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Effect of salt stress on the photosynthesis of different hybrid lines sorghum

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Aim: The effects of different NaCl concentrations (0 - 250 mM) on the photosynthesis of three hybrid lines of sorghum (*ES Albanus*, *ES Shamal* and *ES Foehn*) for six days were investigated.

Methods:

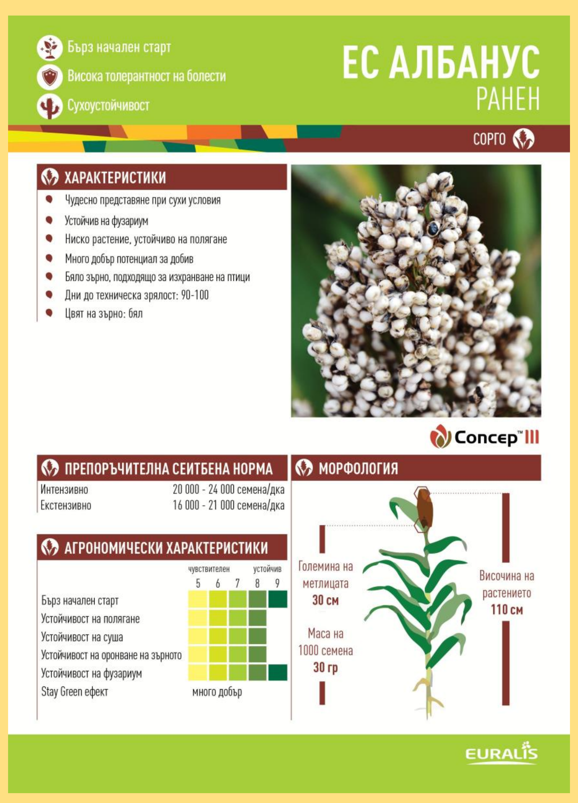
1. Spectrophotometrically determination of chlorophyll *a*, *b* and carotenoid concentrations by Lichtenthaler equations. These pigments are extracted from leaves with 80% acetone.
2. Determination of electrolyte leakage and stress markers (MDA and H_2O_2).
3. Pulse Amplitude Modulated (PAM) Chlorophyll fluorescence was measured on leaf discs by a PAM fluorimeter (H. Walz, Effeltrich, Germany model PAM 101 – 103).
4. OJIP fluorescence transitions was measured on leaf discs by HandyPEA+ (Hansatech, Germany).
5. The redox state of P_{700} was investigated on leaf discs with a dual wavelengths (810 / 860 nm) indicating degree of absorbance change in photosystem I complex. These measurements were carried out by Walz ED 700 DW-E attached to a PAM 101 E main control unit.

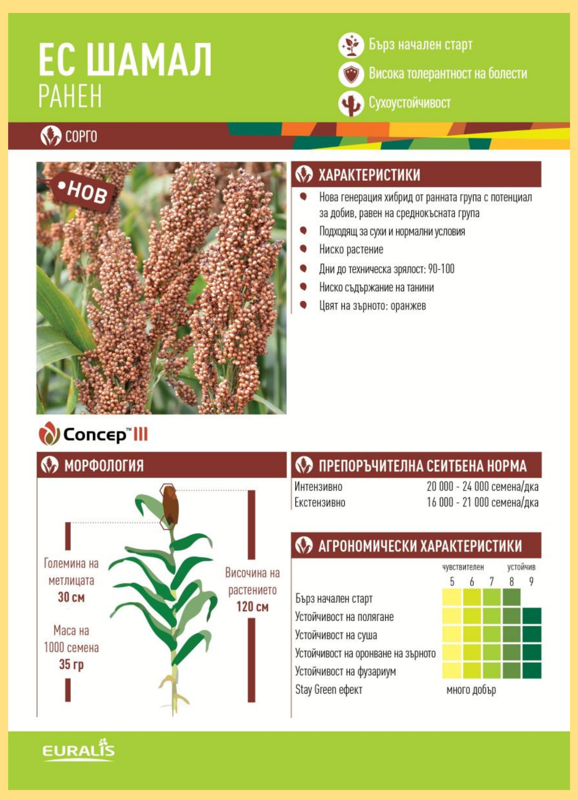
Materials:

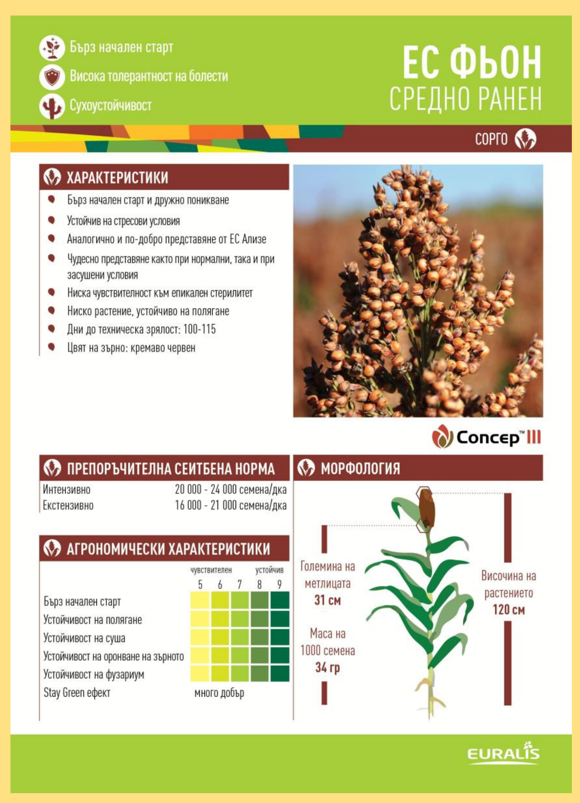
Hydroponically growth plants on ½ Hoagland solutions with different NaCl concentrations (0 - 250 mM). The electrical conductivity of nutrient solutions were evaluated (table 1).

Table 1: The electrical conductivity of 5 Hoagland solutions with different NaCl concentrations. Values indicated by different letters have statistically significant differences at $p < 0.05$:

Hoagland solutions (NaCl, mM)	control	50 mM	150 mM	200 mM	250 mM
Electrical conductivity (mS/cm)	1.03±0.07 a	6.25±0.31 d	14.80±0.24 c	18.80±0.29 b	22.80±0.50 a







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Results:

Table 2: Pigment composition (mg/g DW) of leaves of three sorghum hybrids grown in nutrient solutions with different NaCl concentrations for six days. Data are from 7 independent measurements ± standard error (s.e.).

NaCl	Chl a+b (mg/g DW)	Car (mg/g DW)	Chl a/b	Car/Chl
Albanus concep				
control	**26.4** ± 1.6 **a**	**5.3** ± 0.3 **a**	**4.68** ± 0.05 **a**	**0.201** ± 0.004 **c**
50 mM	**27.9** ± 1.2 **a**	**5.4** ± 0.2 **a**	**4.85** ± 0.08 **a**	**0.192** ± 0.004 **c**
150 mM	**17.0** ± 0.8 **b**	**3.9** ± 0.2 **b**	**4.86** ± *0.14* **a**	**0.226** ± 0.003 **b**
200 mM	**11.8** ± 1.0 **c**	**2.6** ± 0.2 **c**	***4.64*** ± 0.05 **a**	**0.221** ± 0.002 **b**
250 mM	**8.1** ± 0.5 **d**	**2.0** ± *0.1* **c**	**3.77** ± 0.09 **b**	**0.248** ± 0.005 **a**
ES *Shamal*				
control	**26.0** ± 0.6 **a**	**4.9** ± 0.1 **a**	**4.6** ± 0.04 **d**	**0.191** ± 0.002 **b**
50 mM	**25.1** ± 0.6 **a**	**4.9** ± 0.1 **a**	**4.60** ± 0.02 **d**	**0.193** ± 0.003 **b**
150 mM	**18.7** ± 1.6 **b**	**4.1** ± 0.3 **b**	**4.74** ± 0.01 **c**	**0.223** ± 0.003 **a**
200 mM	**13.7** ± 0.3 **c**	**3.0** ± 0.1 **c**	**4.93** ± 0.02 **b**	**0.217** ± 0.007 **a**
250 mM	**10.8** ± 0.3 **d**	**2.5** ± 0.1 **d**	**5.29** ± 0.06 **a**	**0.230** ± 0.009 **a**
ES *Foehn*				
control	**22.9** ± 1.9 **a**	**4.7** ± 0.3 **a**	**4.47** ± 0.15 **bc**	**0.205** ± 0.009 **b**
50 mM	**22.1** ± 0.7 **a**	**4.7** ± 0.1 **a**	**5.03** ± 0.03 **a**	**0.214** ± 0.003 **b**
150 mM	**17.0** ± 1.5 **b**	**3.6** ± 0.3 **b**	**4.66** ± 0.15 **b**	**0.210** ± 0.008 **b**
200 mM	**10.0** ± 1.3 **c**	**2.3** ± 0.2 **c**	**4.75** ± 0.11 **b**	**0.230** ± 0.019 **ab**
250 mM	**7.6** ± 1.1 **c**	**2.0** ± 0.3 **c**	**3.51** ± 0.44 **a**	**0.261** ± 0.007 **a**

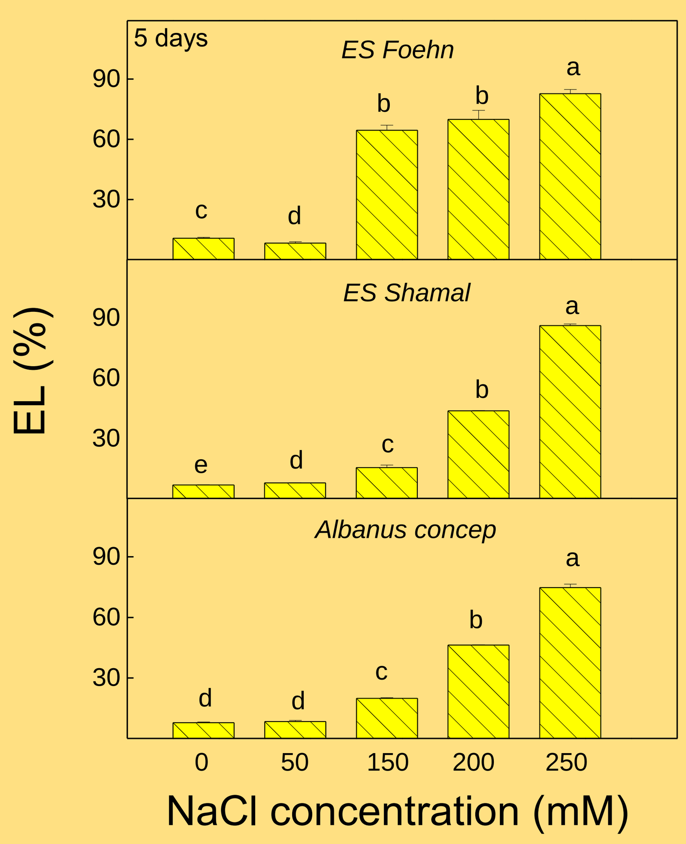

Figure 1: Electrolytic leakage (%) of leaves of three sorghum hybrids grown in nutrient solutions with different NaCl concentrations for six days. Data are from 7 independent measurements ± standard error (s.e.).

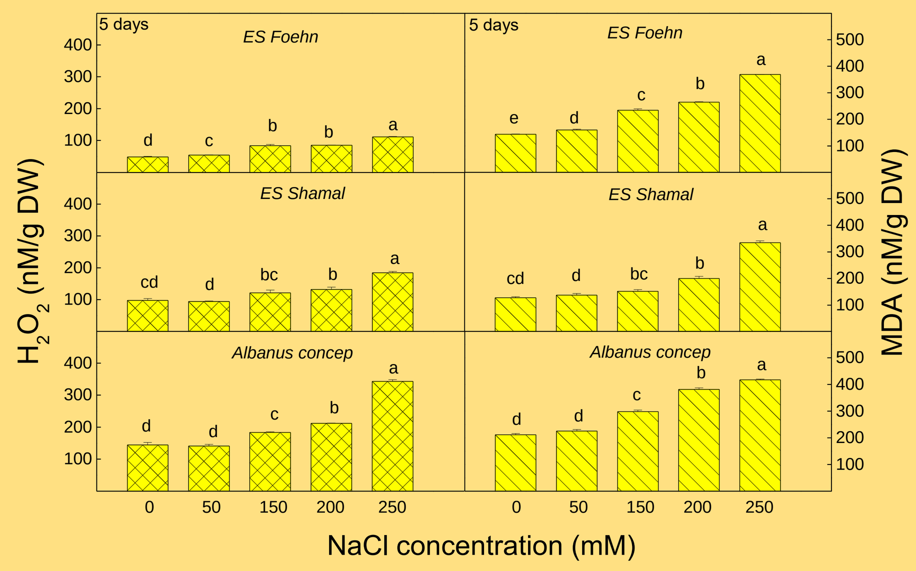

Figure 2: Determination of H_2O_2 and MDA (nM/g DW) in the leaves of three sorghum hybrids grown in nutrient solutions with different NaCl concentrations for six days. Data are from 7 independent measurements ± standard error (s.e.).

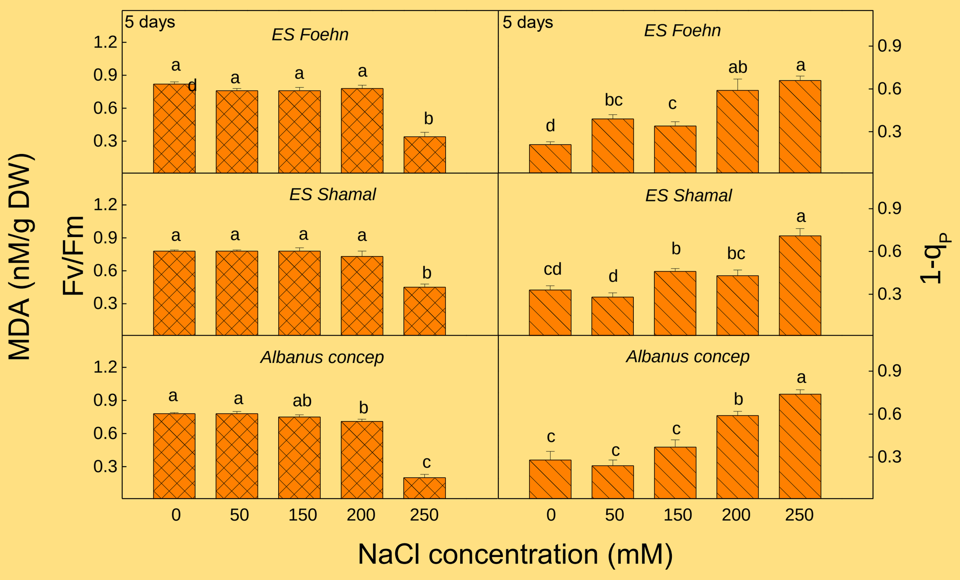

Figure 3: Determination of maximal quantum yield (FvFm) in dark adapted state and the amount of the closed PSII centers ($1-q_p$) in the leaves of three sorghum hybrids grown in nutrient solutions with different NaCl concentrations for six days. Data are from 7 independent measurements ± standard error (s.e.).

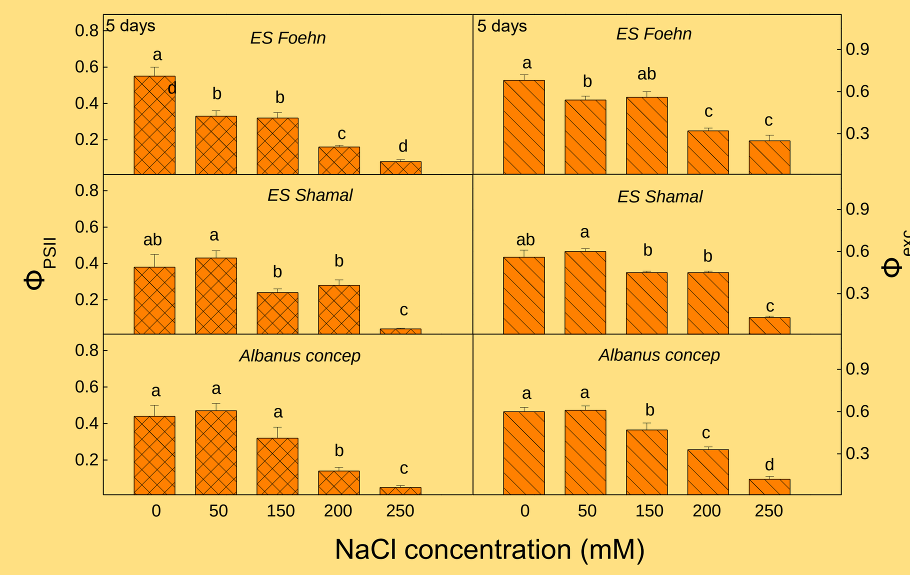

Figure 4: Determination of the effective quantum yield of a photochemical energy conversion of PSII (Φ_{PSII}) and the efficiency of PSII centers (Φ_{exc}) in the leaves of three sorghum hybrids grown in nutrient solutions with different NaCl concentrations for six days. Data are from 7 independent measurements ± standard error (s.e.).

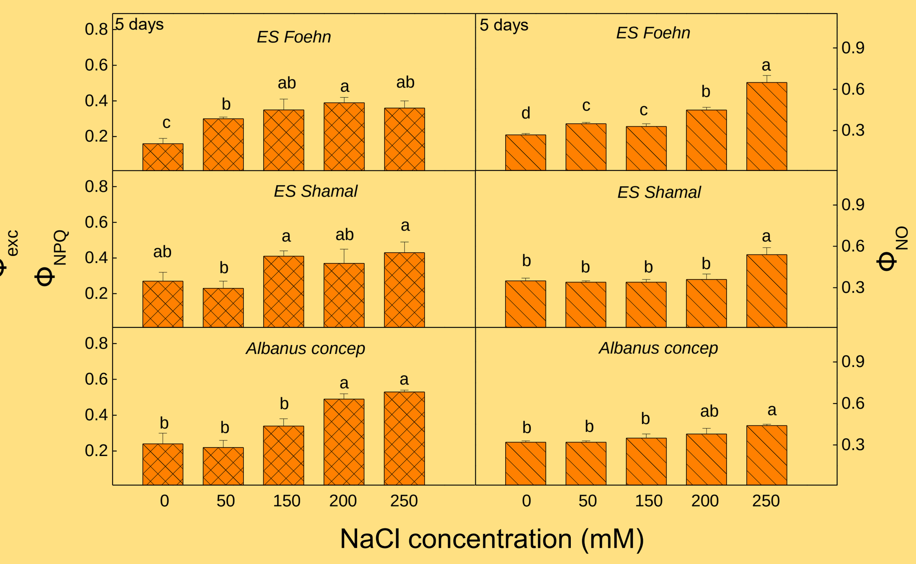

Figure 5: Determination of the ratio of regulated (Φ_{NPQ}) and non-regulated (Φ_{NO}) energy loss in PSII in the leaves of three sorghum hybrids grown in nutrient solutions with different NaCl concentrations for six days. Data are from 7 independent measurements ± standard error (s.e.).

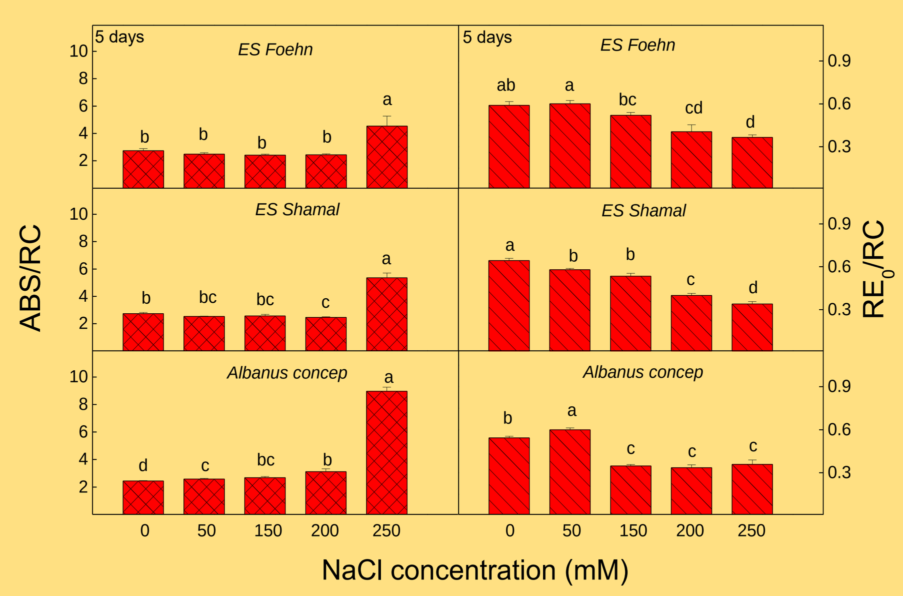

Figure 6: Determination of the apparent antenna size of the active PSII centers (ABS/RC) and the electron flux reducing end acceptors at the acceptor side of PSI (RE_0/RC) in the leaves of three sorghum hybrids grown in nutrient solutions with different NaCl concentrations for six days. Data are from 7 independent measurements ± standard error (s.e.).

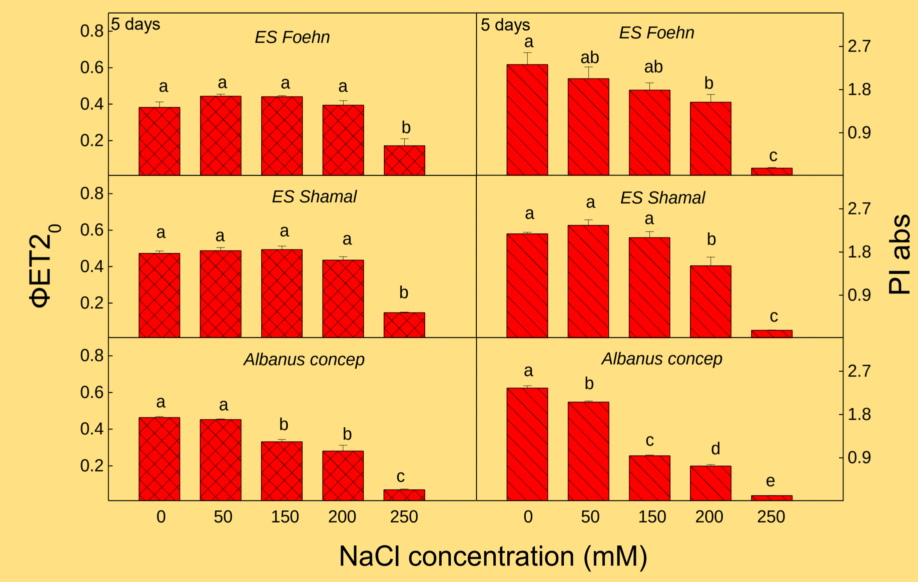

Figure 7: Determination of the quantum yield of the electron transport flux from Q_A to Q_B per PSII (φ_{ET20}) and the performance index for energy conservation (PI abs) in the leaves of three sorghum hybrids grown in nutrient solutions with different NaCl concentrations for six days. Data are from 7 independent measurements ± standard error (s.e.).

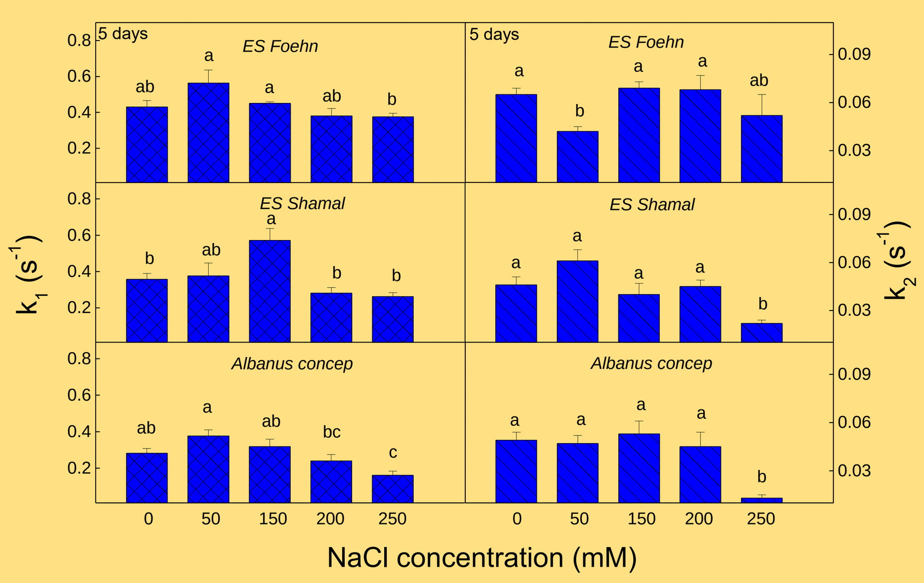

Figure 8: Determination of fast (k_1) and slow (k_2) slow rate constant of re-reduction of P_{700} in the leaves of three sorghum hybrids grown in nutrient solutions with different NaCl concentrations for six days. Data are from 7 independent measurements ± standard error (s.e.).

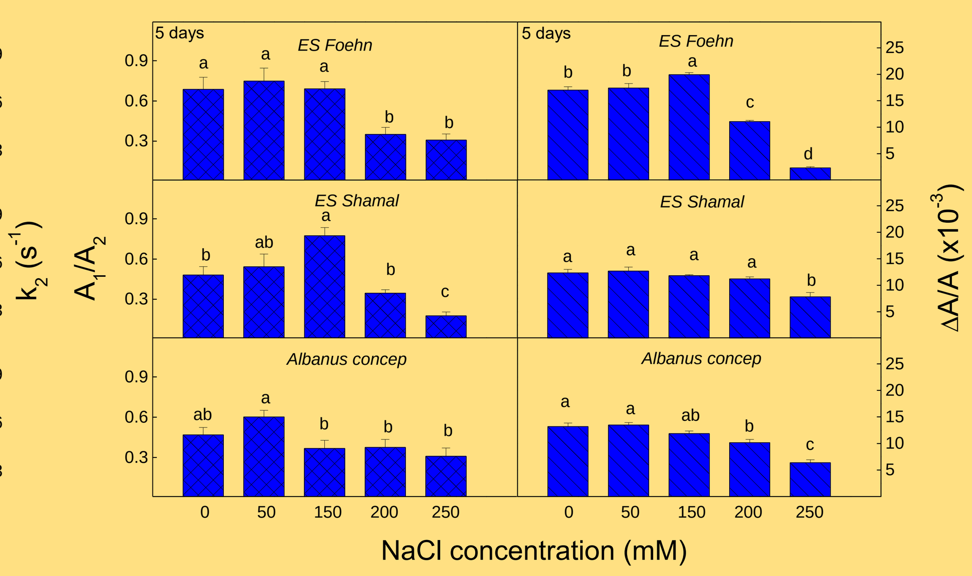

Figure 9: Determination of ratio of the amplitudes of the fast and slow component (A_1/A_2) and relative changes in the amount of P_{700^+} (ΔA/A) in the leaves of three sorghum hybrids grown in nutrient solutions with different NaCl concentrations for six days. Data are from 7 independent measurements ± standard error (s.e.).

Conclusions:

The effects of NaCl concentration varied in the studied hybrid sorghum lines.

OJIP fluorescence transitions of leaves from plants treated with 150 mM and 200 mM NaCl showed an influence on the antenna size of PSII, a decrease of the electron transport flux from Q_A to Q_B and changes in the photosynthetic processes that lead to lowering of the possibility of the reduction of PSI end acceptors.

Salt stress induced changes at concentrations of NaCl -150 mM and higher, as the changes were higher at ES *Foenh* in comparison to the *Albanus concep* and ES *Shamal*. These concentrations led to:

- an increase of the electrolytic leakage;
- a decrease of the pigment amount and an increase of the stress markers (H_2O_2 and MDA);
- a decrease of the open PSII centers and their efficiency;
- an inhibition of the effective quantum yield of PSII which corresponds with an increase quantum yield of a regulated non-photochemical energy loss in PSII in *Albanus concep* and ES *Shamal*, while in ES *Foehn* increased both the quantum yield of a non-regulated and regulated energy loss in PSII.

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