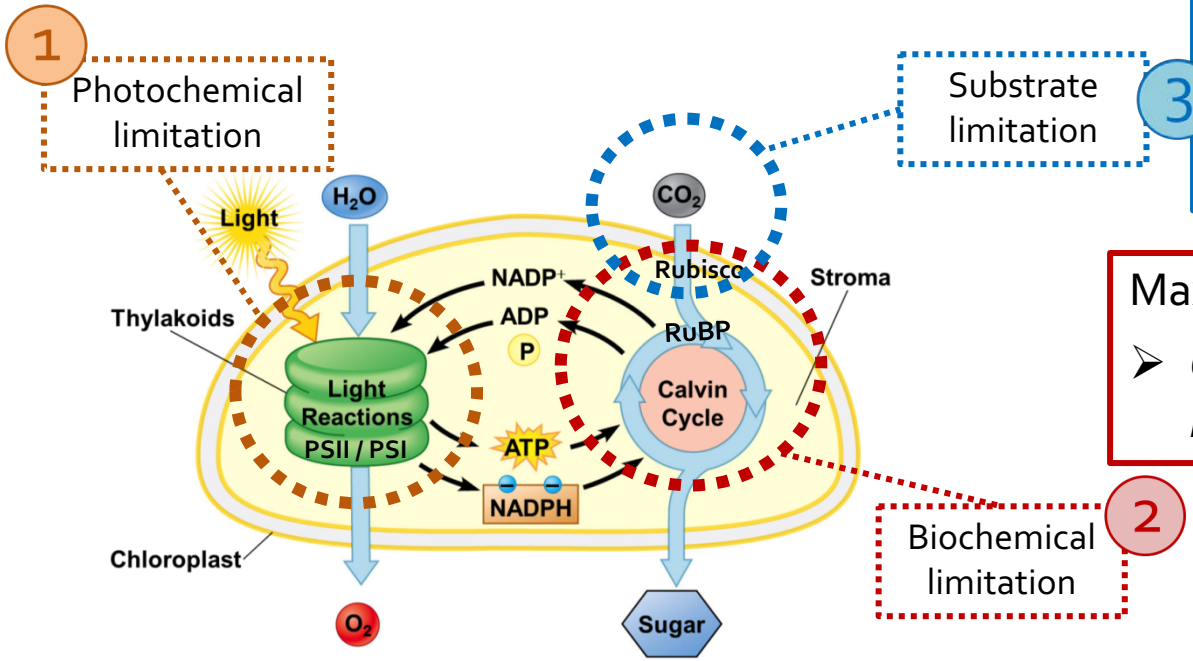
Experimental setup

Maximum photochemical efficiency (F_v/F_m)

- *PSII chlorophyll fluorescence imaging*

Limitations to CO2 diffusion:

- Stomatal conductance g_s
- Mesophyll conductance g_m
- *Combined leaf gas exchange and PSII chlorophyll fluorescence*



Maximum Rubisco activity $V_{c,max}$:

- *Combined leaf gas exchange and PSII chlorophyll fluorescence*

Which of the three major limitations dominate under K deficiency?

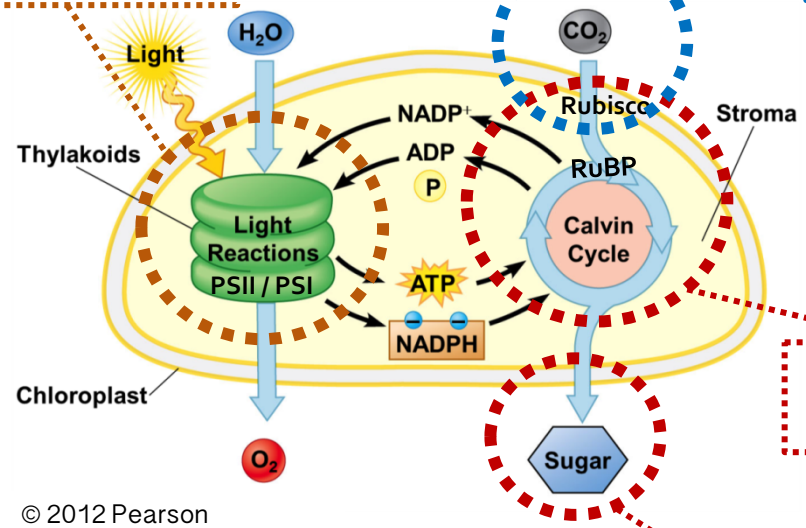
Experimental setup

Maximum photochemical efficiency (Fv/Fm)

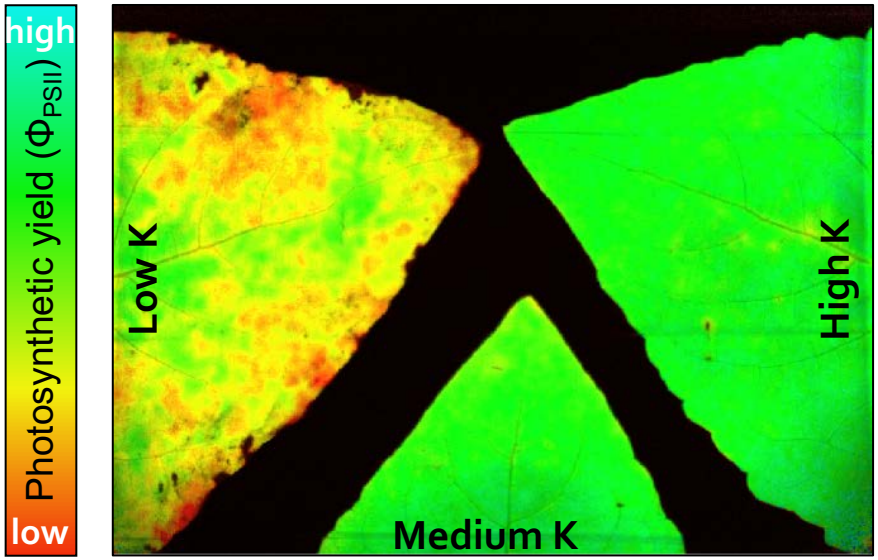
- *PSII chlorophyll fluorescence imaging*

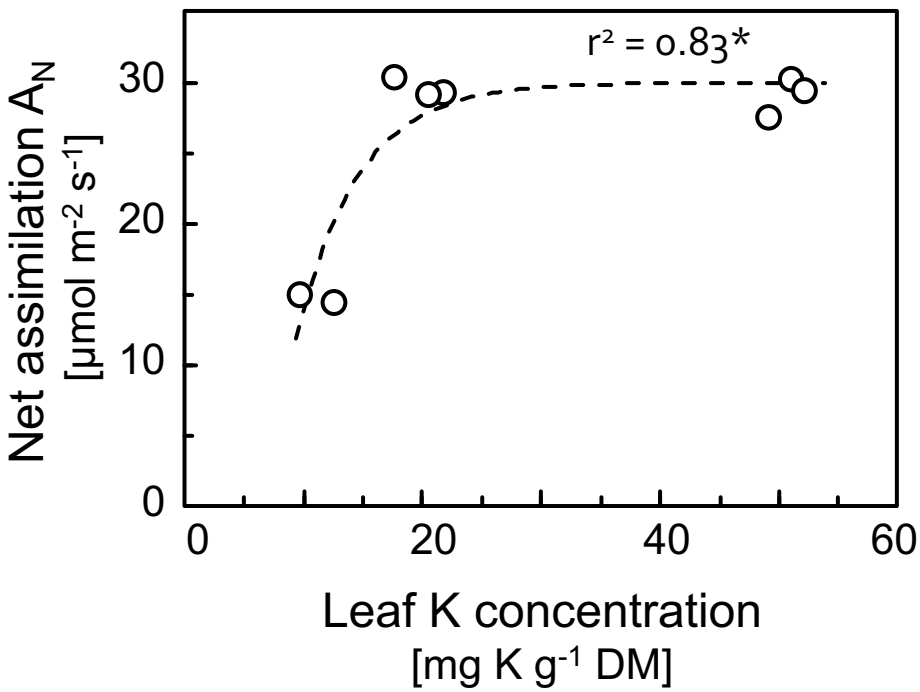
1

Photochemical limitation



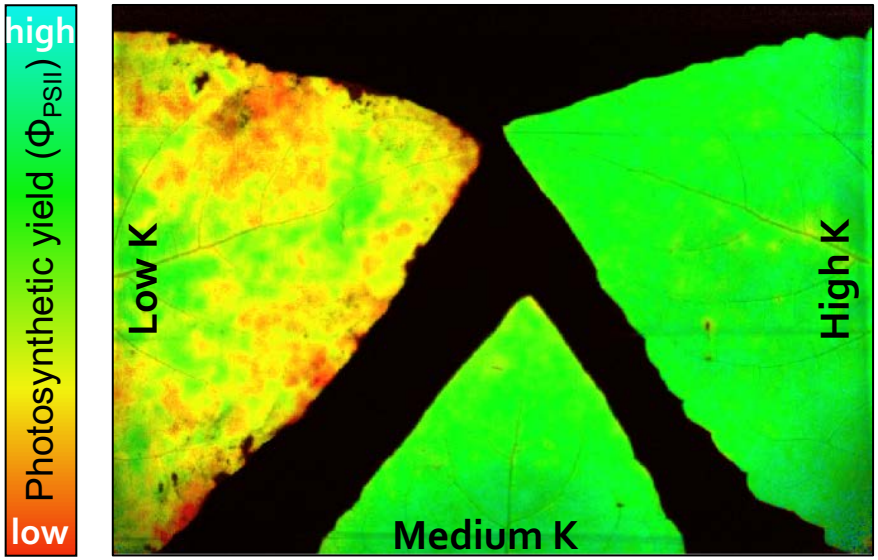
Relationship between assimilation and K nutrition

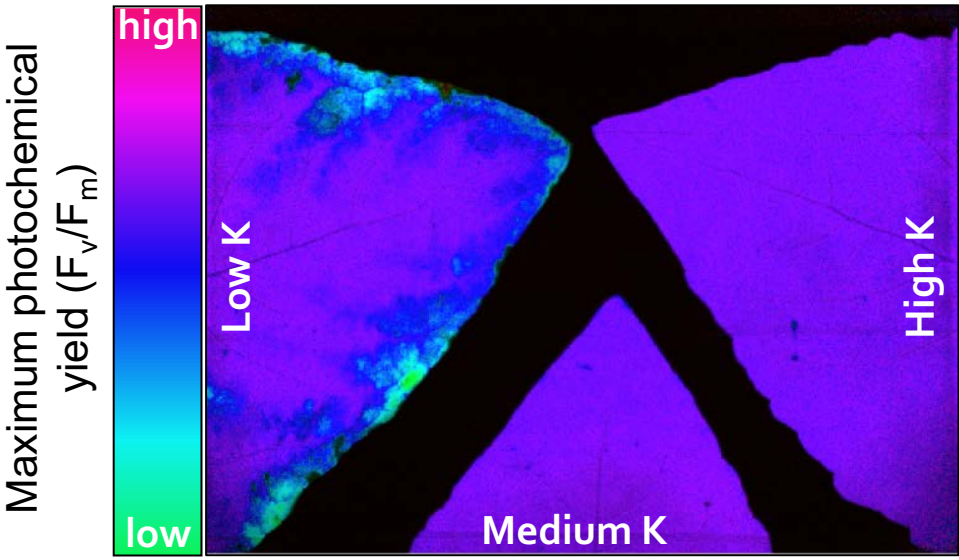




→ Photosynthesis is reduced in K deficient sunflower

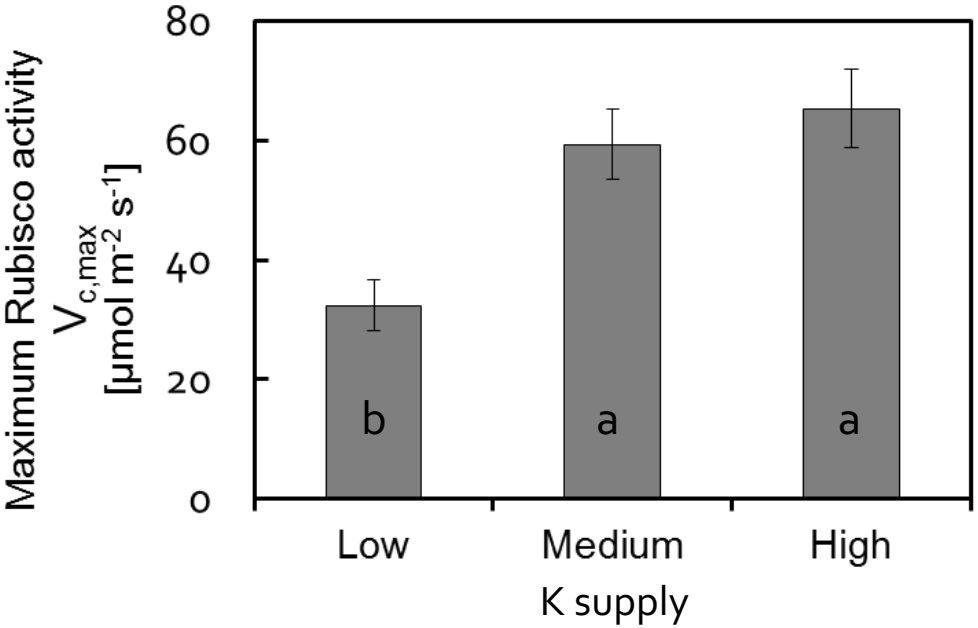
1 Photochemical limitations

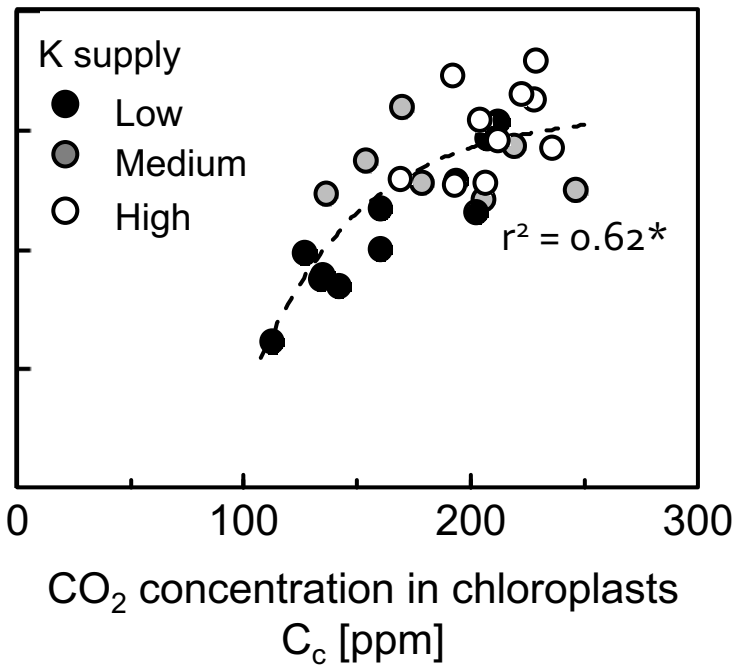




- Photochemical energy conversion is affected only on chlorotic leaf margins

2 Biochemical limitations

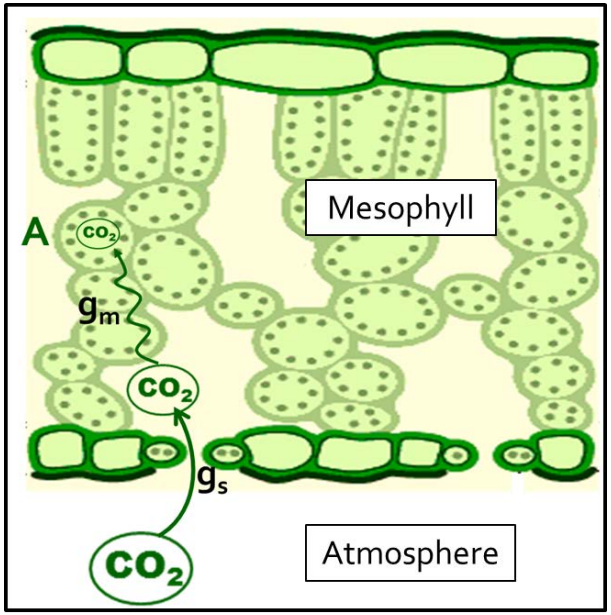


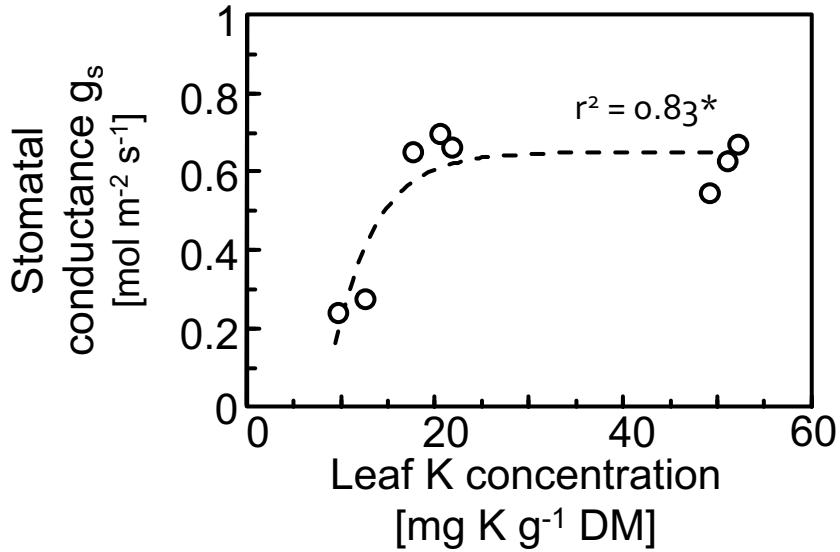


- Sugar accumulation inhibits Rubisco (Goldschmidt & Huber, Plant Phys., 1992)
- Low substrate availability in chloroplasts inhibits Rubisco

  (Galmés et al., J. Exp. Bot, 2011)

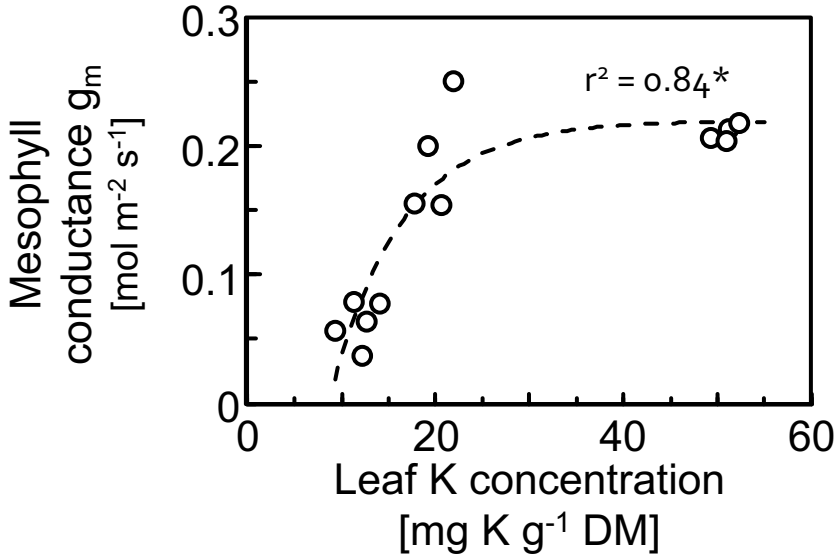
3 Limitations to photosynthesis by CO_2 diffusion



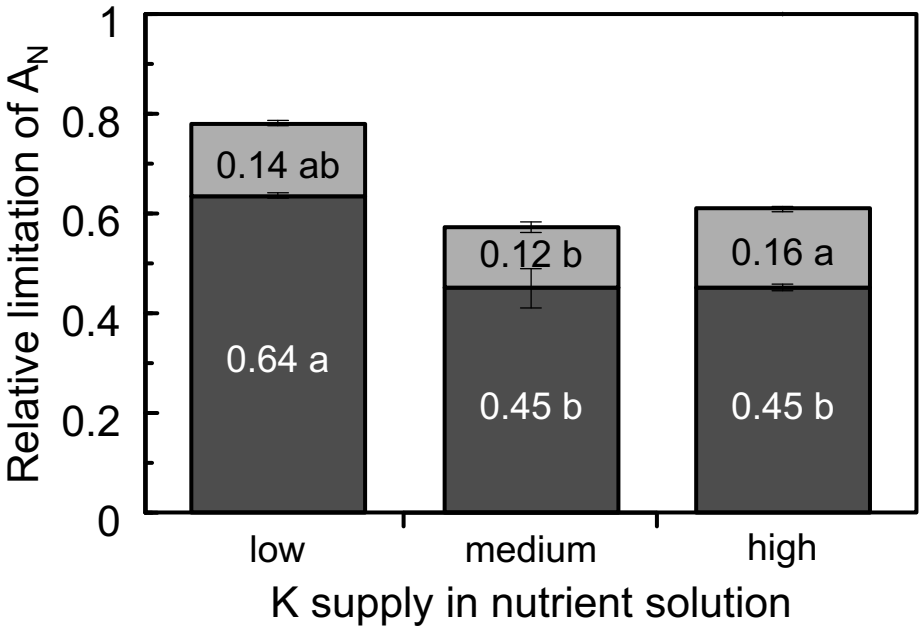


Is g_s or g_m the most limiting factor?

- Quantitative limitation analysis based on the methodological approach of GRASSI and MAGNANI (2005) using A - C_i curves (Grassi G, Magnani F, Plant Cell Environ., 2005)



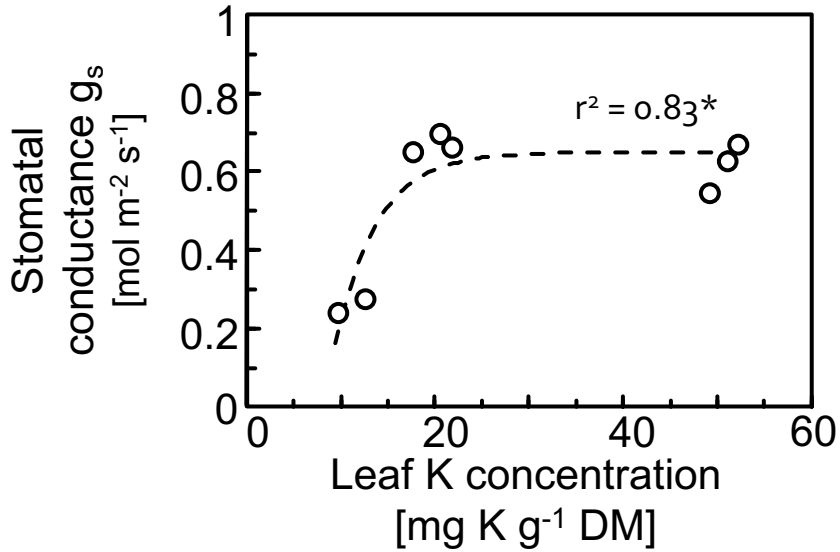
Limitations to photosynthesis by CO_2 diffusion

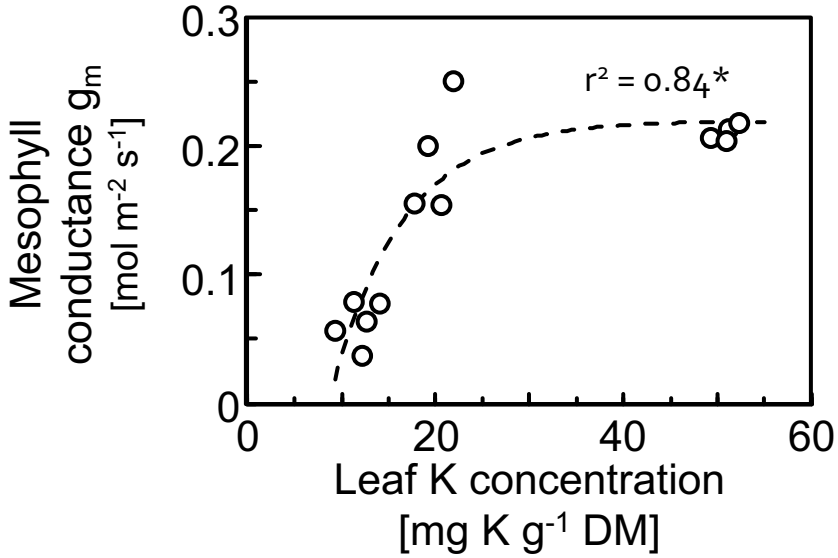


1 = total limitation of photosynthesis

Fraction of limitation posed by:

- mesophyll conductance
- stomatal conductance





Photosynthesis is reduced in K deficient plants

1 Photochemical limitations

- Photochemical energy conversion is not generally impeded

2 Biochemical limitations

- Rubisco inhibition

3 Substrate limitations

- Restricted CO_2 diffusion through the leaf mesophyll
- Stomata adjust to the reduced CO_2 demand by photosynthesis

→ Stomatal functioning is maintained

The whole story can be found here…

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Original article

Quantitative limitations to photosynthesis in K deficient sunflower and their implications on water-use efficiency

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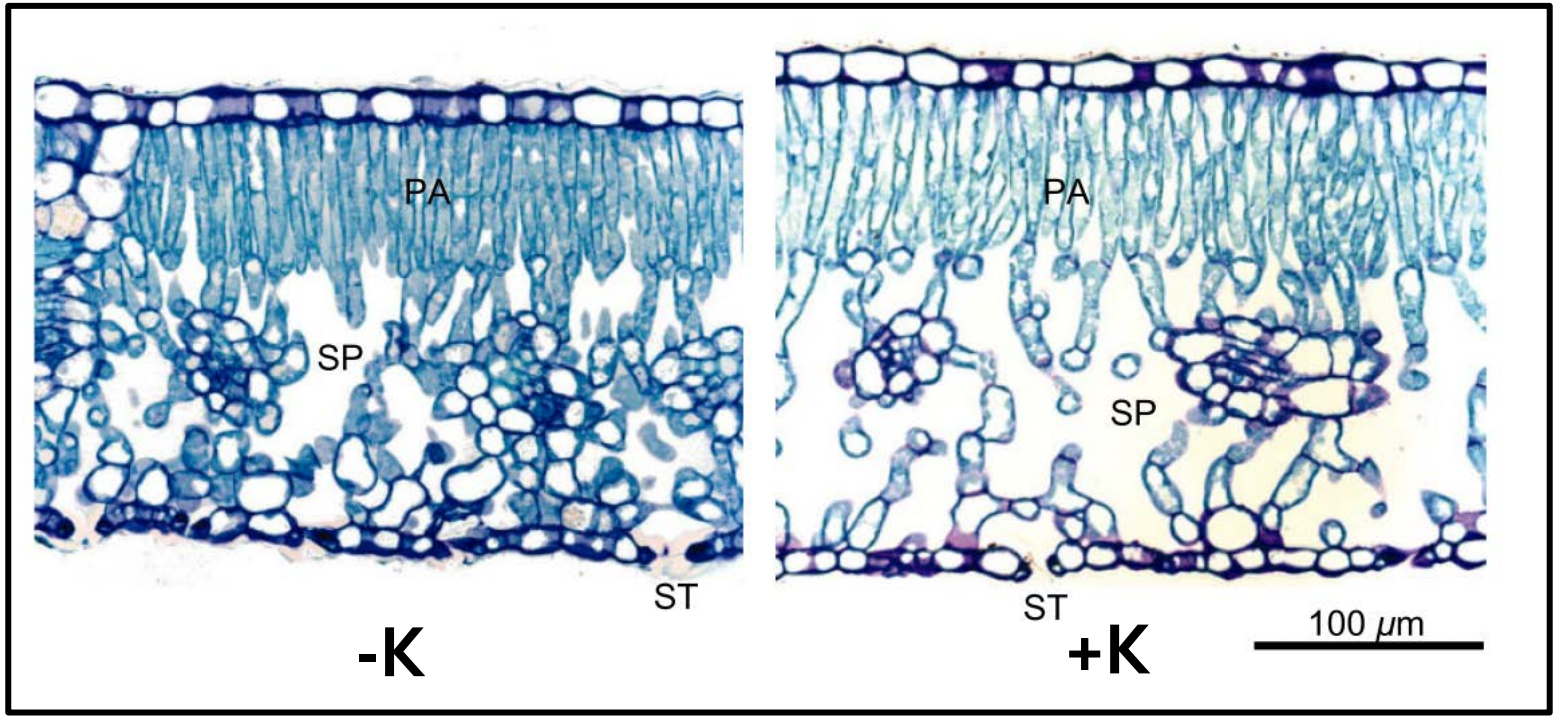
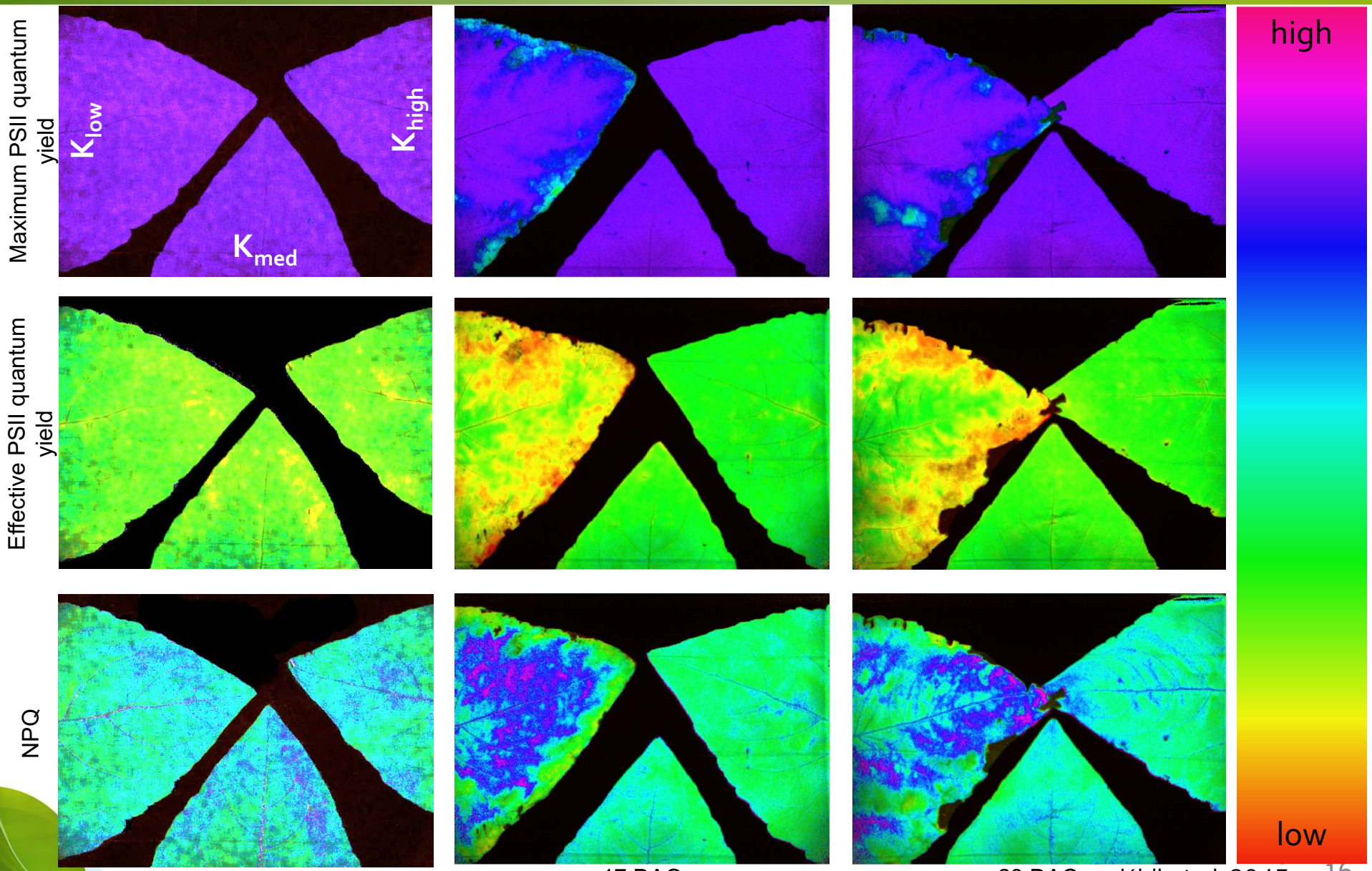
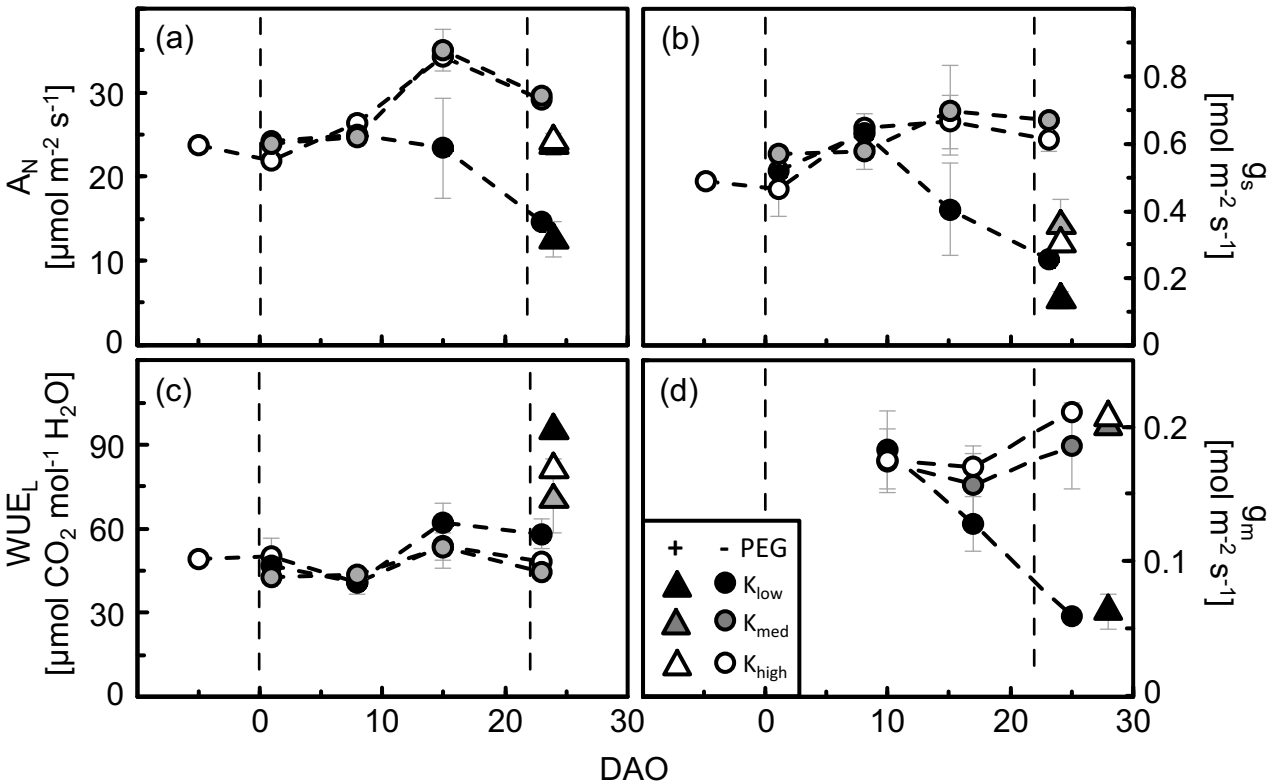
Substrate limitation by restricted CO_2 diffusion

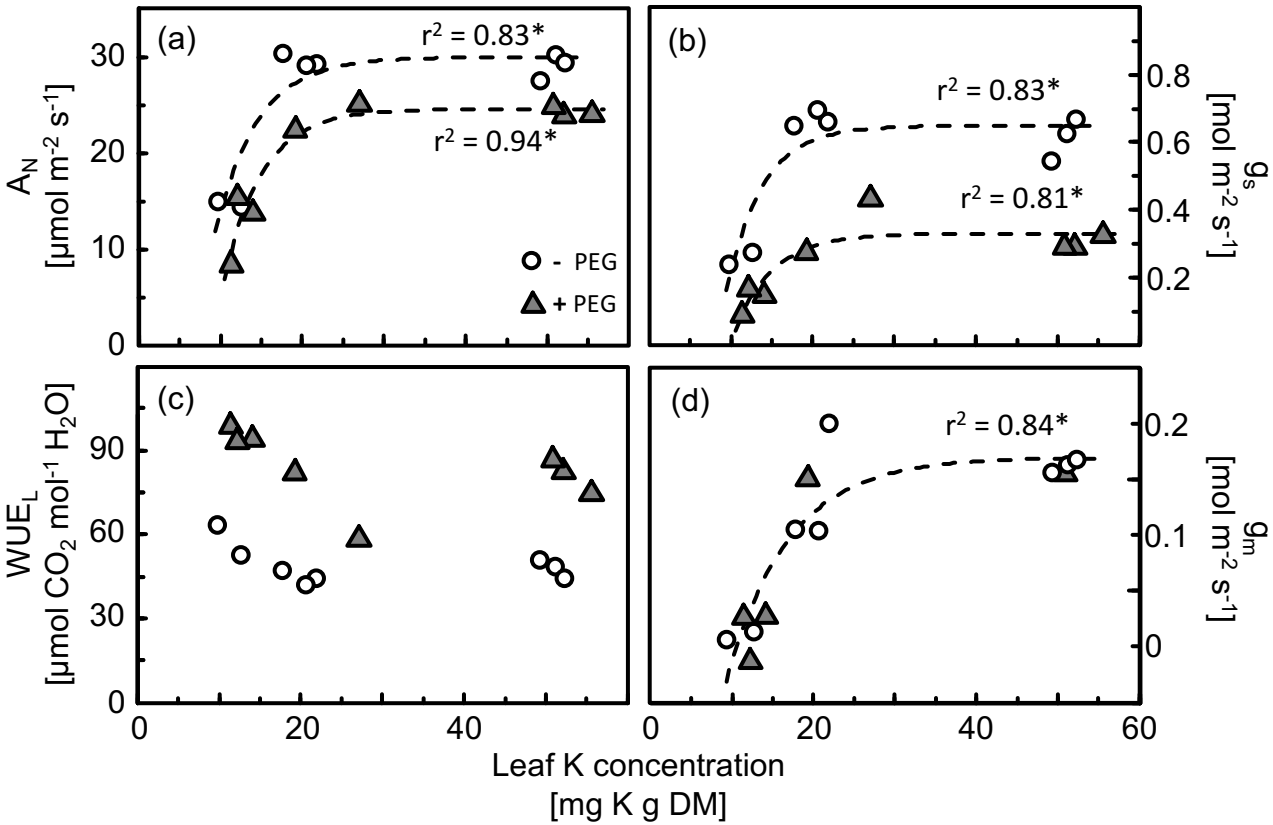


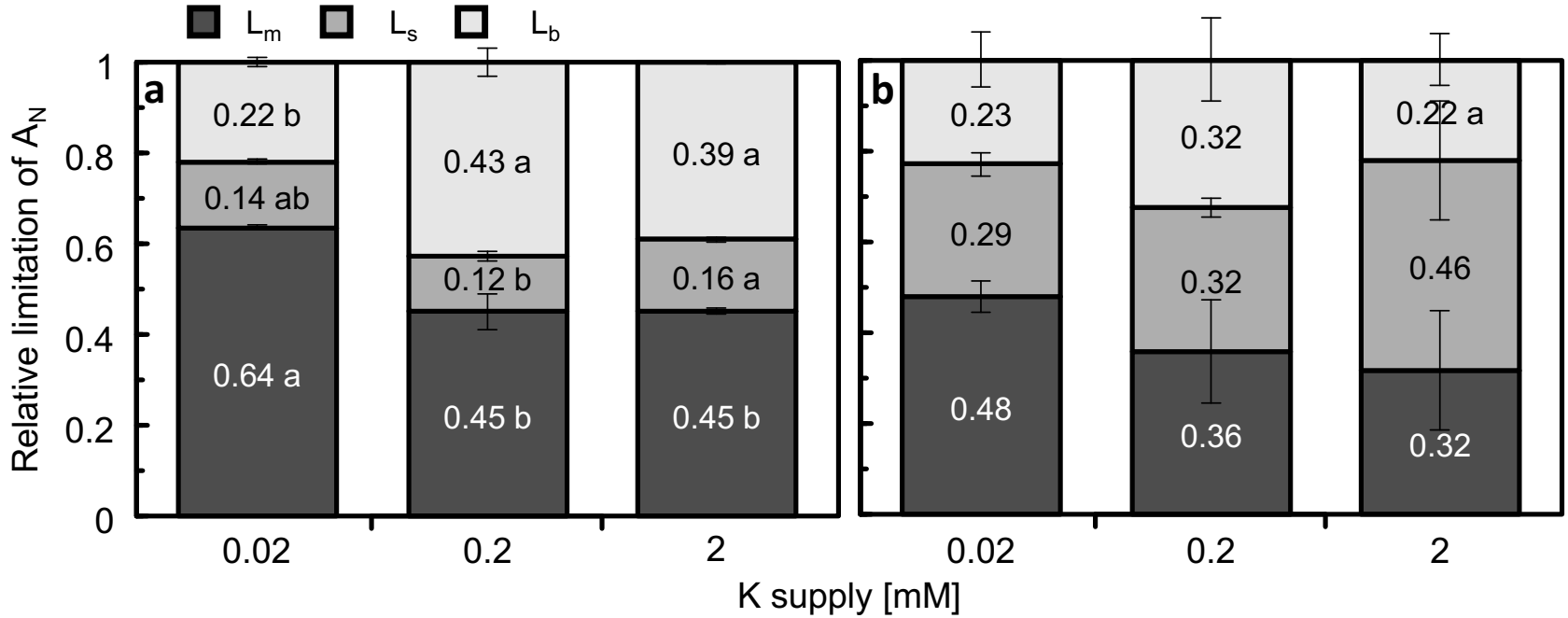
BATTIE-LACLAU et al., Plant Cell Environ, 2014



Jákli et al. 2015,


(a)
(b)
(c)
(d)
A_N [µmol m^{-2} s^{-1}]
g_s [mol m^{-2} s^{-1}]
WUE_L [µmol CO_2 mol^{-1} H_2O]
g_m [mol m^{-2} s^{-1}]
+ - PEG
K_{low}
K_{med}
K_{high}
DAO


(a)
(b)
(c)
(d)
r^2 = 0.83*
r^2 = 0.94*
r^2 = 0.83*
r^2 = 0.81*
r^2 = 0.84*
- PEG
+ PEG
A_N [µmol m^{-2} s^{-1}]
g_s [mol m^{-2} s^{-1}]
WUE_L [µmol CO_2 mol^{-1} H_2O]
g_m [mol m^{-2} s^{-1}]
Leaf K concentration
[mg K g DM]


L_m
L_s
L_b
a
b
Relative limitation of A_N
1
0.8
0.6
0.4
0.2
0
0.22 b
0.14 ab
0.64 a
0.43 a
0.12 b
0.45 b
0.39 a
0.16 a
0.45 b
0.23
0.29
0.48
0.32
0.32
0.36
0.22 a
0.46
0.32
0.02
0.2
2
0.02
0.2
2
K supply [mM]