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*Original article*

# Interactive Effects of Potassium and Salt Stress on Selected Physiological Traits in Two Sunflower (*Helianthus annuus L.*) Cultivars

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**Abstract**
Salinity is considered one of the most important factors that limit plant growth and production through its adverse effects on physiological and biochemical processes in plant cells. It is noteworthy that the physiological response of salt-stressed plants varies according to the plant species and cultivars, as well as the type and salt concentrations. The sterilized sunflower seeds were transferred to plastic pots (15 cm in diameter, 20 cm length with a hole at the bottom) filled with a fixed amount of previously acid-washed quartz sand. The water holding capacity was kept at 80% during the whole experimental period. The pots were divided into two sets: first set was irrigated with 1/10 strength modified Hoagland solution (adequate $K^+$, 6 mM) supplemented with 0, 20, 50 and 100 mM NaCl, while the second set was irrigated with 1/10 Hoagland solution supplemented 0, 20, 50 and 100 mM NaCl in presence of with double $K^+$ concentration (double $K^+$ concentration, 12 mM). At 25 d, homologous samples (of two sunflower cultivars) were harvested, dissected into leaves and roots, and quickly saved for estimation of the various chemical analyses.
**Keywords:** *Helianthus annuus*, Salinity, Salt Stress, Potassium Nutrition.

## Introduction

Salinity is a major abiotic stress limiting agricultural productivity on nearly 20% of the cultivated area and half of the irrigated area worldwide, and the amount is increasing day by day. Plants can be divided into two categories in response to salt stress: glycophytes and halophytes. Glycophytes are extremely sensitive to salt in soils; halophytes are salt-tolerant and often grow in saline environments. Glycophytes comprise most of the plant life and all major crops, so the increasing salinity in soils is of major concern [6].

Salinity induced osmotic stress, ionic imbalance, ion toxicity, and nutrient deficiency regarding plant growth [36]. Ionic imbalance and ion toxicity are due to the substitution of potassium with sodium ions [56]. Consequently, the capability of plants to sustain a high $K^+/Na^+$ ratio is the most important attribute of crop plants regarding salt tolerance mechanisms [1].

Generally, the response of glycophytes to salt stress is complex and involves different changes in their morphological, anatomical, metabolic, and physiological processes [54][3]. The response of plants to salt stress varies with the degree of stress and the growth stage. Many studies indicate that inhibition of seed germination under saline conditions could be related to the toxicity of $Na^+$ and $Cl^-$ to the embryo [13].

In addition, the decline of seed germination is related mainly to lowering the osmotic potential of soil and the retardation of water absorption by seeds [55].

Photosynthesis is one of the most important processes that is severely affected by the onset of salt stress. The increase of toxic $Na^+$ and $Cl^-$ levels can result in a marked decline of chlorophyll content, and hence suppress photosynthesis [43]. Many researchers have suggested that the suppression of photosynthetic rate is related to a decrease in chlorophyll content and the induction of stomatal closure [8]. Moreover, it has been reported that the increase in carotenoid levels was responsible for better adaptation of sugarcane plants grown under salinity stress [16].

Potassium is an essential macronutrient that plays vital roles in most biochemical and physiological processes, such as enzyme activation, protein synthesis, photosynthesis, osmoregulation, stomatal movement, energy transfer, phloem transport, cation-anion balance, and stress resistance [28]. It is, mainly, transported against a concentration gradient through specific channels and transporters [31].

Sunflower (*Helianthus annuus* L.) plants are tall annuals grown in Egypt to produce edible oil. Over 90% of the total oils in seeds are unsaturated oleic (C18:2) and linolenic (C18:3) acids, and protein content represents 20-30% of the seed. Sunflower plants grow best on high-holding capacity soils with a neutral pH (6.5-7.5). The yield of seeds and oil is reduced under environmental stresses such as salinity, drought, and heavy metals (https://www.agmrc.org/media/cms/sunflower7185B2B36D8B9. pdf).

## Materials and methods

Sunflower **(*Helianthus annuus* L.)** seeds (cv. Giza 102 and cv. Sakha 53) were utilized in this study. The seeds were supplied by the Agricultural Research Center, Giza, Egypt. Two cultivars of sunflower (Family name: Asteraceae) were used during this study.

### *Sterilization and germination of seeds*

The seeds were selected for uniformity of size, shape, and color. Before germination, seeds were surface

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sterilized by soaking for two minutes in 4% (v/v) sodium hypochlorite, then washed several times with distilled water. As a pre-experiment to choose the suitable concentration of sodium chloride and potassium ($KNO_3$) for giving a high germination percentage, the seeds (20 seeds) were transferred to Petri dishes containing 20 ml distilled $H_2O$ (control) or 20 ml of 20, 50, 100, 150, and 200 mM NaCl to choose the sub-lethal NaCl concentration. All dishes were placed at natural environmental conditions (photoperiod, 16L/8D; temperature, 27±2°C light/23±2°C dark; light intensity PPFD, 23 µmol $m^{-2}$ $s^{-1}$) for 1-6 days. The preliminary experiment indicated that 100 mM NaCl is a sub-lethal concentration in which 55% of soaked seeds showed radical growth. Thus, the 20-100 mM NaCl solutions have been used during this study.

***Treatments***

The sterilized sunflower seeds were transferred to plastic pots (15 cm in diameter, 20 cm length with a hole at the bottom) filled with a fixed amount of previously acid-washed quartz sand. Twenty seeds were germinated in each pot, and the pots were placed under natural environmental conditions as mentioned above. The water holding capacity was kept at 80% during the whole experimental period. The pots were divided into two sets; first set was irrigated with 1/10 strength modified Hoagland solution [11] (containing 6 mM K+, adequate K+ level) supplemented with 0, 20, 50 and 100 mM NaCl, the second set was irrigated with Hoagland solution with 12 mM K+ (double adequate K+ level) and supplemented with 0, 20, 50 and 100 mM NaCl. The irrigation was carried out every two-day interval throughout the whole experiment period.

To prevent salt accumulation, an amount of distilled water was added to the pots every two-day interval to keep the water holding capacity at 80%. At 25 d, plants were harvested, washed thoroughly from adhering sand, gently plotted, and homologous plants were dissected into leaves and roots and quickly saved for estimating the various growth biomarkers. Other samples were dried at 60 °C in an oven to constant weight and were saved for chemical analyses. All chemical analyses were performed on leaves and roots for the two cultivars. For the enzyme assay, fresh samples were saved in liquid $N_2$.

***Growth biomarkers***

**Determination of fresh and dry biomasses**

For fresh biomass (f.m.) determination, homologous plants (three replicates) were removed, washed, gently blotted, dissected into roots and leaves, then weighed separately. The dry biomass (d.m.) was determined after drying the samples in an oven at 60°C till constant weight.

**Determination of water content**

The water content of the plants was determined as follows:

$$\%\text{Water content} = \frac{\text{Fresh weight} - \text{dry weight}}{\text{Fresh weight}} \times 100$$

***Chemical analyses***

**Determination of photosynthetic pigments**

The photosynthetic pigments chlorophyll a, b (Chl.a, Chl.b) and carotenoids (Carot.) were determined following the N, N-dimethylformamide (DMF) method described by [19]. A known weight of the dissected fresh leaves (50 mg) was incubated in 10 ml of DMF reagent and kept at 4°C for 24h in the dark. The extract-containing pigments were decanted, and the absorbance was measured at the following wavelengths: 647, 665, and 453nm using a spectrophotometer (JENWAY, 6305, UK). The formula and extinction coefficients used for the determination of Chl.a and Chl.b were:

Chl. a= 12.70 $A_{665}$ – 2.79 $A_{647}$ Chl. b= 20.70

$A_{647}$ – 4.62 $A_{665}$

The carotenoids were estimated according to [26]. Carotenoids (Carot.) = 4.2 $A_{453}$ – 0.0264 Chl. a + 0.426 Chl. b). The values were then expressed as mg $g^{-1}$f.m.

(**Measurement of quantum yield of PSII (Fv/Fm)**

In *vivo,* this measurement was monitored in fully expanded and young leaves according to [9]. The measurements were performed with an OS-30P pulse modulated chlorophyll fluorimeter (Opti-sciences, Hudson, USA). Fluorescence was excited by illuminating leaves with a weak, red pulsed measuring light intensity (<0.1µmol $m^{-2}$ $s^{-1}$) with a peak wavelength of 650 nm. Before measurement of fluorescence, plants were kept in darkness at 22 ± 2°C for at least 40min to allow dark adaptation to ensure that the primary quinine acceptor (QA) was maximally oxidized. The basal non-variable chlorophyll fluorescence level with open PSII reaction centers (Fo) and the maximal fluorescence intensity indicator (Fm) level with closed PSII were determined at room temperature on intact leaves of 10 replicate plants from all treatments. The Fo (as initial fluorescence level) was measured by a weak red measuring beam, followed by a saturation light pulse to measure the maximum Fm level. Variable fluorescence (Fv) was calculated as the difference between Fm and Fo [30]. Also, the maximum quantum yield of PSII (Fv / Fm) was calculated [29].

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## Experimental results

### *Changes in growth biomarkers, photosynthetic pigments in leaves and roots of sunflower plants in response to salt stress and double adequate potassium concentration*

The sterilized sunflower seeds (*Helianthus annuus*, cv. Giza 102 and Sakha 53) were transferred to plastic pots (15 cm in diameter, 20 cm length with a hole at the bottom) filled with a fixed amount of previously acid-washed quartz sand. Twenty seeds were germinated in each pot, and the pots were placed under natural environmental conditions. The pots were divided into two sets; the first set was irrigated with 1/10 strength modified Hoagland solution (adequate $K^+$, 6 mM) supplemented with 0, 20, 50, and 100 mM NaCl, while the second set was irrigated with 1/10 Hoagland solution supplemented with double $K^+$ concentration (12 mM). The irrigation was carried out every two days throughout the whole experimental period. To prevent salt accumulation, an amount of distilled water was added to the pots every two-day interval to keep the water holding capacity at 80%. At 25 days, homologous plants were harvested, washed thoroughly from adhering soil particles, gently plotted, dissected into leaves and roots, and quickly saved for estimating the various growth biomarkers and photosynthetic pigments. Other samples were dried at 60 °C in an oven to constant weight and saved for chemical analyses.

### *Changes in fresh (f.m.) and dry (d.m.) biomasses*

Increasing salinization of the nutrient solution with NaCl resulted in a significant suppression of fresh and dry biomasses of leaves and roots of both sunflower cultivars. At the end of the experimental period, the decrease in f.m. of 100 mM NaCl-stressed Sakha and Giza leaves was 56% and 70%, respectively, compared to controls; the corresponding values for d.m. were 34% and 41%, respectively (Table 1 a, b). A similar trend was noted for roots, in which the decrease of f.m. of highly salt-stressed Sakha and Giza roots was 63% and 73% respectively, compared to controls, whereas the decrease of d.m. was 23% and 39% respectively. These observations might denote that the Giza cultivar was relatively more sensitive to salinity stress than the Sakha cultivar.

It is well noted that increasing K+ to double the level (12 mM) in the salinized nutrient media alleviated, to some extent, the inhibitory effect of salinity compared to those plants grown on an adequate K+ level (6 mM). As shown in Table 1a and b, the increase in f.m. of Sakha and Giza leaves subjected to 100 mM NaCl-12 mM K+-treated plants was 68% and 37% respectively, compared to those subjected to 100 mM NaCl-6 mM $K^+$- treated ones. The corresponding values for roots were 51% and 36%, respectively.

***Table 1a: Changes of fresh (f.m.) and dry (d.m.) biomasses (mg plant $^{-1}$) in leaves and roots of Sakha cultivar irrigated with 1/10 strength Hoagland solution supplemented with 0, 20, 50, and 100 mM NaCl in the presence of 6- or 12-mM $K^+$.***

| Treatment | | | Leaves | | Roots | |
|---|---|---|---|---|---|---|
| $Na^+$ mM | : | $K^+$ mM | f.m. | d.m. | f.m. | d.m. |
| 0 | : | 6 | 33.5±3.05 | 6.5±0.72 | 24.1±2.68 | 3.1±0.31 |
| 20 | : | 6 | 31.2±3.12 | 6.1±0.68 | 20.5±2.28 | 2.9±0.26 |
| 50 | : | 6 | 22.9±2.54 | 5.3±0.48 | 12.3±1.37 | 2.6±0.24 |
| 100 | : | 6 | 14.8±1.48 | 4.3±0.43 | 8.8±0.80 | 2.4±0.22 |
| 0 | : | 12 | 47.8±4.35 | 6.9±0.63 | 28.6±3.18 | 3.5±0.32 |
| 20 | : | 12 | 46.2±4.62 | 6.8±0.62 | 24.7±2.47 | 3.3±0.37 |
| 50 | : | 12 | 30.3±3.03 | 6.2±0.69 | 19.7±1.97 | 3.1±0.28 |
| 100 | : | 12 | 24.9±2.77 | 5.5±0.50 | 13.3±1.48 | 2.9±0.29 |
| F<br>p<br>LSD | | | 26.5<br>0.001*<br>5.1 | 4.25<br>0.023*<br>2.00 | 8.52<br>0.015*<br>3.50 | 2.01<br>0.107<br>N.S. |

***Table 1b: Changes of fresh (f.m.) and dry (d.m.) biomasses (mg plant $^{-1}$) in leaves and roots of Giza cultivar irrigated with 1/10 strength Hoagland solution supplemented with 0, 20, 50, and 100 mM NaCl in the presence of 6- or 12-mM $K^+$.***

| Treatment | | | Leaves | | Roots | |
|---|---|---|---|---|---|---|
| Na+ mM | : | K+mM | f.m. | d.m. | f.m. | d.m. |
| 0 | : | 6 | 33.4±3.04 | 6.1±0.68 | 22.6±2.51 | 3.1±0.34 |
| 20 | : | 6 | 24.5±2.23 | 5.4±0.49 | 17.2±1.91 | 2.8±0.28 |
| 50 | : | 6 | 14.6±1.22 | 4.5±0.41 | 8.5±0.65 | 2.2±0.22 |
| 100 | : | 6 | 10.1±0.92 | 3.6±0.36 | 6.1±0.61 | 1.9±0.21 |
| 0 | : | 12 | 43.1±4.79 | 6.6±0.60 | 26.4±2.40 | 3.2±0.36 |
| 20 | : | 12 | 33.5±3.72 | 6.0±0.55 | 22.2±2.47 | 3.0±0.30 |
| 50 | : | 12 | 18.9±2.10 | 5.2±0.52 | 13.4±1.22 | 2.7±0.25 |

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| | | | | | | |
|---|---|---|---|---|---|---|
| 100 | : | 12 | 13.8±1.25 | 4.7±0.43 | 8.3±0.92 | 2.2±0.20 |
| F<br>p<br>LSD | | | 27.72<br>0.001*<br>2.50 | 6.98<br>0.041*<br>2.10 | 14.7<br>0.003*<br>2.00 | 4.65<br>0.021*<br>1.6 |

***Water content***

Generally, the water content of leaves and roots of both cultivars was markedly decreased with increasing salinity levels (Figure 1). It was noted that the percentage of water content in leaves and roots of 100 mM NaCl-stressed Sakha plants was 70.9% and 72.7% respectively, compared to 80.6% and 87.1% in controls. The corresponding values were 64.4% and 68.9% in 100 mM NaCl-stressed Giza plants, compared to 81.7% and 86.3% in the control, respectively. Supplementation of the nutrient medium with double $K^+$ level (12 mM) resulted in an increase in the water content of NaCl-stressed plants in comparison to those salinized with an adequate $K^+$ level. These observations might indicate the high tendency of the Sakha cultivar to maintain a considerable water content under NaCl stress conditions.

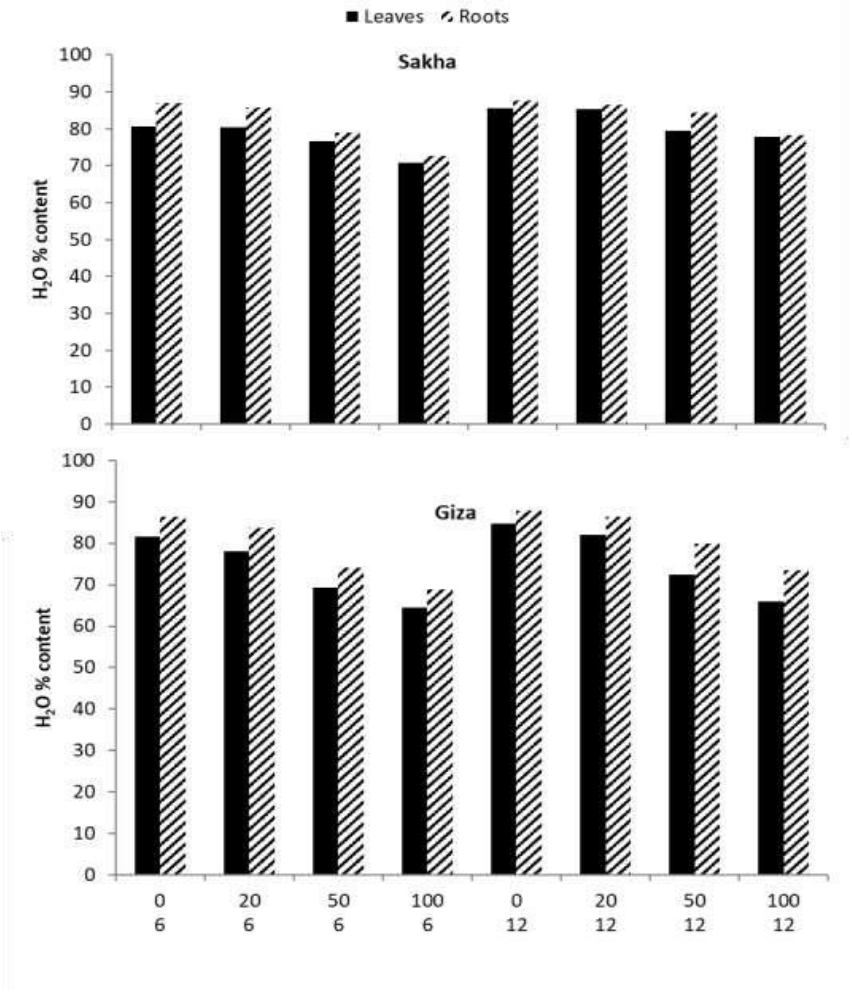


***Figure 1: Changes in $H_2O$% content in leaves and roots of Sakha and Giza cultivars in response to NaCl stress in the presence of adequate and double adequate $K^+$ levels.***

***Changes in photosynthetic pigment content***

Sunflower seeds were germinated and grown as previously described in Materials and Methods. Fresh leaves of third nodes of 25-d-old plants were taken and subjected to estimation of the photosynthetic pigments content. There was a marked decrease in total photosynthetic pigments content of Sakha and Giza plants with increasing NaCl concentrations in the presence of adequate or double adequate $K^+$ levels; the reduction is more obvious in the Giza cultivar than in Sakha. At the end of the experimental period, the decrease of total photosynthetic pigments in Sakha and Giza leaves of 100 mM NaCl-stressed in the presence of 6 mM $K^+$ was 54% and 72%, respectively, compared to the control. The reduction was mainly related to the decrease of Chl.a content, in which the reduction amounted to78% and 88% in Sakha and Giza plants, respectively (Table 2).

Supplementation of the nutrient medium with double $K^+$ concentration resulted in an insignificant change in photosynthetic pigment content compared to the control. Furthermore, the decrease in total photosynthetic pigment content in Sakha and Giza plants grown under 100 mM NaCl was 47% and 60% respectively, compared to those plants grown on 0 NaCl: 12 mM K+. These observations indicate that double K+ concentration could shift off, to some extent, the inhibitory effect of salinity stress on the synthesis of

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photosynthetic pigments, in comparison to the presence of an adequate K+ level.
Although carotenoid content in Sakha and Giza leaves showed an insignificant change in response to NaCl stress (Table 2), the Carot./Chl.a+b ratios increased markedly with increasing NaCl levels compared to control (Figure 2). The Carot./Chl.a+b ratio increased from 12% in NaCl-unstressed Sakha leaves in the presence of 6 mM $K^+$ to 59% with 100 mM NaCl-stressed leaves. The corresponding values for Giza leaves were increased from 12% to 61%, respectively (Figure 2). Addition of 12 mM $K^+$ to the stressed nutrient solution greatly suppressed the Carot./Chl.a+b ratio compared to those plants grown under an adequate $K^+$ level (6 mM).

***Table 2: Changes of photosynthetic pigments content (mg $g^{-1}$ f.m.) in leaves of Sakha and Giza cultivars irrigated with 1/10 strength Hoagland solution supplemented with 0,20,50, and 100 mM NaCl in the presence of 6 or 12 mM $K^+$.***

| $Na^+$ mM | : | K+ mM | Sakha | | | | Giza | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | Chl. a | Chl. b | Carot. | Total | Chl. a | Chl. b | Carot. | Total |
| 0 | : | 6 | 6.18±0.62 | 2.36±0.24 | 1.06±0.12 | 9.60±0.96 | 6.75±0.68 | 2.80±0.31 | 1.13±0.13 | 10.68±1.19 |
| 20 | : | 6 | 5.22±0.47 | 2.09±0.21 | 1.16±0.13 | 8.47±0.94 | 4.61±0.51 | 2.35±0.21 | 1.19±0.13 | 8.15±0.82 |
| 50 | : | 6 | 3.06±0.31 | 1.76±0.16 | 1.87±0.19 | 6.69±0.74 | 1.03±0.10 | 1.61±0.18 | 1.66±0.17 | 4.30±0.43 |
| 100 | : | 6 | 1.34±0.15 | 1.41±0.13 | 1.62±0.15 | 4.37±0.40 | 0.81±0.08 | 1.05±0.12 | 1.14±0.13 | 3.00±0.33 |
| 0 | : | 12 | 7.36±0.74 | 2.39±0.22 | 1.04±0.09 | 10.79±1.08 | 6.85±0.62 | 2.85±0.32 | 1.18±0.13 | 10.88±0.99 |
| 20 | : | 12 | 6.70±0.67 | 2.47±0.25 | 1.18±0.13 | 10.35±1.04 | 5.27±0.48 | 2.26±0.23 | 1.20±0.12 | 8.73±0.97 |
| 50 | : | 12 | 4.19±0.42 | 1.95±0.22 | 1.56±0.14 | 7.70±0.77 | 2.28±0.25 | 1.98±0.18 | 1.57±0.17 | 6.03±0.67 |
| 100 | : | 12 | 2.49±0.23 | 1.54±0.17 | 1.71±0.16 | 5.74±0.57 | 1.95±0.09 | 1.08±0.10 | 1.34±0.15 | 4.37±0.36 |
| F<br>p<br>LSD | | | 14.2<br>0.003*<br>1.66 | 2.01<br>0.166<br>N.S. | 0.98<br>0.68<br>N.S. | 7.68<br>0.013*<br>2.1 | 11.89<br>0.006*<br>2.03 | 5.02<br>0.036*<br>1.2 | 1.07<br>0.36<br>N.S. | 17.6<br>0.001*<br>2.99 |

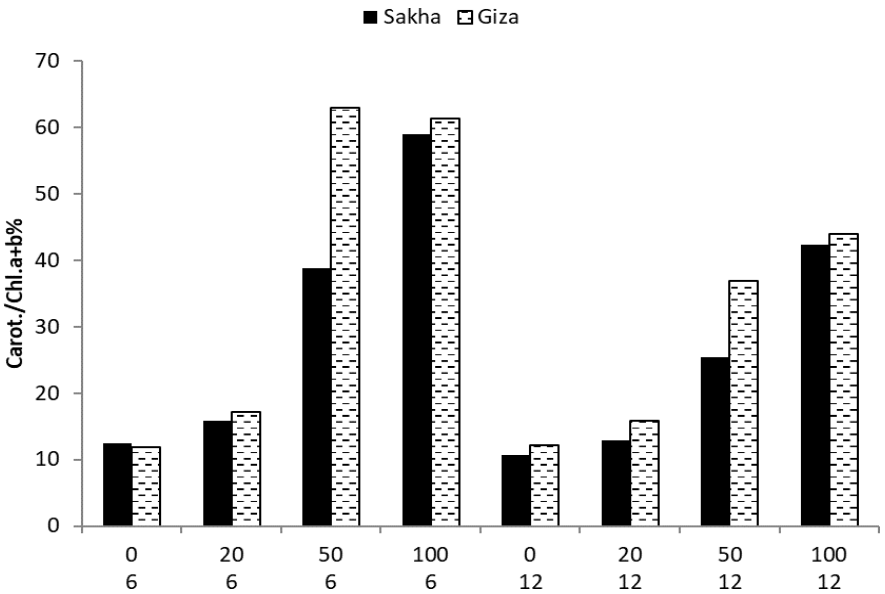


***Figure 2: Changes in % Carot./Chl.a+b ratios in Sakha and Giza leaves plants in response to NaCl stress in the presence of adequate and double adequate $K^+$ levels.***

***Changes in quantum yield (Fv/Fm)***
It is clearly shown (Figure 3) that increasing salt stress suppressed markedly the maximum quantum yield of photosystem II in sunflower plants. The suppression was more obvious in the Giza cultivar than in the Sakha ones. The decline of the Fv/Fm value decreased from 0.826 in the control plant to 0.601 in 100 mM NaCl-stressed Sakha plants. The corresponding values for Giza plants were decreased from 0.823 to 0.576 (Figure 3) maximum quantum yield of photosystem II in sunflower plants. The suppression was more obvious in the Giza cultivar than Sakha ones. The decline of Fv/Fm value decreased from 0.826 of the control plant to 0.601 in 100 mM NaCl-stressed Sakha plants. The corresponding values for Giza plants were decreased from 0.823 to 0.576 (Fig. 3).

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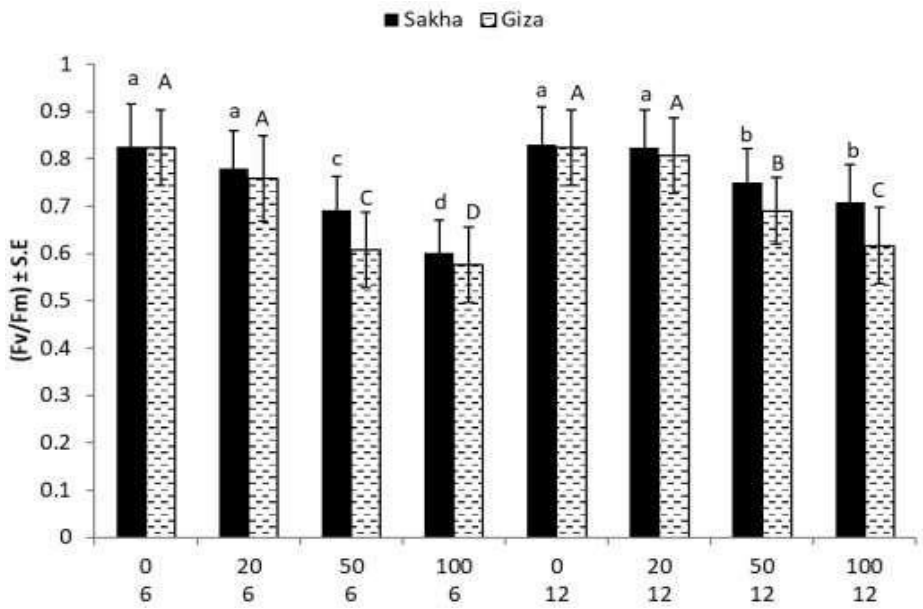


***Figure 3: Changes of Fv/Fm in Sakha and Giza leaves in response to NaCl stress in the presence of adequate and double adequate $K^+$ levels.***

**LSD Mean ± S.E indexed by the same superscript are not significantly different at P≤ 0.05 (n=3)**

Supplementing the salinized nutrient solution with double $K^+$ concentration alleviated the inhibitory effects of NaCl stress on quantum yield in comparison to an adequate $K^+$ level. These observations indicated that increasing the $K^+$ level might improve the photochemical efficiency of PSII (Fv/Fm) of salt-stressed sunflower plants and hence increase the net photosynthetic rate and growth.

## Discussion

Salt stress is generally one of the abiotic threats to plant growth, which adversely modifies gene expression, various physiological processes, and metabolic reactions in plants. Such modifications could lead to water and nutrient imbalance, accumulation of toxic ions (as Na+ and Cl-), reactive oxygen species (ROS), and finally result in limitation of plant growth and productivity [21][2].

Increasing salinization of nutrient media resulted in a significant decline of fresh and dry biomasses in leaves and roots of Sakha and Giza plants; the suppression in Giza was higher than that in Sakha, revealing the sensitivity of the former to salt stress. In agreement with these observations, many authors have reported that increasing salinity in the root zone markedly suppressed the growth of several plants, including tomato [5][12], bean cultivars [10][20], and fenugreek variety [24]. It has been reported that the reduction in plant growth by salinity might be attributed to a decrease in water absorption, disorder of plasma membrane integrity, inhibition of photosynthetic machinery, disturbance of various biochemical and metabolic reactions [18][36][27][47][35]. One of the inhibitory effects of accumulated Na+ in cytoplasm (not sequestered in the vacuoles) is replacing K+ as cofactor for several enzymes, resulting in suppression of their activities [44]. It is shown that, in this study, there was a marked increase of uptake and accumulation of Na+ in leaves and roots of Sakha and Giza plants with increasing Na+/K+ ratio, and that was accompanied by a significant decrease of fresh and dry biomass i.e. suppression of growth. These observations indicated that the accumulation of Na+ (in the cytosol) might interfere with the functions of K+ for a variety of enzymes, resulting in the disturbance of several metabolic and biochemical reactions, and hence reduce the growth.

Salinity stress decreases water content and membrane stability index [42]. The suppression of plant growth under saline conditions was related to a reduction in turgor potential [38], while the salt stress expressed membrane dysfunction resulting in a disturbance of water status and an increase in electrolyte leakage [45]. In this study, there was a marked decrease in water content in leaves and roots of Sakha and Giza plants in response to an increase in Na+ levels in the nutrient media, which reveals the destructive effect of Na+ ions on plasma membrane integrity and hence decline of water absorption.

During this study, an increase in K+ levels in the NaCl-salinized nutrient media (double adequate K+) resulted in a marked increase in measured growth biomarkers of both cultivars, compared to those in adequate K+ levels.

That K+ plays an important role in the protection of plasma membrane potential, regulating the osmotic pressure and enzyme activities [25]. In addition, there is a positive correlation between increasing K+ level and enhancement of aquaporin activities and K channel transporters, which increases root hydraulic conductance and water absorption by plants [23][52].

It has been reported that salinity stress inhibited photosynthesis and that was related to the reduction of photosynthetic pigments biosynthesis as well as destruction of photosynthetic apparatus [32][17][35]. The

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decrease of Chl.a and Chl.b and carotenoid contents were accompanied by a decline of photosynthetic rate under salinity stress [39]. In this connection, increasing NaCl level in the nutrient media of Sakha and Giza plants significantly decreased Chl.a and Chl.b contents, particularly Chl a, and maximum quantum yield of photosystem II (Fv/Fm). These results might be attributed to the enhancement of chlorophyll degradation and inhibition of chlorophyll biosynthesis [41], destruction of the chloroplastic and thylakoid membranes [53], and the instability of pigment proteins [46][49]. Furthermore, the suppression of photosynthetic rate under saline conditions is related to the reduction of chlorophyll content and induction of stomatal closure [7][1].

The carotenoids are accessory light-harvesting pigments and also play an important role as ROS scavengers to protect the photosynthetic apparatus [4][14]. Under prevailing experimental conditions, carotenoid content in leaves of NaCl-salinized Sakha and Giza plants in the presence of adequate or double K+ levels were insignificantly changed compared to controls. Similarly, it was found that carotenoid content in mung bean and sugar cane leaves, respectively, insignificantly increased in response to salt stress [50][51]. In contrast, it was noted that there is a significant increase in carotenoid content in salinized tomato [37].

However, the carotenoid contents in Sakha and Giza leaves were insignificantly changed with increasing Na+/K+ ratio; the Carot./Chl.a+b markedly increased, indicating the enhancement of oxidative stress. That the increase of Carot./Chl. a+b could reflect the increase in non-radiative energy dissipation and hence lower biochemical efficiency and growth [15][33].

It has been reported that K+ plays a vital role in controlling stomatal conductance, photosynthetic efficiency, translocation of photosynthates, and water use [40][17][39]. During this study, increasing K+ concentrations to 12 mM in the NaCl-salinized nutrient media resulted in a significant increase in Chl. a and b contents and Fv/Fm ratios of Sakha and Giza plants in comparison to those in an adequate K+ level (6 mM), revealing the role of K+ in improving photosynthesis. Furthermore, the salinity stress impaired photosynthesis in sugar cane plants, but application of K+ alleviated this inhibitory effect and improved photosynthetic parameters [34]. That K+ deficiency could result in stomatal closure and inhibit photosynthesis in several crops [48][22]. In addition, salt stress and K+ deficiency suppressed the light reaction of photosystem I and II in maize plants [39].

## Conclusion

Fresh and dry biomasses, as well as the water content of leaves and roots of both Sakha and Giza cultivars, were significantly decreased under NaCl stress. The reduction of growth parameters was greater in Giza than in Sakha. Increasing theK+ concentration to double the level (12 mM) in the salinized nutrient media alleviates, to some extent, the inhibitory effect of salinity compared to those plants grown on an adequate K+ level (6 mM). There was a marked decrease in total photosynthetic pigments content of Sakha and Giza plants with increasing NaCl concentrations in the presence of adequate or double adequate K+ levels; the reduction is more obvious in the Giza cultivar than in Sakha. Although carotenoid content in Sakha and Giza leaves showed insignificant changes in response to NaCl stress, the Carot./Chl.a+b ratios increased markedly with increasing NaCl levels compared to the control. However, Addition of 12 mM K+ to the stressed nutrient solution greatly suppressed the Carot./Chl.a+b ratio compared to those plants grown under an adequate K+ level (6 mM). Increasing salt stress suppressed markedly the maximum quantum yield of photosystem II in sunflower plants. The suppression was more obvious in the Giza cultivar than in the Sakha ones. Supplementing the salinized nutrient solution with double the concentration of K+ alleviated the inhibitory effects of NaCl stress on quantum yield in comparison to an adequate K+ level. These observations indicated that increasing the K+ level might improve the photochemical efficiency of PSII (Fv/Fm) of salt-stressed sunflower plants and hence increase net photosynthetic rate and growth.

***Conflict of interest***. Nil

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