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Irrigation water salinity limits faba bean (*Vicia faba* L.) photosynthesis

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INTRODUCTION

- High productivity – the aim of the agricultural production: extensive irrigation of crops favors secondary salinization of soil
- Salinity affects 20% and up to 50% of the irrigated land worldwide

- Accumulation of soluble salts in the rhizosphere induces **plant salt stress**
- Salt stress, amongst other disorders which may emerge, disrupts plant pigment composition and decreases photosynthesis, ultimately reflecting on crop productivity

INTRODUCTION

- Photosynthesis, as a prerequisite for biomass production, is considered a valuable parameter when studying plant adaptive responses to salinity

- Measuring the photosynthetic rate of horticultural crops under saline conditions is useful tool in managing salinity stress

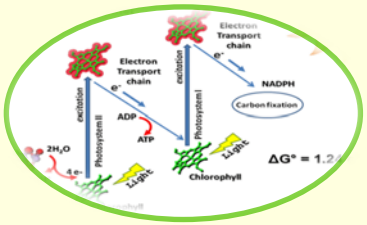
Salinity affects photosynthesis via reduction in

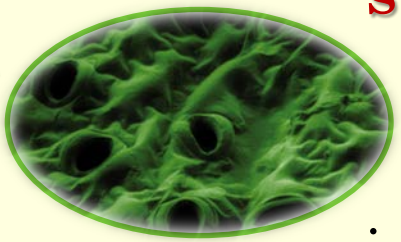
- leaf area
- chlorophyll content
- and stomatal conductance

but also through a decrease in photosystem II efficiency

INTRODUCTION

- **RESTRICTION OF PHOTOSYNTHESIS BY EXCESSIVE SALTS IN THE RHIZOSPHERE**





non–stomatal effects

restrain **product export in primary reactions** of photosynthesis:

- electron transport inhibition,
- increased chlorophyll fluorescence light emission,
- enhanced reactive oxygen species (ROS) production

stomatal effects

secondary effect induced by abscisic acid (ABA) released from the plant roots: **stomatal closure** and consequent inhibition of gas exchange

INTRODUCTION

Vicia faba L. is a legume crop
high yield and protein content
moderately sensitive to salinity

- Salinity effects on faba bean photosynthesis has been studied:
  yet the obtained results do not seem to show a consistent trend

For example

El Sayed (2011): NaCl treatments did not generate a coherent trend in faba bean photosynthetic activity

Abdul Qados (2011): differences in total chlorophyll content measured
10 days after NaCl salinity treatments started ⟹ decreased
at the death of 40% of plants ⟹ increased in regard to control plants

- ***For this reason, faba bean photosynthetic rate and total chlorophyll content under saline conditions were measured in order to elucidate plant responses to salt stress***

MATERIAL AND METHODS

- The study was carried out in 2012 (April, 2 – June, 15)
- Uniform faba bean seedlings
- Fertigation: automatic drip irrigation system

Treatment with NaCl salinity was applied in a nutrient solution:

- **$NaCl_0$ – control**
- **$NaCl_{50}$ – control + 50 mM NaCl**
- **$NaCl_{100}$ – control + 100 mM NaCl**

- Randomized block design with three replicates was applied in the experiment

MATERIAL AND METHODS

Five weeks after salinity treatment started (at the pod filling stage), faba bean leaf:

- **intercellular CO_2 concentration**
  Ci [µmol mol^{-1}]
- **stomatal conductance**
  g_s [mol H2O m^{-2} s^{-1}]
- **transpiration rate**
  E [mol H_2O m^{-2} s^{-1}]
- **photosynthetic rate**
  A [µmol CO_2 m^{-2} s^{-1}]

measured in a triplicate, on the youngest fully developed leaf, with **LCpro+ portable photosynthesis system** *(ADC BioScientific Ltd., Great Britain)*

MATERIAL AND METHODS

- Chlorophyll content index (CCI) was measured at the same time and on the same leaf with a **CCM-200 plus Chlorophyll Content Meter** (ADC BioScientific Ltd., Great Britain)

- Data were subjected to the analysis of variance (ANOVA) using the SAS statistical software package (SAS Institute, 2007)
- The significance of differences between the means was determined with Tukey's HSD test at $P \leq 0.05$

RESULTS

- Ci estimations: assuming that photosynthesis and transpiration are fairly uniform over the leaf area

  ⟹ not as adequate when g_s decreases due to environmental impacts:

lower g_s leads to decreased CO_2 concentration in chloroplasts in spite of the apparent stability of CO_2 in intercellular spaces

Decreased g_s and A do suggest faba bean lower CO_2 uptake under saline conditions

NaCl treatment	Intercellular CO_2 concentration (Ci) [µmol mol^{-1}]	Stomatal conductance (g_s) [mol H_2O m^{-2} s^{-1}]	Photosynthetic rate (A) [µmol CO_2 m^{-2} s^{-1}]
$NaCl_0$	**144 A**	**0.16 A**	**18 A**
$NaCl_{50}$	**126.6 A**	**0.09 B**	**12.1 B**
$NaCl_{100}$	**151.4 A**	**0.08 B**	**10.2 B**
Statistical significance	**n.s.**	**P<0.01**	**P<0.01**

RESULTS

- g_s, E and A significantly decreased in regard to control plants

- PLANT SALT STRESS → IONIC
- PLANT SALT STRESS → OSMOTIC

may result in stomatal closure

- Lower g_s suggested that raised soil salinity imposed water limitation for plants, causing them osmotic stress

NaCl treatment	Stomatal conductance (g_s) [mol H_2O m^{-2} s^{-1}]	Transpiration rate (E) [mol H_2O m^{-2} s^{-1}]	Photosynthetic rate (A) [µmol CO_2 m^{-2} s^{-1}]
$NaCl_0$	**0.16_A**	**2.61_A**	**18_A**
$NaCl_{50}$	**0.09_B**	**1.71_B**	**12.1_B**
$NaCl_{100}$	**0.08_B**	**1.46_B**	**10.2_B**
Statistical significance	**P<0.01**	**P<0.01**	**P<0.01**

RESULTS

STOMATAL EFFECTS OF PLANT SALT STRESS

PLANTS RETAIN WATER BY STOMATAL CLOSURE

decreased rate of E and A

RESULTS

Even though osmotic adaptation was found to be low or even absent in faba beans, our results could suggest otherwise

Adaptation to osmotic stress

→ a plant response to maintain water relations

- Decreased g_s and the fact that all plants in the experiment completed their life cycle despite decreased soil water potential caused by salinity – **the osmotic adaptation is not jet well elucidated for faba beans?**

- Furthermore, lower stomatal density, which we suggested earlier, is actually associated with water conserving attributes and indicates better adaptation to water stress conditions

Further research, focused on the faba bean possible adaptation to water stress, is needed

RESULTS

- Salinity treatments significantly affected CCI: the difference was found to be only between the salinity treatments themselves
  - Plant salt stress may cause inhibition of chlorophyll biosynthesis, increase of its degradation, as well as the oxidative stress: degradation of chloroplast structure and decrease in chlorophyll content

NaCl treatment	Chlorophyll content index (CCI)
$NaCl_0$	**64.7 AB**
$NaCl_{50}$	**83.7 A**
$NaCl_{100}$	**52.9 B**
Statistical significance	**P=0.01**

- No significant difference between CCI of control plants and CCI of NaCl treated plants ⟹ the importance of stomatal over non-stomatal effects
- Otherwise, as non-stomatal effects include inhibition of chlorophyll biosynthesis or increase of its degradation:

  should have been reflected on CCI

CONSLUSION

- Decreased g_s and A suggest faba bean lower CO_2 uptake under saline conditions, even though this could not be assumed only by observing Ci values

g_s and A could prove to be a better indicators of plant CO_2 uptake rate under saline conditions

- Lower g_s of salt stressed bean plants suggested that raised soil salinity imposed water limitation for plants, causing them osmotic stress
- Therefore, the application of saline irrigation water, due to stomatal effects of plant salt stress, results in decreased rate of transpiration and limits faba bean photosynthesis as well

CONSLUSION

- Absence of the significant difference between CCI of control plants and CCI of NaCl treated plants emphasized **the importance of stomatal over non-stomatal effects of salt stress on faba bean photosynthesis**

- **Screening for the crops that could maintain photosynthetic activity in a saline environment could provide a basis for identification of salt tolerance in horticultural crops**

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Thank you for your attention!