Effect of Salt Stress on Physiological Behaviors in Four Wheat Cultivars

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Received: *16/1/2010*

Abstract: A field experiment was conducted during winter season of 2005/06 to define the physiological behaviors resulting from inducing salinity tolerant in wheat plant by potassium foliar application at rates of 0, 3, 6 and 9 g fertilzer l^{-1} assoluble k_2SO_4, under irrigation with different saline waters (0.4, 2.5, 5 and 10 dSm^{-1}). Wheat *(Triticum aestivum* L.) varieties viz. Sakha 93, Gimiza 9, Sids 1 and Giza168. were grown to maturity on a sandy soil (EC_e 1.45 dSm-1 . Dry matter of shoot and root, O P (osmotic pressure), RWC (relative water content), chlorophyll a,b and carotenoides were measured. In general the application of potassium proved to be promotive for the chlorophyll (a, b), carotenoidies, shoot dry weight, root dry weight, R.W.C%. and O.P. significant variation among the investigated varieties were observed.

Keywords: wheat varieties, salt stress, K-foliar fertilization, physiological studies

INTRODUCTION

Wheat crop is one of the major cereals can grow in arid and semi-arid regions of the world. In saline environment, when salts are present in higher concentrations plant growth is affected negatively in various ways i.e. shoot and root dry weight O P and RWC, the development of salt tolerant plants depends on physiological basis, may be provided more understanding the term of tolerance. Hence many metabolic changes are known to occur in plants subjected to salt stress, physiological parameters such as O P and RWC, have been suggested for use tolerance indicators since they can be related to salt tolerance mechanisms (Ashraf and Waheed, 1993).

. The decrease in chlorophyll was interpreted to be attributed to the inhibition of chlorophyll synthesis as well as to accelerated turnover of chlorophyll already present. However, mild drought stress increased the chlorophyll content. Indeed the reduction caused by salt stress may be due to the effect of Na^+ which causes osmotic and metabolic problems for plants (Moreshat *et al.*, 1996). Although some of the physiological mechanisms which contribute to salt tolerance in plants are known, there are still some major gaps in understanding and it remains impossible to provide a satisfactory integrated picture for the plant as a whole (Micheal *et al.*, 1997).

In wheat, the photosynthetic depression under salinity and drought was found to be due to both stomatal and nonstomatal factors (Reddy *et al.*, 1998; Shabala *et al.*, 1998; Belkhodja *et al.*, 1999). Irrigation with saline water increased chlorophyll (a), chlorophyll (b), total chlorophyll and carotenoid concentrations in leaves of cotton plants of Giza 83 cultivar (Saeed, 2000). Shoot growth, leaf area and total dry weight of Sultana vines (*Vitis vinifera* L) were reported significantly reduced at all salinity levels (5, 25, 50 and 100 mM of NaCl). Photosynthetic rate and stomatal conductance were greatly reduced by salinity and highly correlated with leaf Cl^{-1} content (Fisarakis *et al.*, 2001). The fresh and dry matter yield of wheat seedlings were observed to be decreased at high salinization levels. With 90 mM NaCl which representing the threshold of salinity, soluble carbohydrates and total protein content of salt stressed seedlings were decreased (Radi *et al.*, 2001). RWC is considered as alternative measure of plant water status, reflecting the metabolic activity in tissues and used as a most meaningful index for identifying legumes with contrasting differences in dehydration tolerance (Sinclair Ludlow, 1986; Madhusudhan *et al.*, 2002). The underlying physiological mechanisms for salt resistance have not been fully identified or characterized (Munns, 2002 ; Apse and Blumwald, 2002). Under salinity conditions, photosynthetic depression into wheat plant was rapid and accompanied with a decline of the energy conversion efficiency in photosystem II (Muranaka *et al.*, 2002).Photosystem II activity and chlorophyll content were used as key parameters to assess photosynthetic performance .There was a marked variation in the photosynthetic rates and ribulose- 1,5 bisphosphate carpoxylase activity among five mulberry caltivars subjected to water stress. A better understanding of the mechanisms that enable plants to adapt to water deficit and maintain growth and productivity during the drought period will ultimately help in the selection of drought tolerant varieties. The effect of water stress on the activities of the photosynthetic enzymes is a secondary effect mediates by the produce CO_2 partial pressure inside the leaf caused by stomatal closure (Chaitanya *et al.*, 2003). Leaf injury of wheat growth under NaCl and Na_2SO_4 salinity, can be quantified by a number of methods such as chlorophyll content which can be measured with a SPAD meter. Turgor and osmotic adjustment are also indicators of leaf injury and Photosynthetic capacity (Iqbal, 2003). At vegetative growth stage increasing salinity decreased chlorophyll content and fresh weight of leaves, when used different salinity levels (0, 100, 200, 300 and 400 mM NaCl). Generally, the value of chlorophyll (total, a and b) decreased with increasing salinity level. The low salinity level (100 mM NaCl) reduced the three forms of chlorophyll to a lesser degree than the other treatment Sherif, 2005).

In the present study, the main objective was to define the physiological behaviors leading to induce salinity tolerant in wheat plant by potassium foliar fertilization under irrigation with saline water. Four wheat varieties viz. Sakha 93, Gimiza 9, Sids1 and Giza168, were investigated by measuring physiological characters. The study was extended to use the osmotic pressure and relative water content to distinguish between the varieties under saline and non-saline conditions. The other objective of the present study was to determine chlorophyll a, b and carotenoides in leaves as well as a/b as affected by saline water irrigation .These objectives would help to understand some of mechanisms of salt tolerance in wheat plant.

MATERIALS AND METHODS

A field experiment was carried out in the Experimental Farm of the Faculty of Agriculture, Suez Canal University, Ismailia Governorate, Egypt. The experiment was carried out during the season 2005-06, and its experimental design was a split split with three replicates. The seeds were sown in plots each 2×1 m, in rows 20 cm apart and 15 cm within the row, after farm yard manure had been applied at a rate of 20 m^3 fed^{-1}. N – fertilizer applied to all plots at a rate of 400 kg fed^{-1} as ammonium nitrate (33.5%N) in three equal split dressing after 15, 45 and 75 days from sowing. P-fertilizer was applied to all plots at rate of 200 kg fed^{-1} as superphosphate (15.5% P_2O_5) in two equal split dressing before sowing and after 15 days from sowing. K-fertilizer was applied to all plots at a rate of 100 Kg fed $^{-1}$ as potassium sulfate (48% K_2O) in three equal split dressings after sowing and after 30 and 60 days from sowing. The micronutrients were applied as a mixed fertilizer (Fe 3%, Zn 3%, Mn 3.5%) at a rate of 1 g l^{-1} of foliar spraying solution. The wheat plants were sprayed two times, i.e., after 25 days from sowing and at initial heading stage. The plants were sprayed till run-off and the volumes of spraying solutions ca 500 ml and one l $plot^{-1}$at the first and second applications, respectively.The main plots were devoted to varieties while irrigation water salinity levels were located in sub plots and potassium foliar rates were presented in sub sub plots.

Experimental Treatments

Four wheat cultivars were used viz, Sakha 93, Gimiza 9, Sids 1 and Giza 168. The origin of those four varieties is Egypt. The wheat plants were irrigated with saline water having four levels of salinity namely 0.4 (control), 2.5, 5 and 10 dSm^{-1}.

Foliar application of potassium was attained at the rates of 0, 3, 6 and 9 g fertilizer l^{-1} as soluble potassium sulfate (50% K_2O), every irrigated by saline water.

The main plots were devoted to varieties while irrigation water salinity levels were located in sub plots and potassium foliar rates were presented in sub sub plots.

Physiological Characters

Relative water content, leaf osmotic pressure and leaf pigment content (chlorophyll a, chlorophyll b and carotenoids) were assayed after 75 days from sowing.

Relative water content (RWC %):

Thirty discs were taken from flag leaf (Barrs, 1968), and calculated as follow:

$$\mathbf{RWC\% = [FW\text{-}DW)/ (TW\text{-}DW)] \times 100}$$

Where:

FW: fresh weigh, DW: dry weigh, TW: Turgid weigh

Leaf osmotic pressure was calculated by multiplying total soluble solids in leaf sap. (dSm^{-1}) by the factor 0.36 (Jackson, 1967).

Leaf pigment content were measured after Fadl and Sari EL- Deen, (1978).

Dry matter weight of shoot and root were measured after being oven dried at 70 °C.

RESULTS AND DISCUSSION

Figures(1 - 4) show that irrigation with different levels of saline water significantly reduced the chlorophyll contents (a, b, a+b) in the flag leaves and dry weights of shoot and root. The higher the level of irrigation water salinity the lower were the chlorophyll contents and dry weight of shoots and roots. This was true with all investigated wheat cultivars. However, an opposite trend was observed to be true regarding the chlorophyll a / b ratio. However, some exceptions are noticed to be existed within the trends of the presented data.

Relative water content % in the flag leaves was found to be decreased under the different levels of irrigation water salinity regardless the K applications, and the higher the salinity levels the lower was the relative water content %. This was found true with all investigated cultivars. However the salinity level of 5.0 dSm^{-1} showed an opposite trend for RWC% for the variety Giza 168 as a sensitive variety.

Osmotic pressure was observed to be decreased in leaf sap under high salt stress and the reverse proved to be correct under moderate salt stress.

Regardless the salinity effect, potassium foliar application caused the osmotic pressure to be increased, and the higher the potassium level, the higher was the osmotic pressure in leaf sap.

In general, the foregoing result trends were found to be consistent in field experiments and pot experiments (Ebtesam – El-Hosini,2009). In this respect,

Zerbi *et al.* (1990) reported that raising solute concentrations of the solution surrounding a plant's root reduces the water potential gradient between solution and root uptake. If the external water potential is lower (more negative) than internally, water uptake will cease. In the short term this will reduce growth, in the long term it will cause wilting and ultimately death. Garcia *et al.* (1997) indicated that NaCl reduced the growth of plants and caused chlorophyll loss in leaves in rice due to disrupted chloroplast integrity. Zeng and Shannon (2000) indicated that the reduction in seedling survival rates and growth are major causes of crop loss in salt – affected rice fields.

In addition,Yeo and Flower (1982) and Criddle *et al.* (1989) reported that NaCl reduces a variety of activities essential for respiration and photosynthesis due to dehydration, which denatured many proteins or membranes and ion displacement, in which the accumulating chemical compound replaces inorganic cofactors needed for some enzymes to work efficiently.

In the present study, the application of potassium proved to be generally promotive for the chlorophyll a, b and carotenoidies, shoot dry weight, root dry weight, R W C. and O P significant variations among the investigated cultivars were observed. Sakha 93 and Gimiza 9 were ranked as the most tolerant cultivars, While, sids 1 cultivar as moderate and Giza 168 as sensitive one.

Teaster and Davenport (2003) interpreted the reduction in physiological characters to be due to the effect of Na^+ which causes osmotic and metabolic problems for plants. Salt resistance is known to mean the ability of plants to grow satisfactorily in saline soil.

Munns *et al* (2006) reviewed important mechanisms of tolerance involve Na^+ exclusion from the transpiration stream, sequestration of Na^+ and Cl^- in the vacuoles of root and leaf cells, and other processes that promote fast growth despite the osmotic stress of the salt outside the roots. They reject the notion that a salt stress induced reduction in cellular turgid pressure is necessarily a primary cause of growth inhibition.

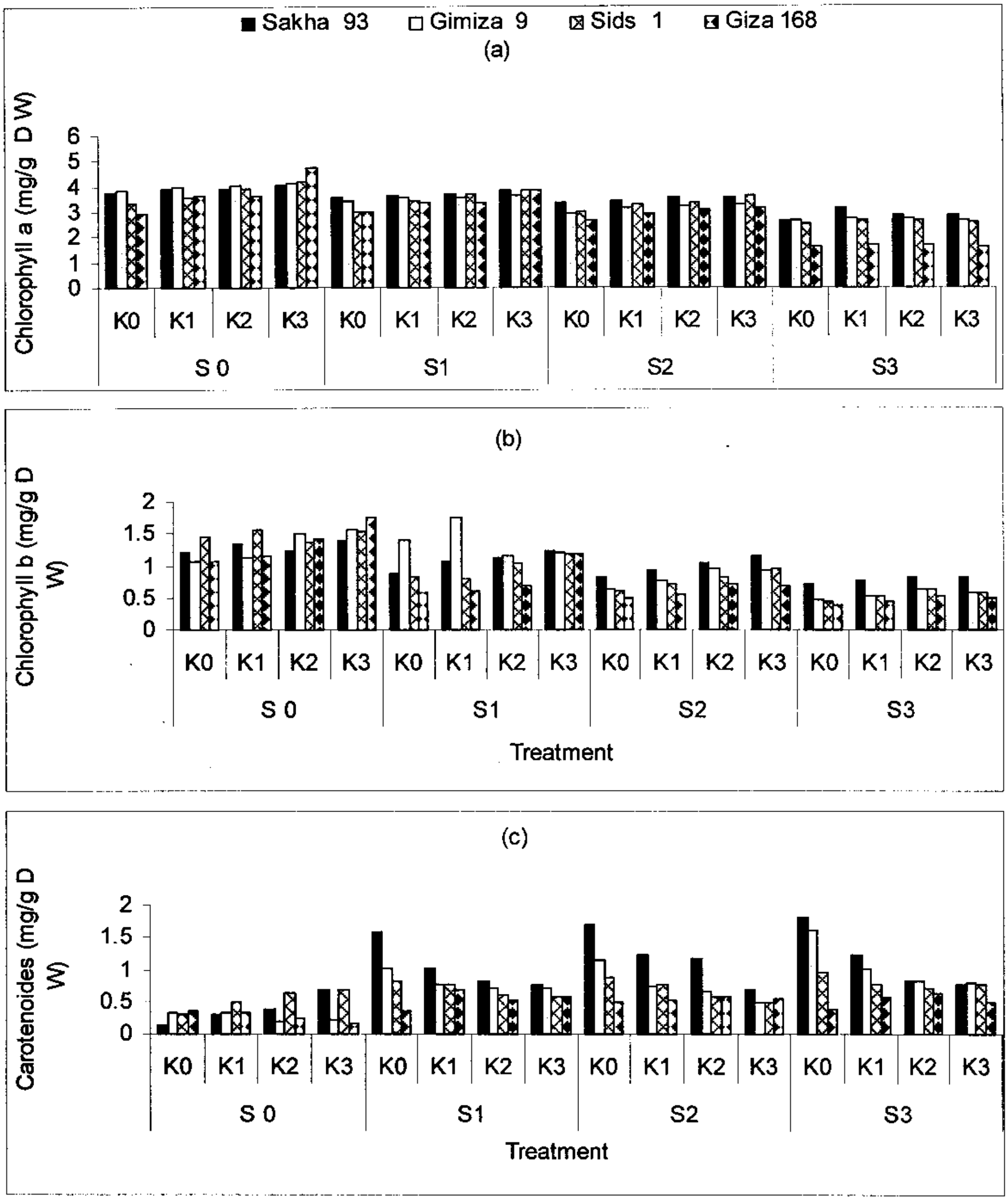

Fig (1): Effect of Salinity and Potassium Levels on (a) Chlorophyll a (b) ;Chlorophyll b and (c) Carotenoides.
S0, S1, S3 and S3 refer to irrigation water salinity at 0.4, 2.5, 5 and 10 dSm^{-1}, respectively.
K0, K1, K2 and K3 refer to K-foliar application rates of 0, 3, 6 and 9 g $K_2SO_4 l^{-1}$, respectively

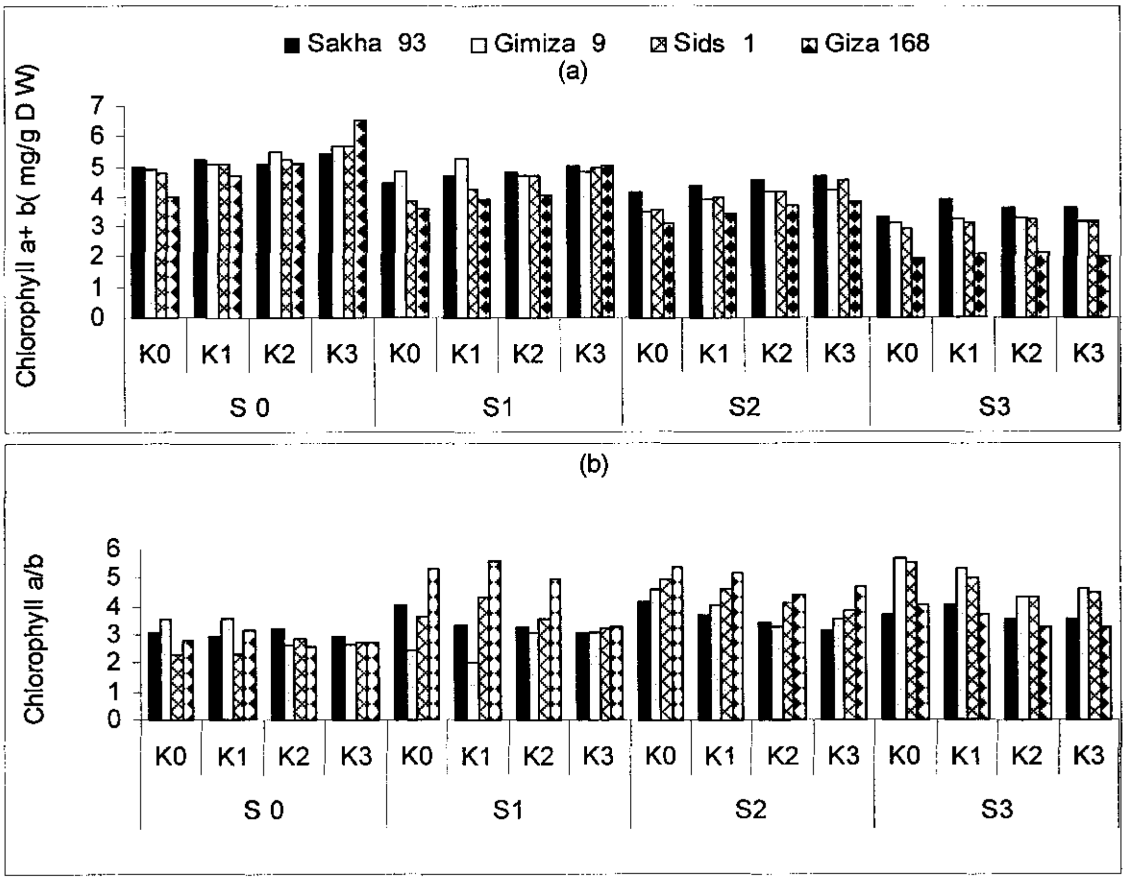

Fig. (2): Effect of Salinity and Potassium Levels on (a) Chlorophyll a/b and (b) Chlorophyll a/b .

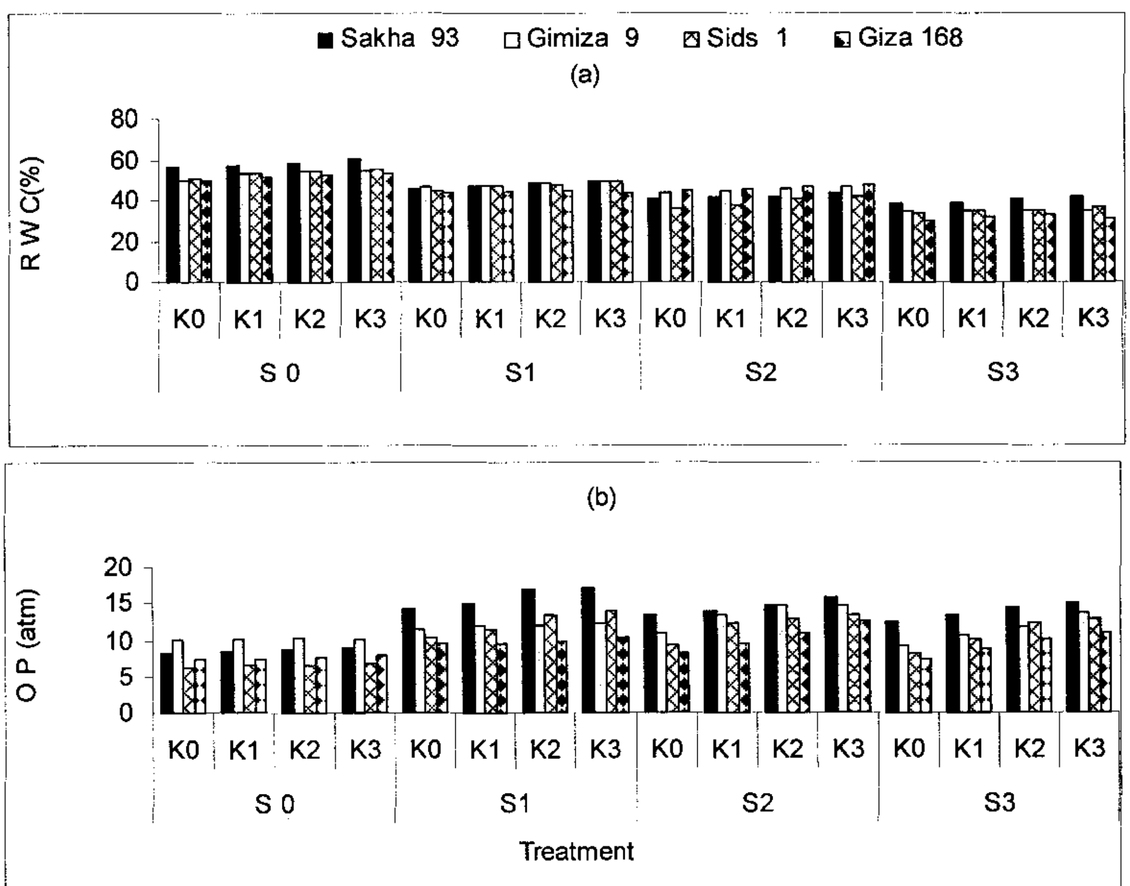

Fig (3): Effect of Salinity and Potassium Levels on(a) R W C and O P (b).

- S0, S1, S3 and S3 refer to irrigation water salinity at 0.4, 2.5, 5 and 10 dSm^{-1}, respectively; K0, K1, K2 and K3 refer to K-foliar application rates of 0, 3, 6 and 9 g $K_2SO_4l^{-1}$, respectively.

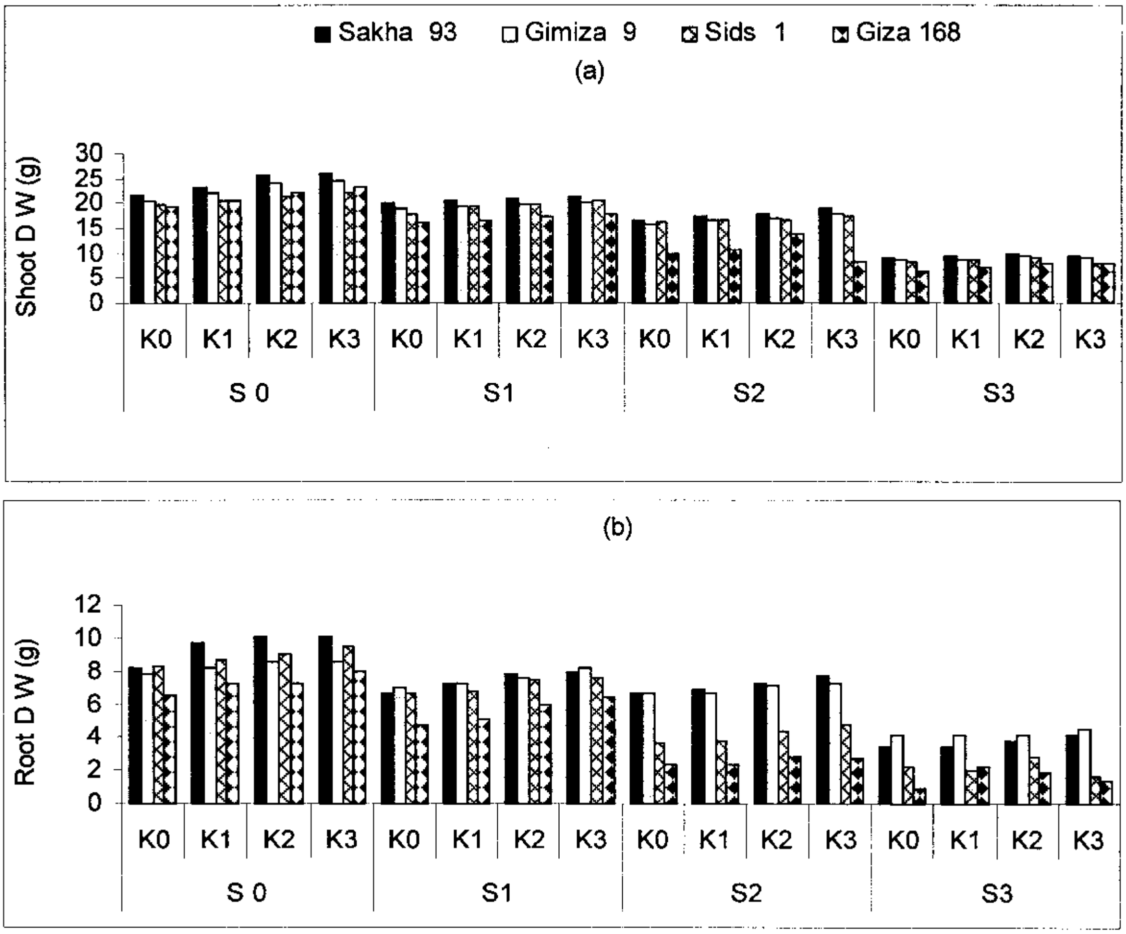

Fig (4): Effect of Salinity and Potassium Levels on (a) Shoot D Wt. and (b) Root D. Wt.(g).

- S0, S1, S3 and S3 refer to irrigation water salinity at 0.4, 2.5, 5 and 10 dSm^{-1}, respectively.
- K0, K1, K2 and K3 refer to K-foliar application rates of 0, 3, 6 and 9 g K_2SO_4 l^{-1}, respectively.

REFERENCES

Ashraf, M. and A. Waheed (1993). Responses of some genetically diverse lines of chickpea (*Cicer arietinum L.)* to salt. Plantl Soil, 154:257 -266

Barrs, H. D. (1968). Determination of water deficits in plant tissues. P.235-368. In T.T. Kozlowski (ed.) water deficits and plant growth .Vol. I . Academic Press,New Yourk.

Belkhodja, R., F. Morales, A. Abadia and H. Abadia (1999). Effects of salinity on chlorophyll fluorescence and photosynthesis of barley (*Hordeum vulgare* L.) grown under a tripleline-source sprinkler system in the field. Photosynthetica 36:375-378.

Chaitanya, K. V., P. P. Jutur, D. Sundar and A. Ramachandra (2003). Water stress effects on photosynthesis in different mulberry cultivars. Plant Growth Regulation, 40:75-80.

Colom, M. R. and C. Vazzana (2001). Drought stress effects on three cultivars of *Eragrostis curvula:* Photosynthesis and water relations. Plant Growth Regulation, 34: 195-202.

Criddle, R., L. Hansen, R. Breidenbach, M. Ward and R. Huffaker (1989). Effects of NaCl on metabolic heat evolution rates by barley roots .Plant Physiol. 90:53-58.

EL-Housini, E. A. E. (2009). Physiological and biochemical studies on wheat plant grown under salt stress conditions, PH D Thesis.

Fadl, M. S. and S. A. Sari El-Deen (1978). Effect of N-benzyl adenine on photosynthetic pigments and total soluble sugars of olive seeding grown under saline condition. Egypt. J.Hort., 6:169-183.

Fisarakis, I., K. Chartzoulakis and D. Stavrakas (2001). Response of Sultana vines (V. *vinifera* L.) on sex root stocks to NaCl salinity exposure and recovery. Agric.Water Management, 51: 13 -27.

Garcia, A., C. A. Rizzo, J. Ud-Din, S. L. Bartos, D. Senadhira, T. J. Flowers and A. R.Yeo (1997). Sodium and potassium transport to the xylem are inherited independently in rice and the mechanism of sodium: potassium selectivity differs between rice and wheat . Plant Cell Envi. 20:1167-1174.

Iqbal, R. M. (2003). Leaf extension growth of wheat growth under NaCl and Na_2 SO_4 salinity. Asian J. of Plant Sci. 2: 1092-1096.

Jakson, M. L. (1967). Soil Chemical Analysis. Prentice Hall, Inc., Englewood Cliffs, N.J., Library of congress,USA.

Madhusudhan, K. V., S. Giridarakumar, G. S. Ranjanayakulu, P. Chandraobul and C. Sudhakar (2002). Effect of water stress on some physiological responses in two groundnut (*Arachis hypogaea* L.) cultivars with contrasting drought tolerance. J. Plant Biol. 29: 199-202.

Micheal, F. R., A. A. Very, D. Sanders and T. A. Mansfield (1997). How can stomata contribute to salt tolerance? Ann. Botany 80: 387-393.

Moreshat, S., D. C. Bridges, D. S. Nesmith and B. Huang (1996). Effect of water stress on competitive interaction of peanut and sicklepod. Agron. J. 88: 636-644.

Munns, R. (2002). Comparative physiology of salt and water stress. Plant, cell and environ.25: 239-250.

Munns, R., R. A. James and A. Läuchli (2006). Approaches to increasing the salt tolerance of wheat and other cereals. J. Exp. Botany, 57: 1025-1040.

Muranaka, S., K. Shimizu and M. Kato (2002). Ionic and osmotic effects of salinity on single –leaf photosynthesis into wheat cultivars with different drought tolerance. Photosynthetica 40(2)201-207.

Radi, A. F., M. A. R. Shaddad, A. E. EL-Enang, F. M. Omran and W. J. Horst (2001). Interactive effect of plant hormones (GA_3 or ABA) and salinity on growth and some metabolites of wheat seedlings, Fourteenth International Plant Nutrition Colloquium, Honnover,Germany 436-437

Reddy P. S., S. Ramanjulu, C. Sudhakar and K. Veeranjaneyulu (1998). Differential sensitivity of stomatal and non stomatal components to NaCl and $Na_2 SO_4$ salinity in horsegram, *Macrotyloma uniflorum*. Photosynthetica.53:99-105.

Saeed, M. A. (2000). Effect of irrigation with saline water of on cotton plants of Giza 83 cultivar. Egypt. J. Agric. Res. 78:2029 -2045.

Shabala, S. N., S. I. Shabala, A. I. Martynenko, O. Babourina and I. A. Newman (1998). Salinity effect on bioelectric activity, growth, Na^{-} accumulation and chlorophyll fluorescence of maize leaves: a comparative survey and prospects for screening. Aust. J. Plant physiol. 25:609 -616.

Sherif, F. K. (2005). Comparative performance of some wheat (*Triticum aestivum l.*) genotypes in trace elements composition under salinity stress. Alex. J. Agric. Res. 50: 131-139.

Sinclair, T. R. and M. M. Ludlow (1986). Who taught plants thermodynamics? The unfulfilled potential of plant water potential. Aust. J. Plant Phsiol. 12: 213 -217.

Teaster, M. and R., Davenport (2003). Na tolerance and Na transport in higher plants. Ann. of Bot. 91:503-527.

Yeo, A. R. and T. J. Flowers (1982). Accumulation and location of sodium ions within the shoots of rice varieties differing in salinity resistance. Physiol. Plant. 56:343-348.

Zeng, L., M. Shammom and C. M. Grieve (2002). Evaluation of Salt to Lerance in rice genotypes by multiple agronomic parameters. Euphytica. 127: 235-245.

Zerbi, G., D. Lecain and J. Morgan (1990). Concurrent action of salinity and water stress on leaf gas exchange and water relations of tomato. J. Hort.Sci.,65:675-681.

تأثير الإجهاد الملحي على السلوك الفسيولوجي في أربعة أصناف من القمح

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** قسم بحوث المحاصيل -شعبة البحوث الزراعية والبيولوجية-المركز القومي للبحوث

أجريت تجربة حقلية خلال موسم ٢٠٠٥-٢٠٠٦ لمعرفة السلوك الفسيولوجي الذي يؤدى لتحمل الملوحة في النبات من خلال الرش بمعدلات من البوتاسيوم هي المقارن و ٣ و ٦ و ٩ جرام / لتر k_2SO_4 تحت مستويات مختلفة من الماء المالح وهي المقارن و ٢,٥ و ٥ و ١٠ ديسي سيمينز / م وكانت الأصناف المستخدمة تحت الدراسة (سخا ٩٣ وجميزة ٩ و سدس ١ وجيزة ١٦٨) . تم إنماء هذه الأصناف حتى مرحلة النضج في تربة رملية بمزرعة كلية الزراعة بالكيلو ٤,٥ بمحافظة الإسماعيلية . تم تقدير المادة الجافة للمجموع الخضري و الجذري والضغط الأسموزي والكلوروفيل أ و ب والكاروتينيدات. بصفة عامة تطبيقات البوتاسيوم أدت إلى تحسن في المحتوى من هذه المكونات السابقة وكان هناك اختلاف واضح بين الأصناف تحت الدراسة وتم وصف الصنف سخا ٩٣ و جميزة ٩ كصنفين متحملين وسدس ١ كصنف متوسط وصنف جيزة ١٦٨ كصنف حساس.