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, JAKLI 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

Photochemical limitation

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Relationship between assimilation and K nutrition

![Leaf image showing low, medium, and high K levels]

Photosynthesis is reduced in K deficient sunflower
Photochemical limitations

- Photochemical energy conversion is affected only on chlorotic leaf margins.
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)
Is $g_s$ or $g_m$ the most limiting factor?

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 CO2 diffusion through the leaf mesophyll
   - Stomata adjust to the reduced CO2 demand by photosynthesis
   - Stomatal functioning is maintained
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
<table>
<thead>
<tr>
<th>Maximum PSII quantum yield</th>
<th>Effective PSII quantum yield</th>
<th>NPQ</th>
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<tbody>
<tr>
<td>$K_{\text{low}}$</td>
<td>$K_{\text{med}}$</td>
<td>$K_{\text{high}}$</td>
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10 DAO  | 17 DAO  | 23 DAO  |

Jakli et al. 2015, unpublished
Leaf K concentration

\[ \text{mg K g DM} \]

WUE

\[ \text{µmol CO}_2 \text{ mol}^{-1} \text{ H}_2\text{O} \]

\[ r^2 = 0.84^* \]

AN

\[ \text{µmol m}^{-2} \text{ s}^{-1} \]

\[ r^2 = 0.94^* \]

GS

\[ \text{mol m}^{-2} \text{ s}^{-1} \]

\[ r^2 = 0.83^* \]

\[ r^2 = 0.81^* \]
Relative limitation of AN

- **L_m**
- **L_s**
- **L_b**

K supply [mM]

0.02 0.2 2

0.64 a
0.14 ab
0.45 b
0.45 b
0.48
0.36
0.32
0.23
0.29
0.32
0.46
0.22 a