Journal of Applied Sciences Research, 9(8): 4589-4596, 2013
ISSN 1819-544X
This is a refereed journal and all articles are professionally screened and reviewed

ORIGINAL ARTICLES

Response of Some Wheat Cultivars to Salinity and Water Stress

[1]E.E. Kandil, [2]R. Schulz and [2]T. Müller

[1]Plant production Department, The Faculty of Agriculture Saba Basha, Alexandria University, Egypt.
[2]Deparment of Plant Nutrition, Universität Hohenheim (330), 705939 Stuttgart, Germany.

ABSTRACT

A pot trial was executed on three wheat cultivars (Sakha 93, Gemieza7 and Giza 168) grown in clay soil under saline conditions and water stress at the greenhouse of Plant Nutrition Institute, Hohenheim University, Stuttgart, Germany, to determine the individual and the combined effect of salinity and water stress on wheat growth and evaluate the best wheat cultivar under the different salinity levels and water stress. Randomized complete block design was applied as salinity levels (0, 50, 100 and 150 mM NaCl) occupied in main block, water stress (irrigated every day, after 4 and 8 days) assigned in subplot and distributed the cultivars in sub subplot in the pot. Germination percentage, plant height, leaf area, fresh and dry weight, and Na and Cl concentration were determined. The results showed that salinity and water stress had highly significant differences on all the studied characteristics under study conditions, whereas Salinity and water stress decreased germination percentage, plant height, total weight, and shoot weight, and increased Na and Cl concentration significantly in shoots. The cultivar Sakha 93 and Gemmieza 7 surpassed other cultivar (Giza 168) under salinity and water stress in the most of characteristics.

Key words: wheat; cultivars; salinity; water; stress; germination; fresh; dry; Na; Cl.

Introduction

Wheat (*Triticum aestivum* L.) is an important staple food crop in the world including Egypt. According to FAO (2009), wheat is the leading food grain crop covering an area of about 1.2 million hectares with an annual production of 8 million tons. Egypt however still imports about 6 million tons of wheat to cover its consumption. An important objective of the Egyptian government is consequently to reduce the dependence on imported wheat by enhancing grain yield production and cultivating modern wheat cultivars in new reclaimed soil which suffer from salinity also, clay soil as old soil gains salinity from water irrigated salinity and with drought.

An option to cope with higher population densities in developing countries is to increase productivity of cultivated land. This makes also understanding of environmental stress phenomena and related tolerant mechanisms more important in countries such as Egypt. Soil salinity is one of the major problems for agriculture in semi- arid regions. In Egypt, plants are subjected to extreme climatic factors such as high temperatures and drought. Under these conditions, dissolved salts may accumulate in soils because of the insufficient leaching of ions. An accumulation of salt in upper soil layers may be also due to a unsuitable irrigation management (Amal Mohamed *et al*., 2007).

For these reasons we think of the effect of salinity and water stress on some Egyptian wheat cultivars. Salinity decreased leaf area, dry weight per plant significantly at all growth stages. The Egyptian genotypes as Sakha 8 and Sakha 93 and the Indian genotype Kharchia were ranked as the most tolerant to salinity. A change in salt tolerance with growth stages was observed for the genotypes as Sids 1, Gemmieza 7 and Westonia. Drysdale and Sakha 69 were ranked as moderate tolerant. The remaining genotypes showed the lowest tolerance to salinity at all growth stages (El-Hendawy *et al*., 2004). Tillers may have the function of the collective defense. The tillers could control the plant salt tolerance by the sub tillers because they accumulate higher Na^+ and Cl^- than the main stem tiller, which lead to the greater difference in the growth between main stem tiller and sub- tillers. Under saline conditions, the accumulation of mineral contents as well as tiller growth in tillers can be regulated by the different tiller number per plant. In the salt-tolerant cultivar, the exclusion of toxic ions in the individual tiller proposes that more tillers enhance the plant salt tolerance, while in the salt-sensitive cultivar, fewer tillers are better to enhance the tiller growth of wheat plants because the tissue tolerance to toxic ions is increased (Ruan, 2007). Throughout the whole reproductive period, it was noted that net photosynthetic rate, stomatal conductance, pigment contents, ions contents, leaf area index, leaf area duration, leaf relative water content and dry matter accumulation of spikes decreased in both cultivars with saline concentrations increasing.

Corresponding Author: Essam Esmail Kandil, Plant production Department, The Faculty of Agriculture Saba Basha, Alexandria University, Egypt.
E-mail: essam.kandil@yhoo.com /essam.kandil@gmail.com

However, the DK961, salt-tolerant cultivar showed none significant reductions in those parameters compared with control under 0.3% and 0.5% salt concentrations, with only considerable decrease happening when soil salt concentration exceeded to 0.7%. Sharply contrast to salt-tolerant cultivar, the JN17, salt-sensitive cultivar appeared linear reductions in physiological parameters under a series of salt concentrations (0.3%, 0.5% and 0.7%), with the photosynthetic duration being evidently shorter (Zheng *et al*., 2007). In shoots, dry matters was either unchanged or even stimulated to increase toward 180 mM NaCl then a quick reduction was observed. They assumed that it is associated with the increase of leaf area up to 180 mM NaCl. Na^+ content increased significantly in shoot (Amel Tammam *et al.*, 2008).

Different level of salinity significantly affected the growth attributes by reducing shoot length for salinity below 125mM. Fresh and dry weights of shoots were reduced significantly with subsequent treatment. Regarding germination maximum germination was found in variety HD2689 in all the treatments and maximum inhibition was found to be in case of HOW234 variety at 150mM salinity level (Datta *et al.*, 2009). Concentrations of Na^+ and Cl^- of shoots of all the three cultivars were increased with the increasing level of NaCl (Gurmani *et al.*, 2009). Abiotic pressures like salt stress can impose limitations on crop productivity and limit land available also for farming. Often in regions that can ill afford such constraints, thus highlighting a greater need for understanding how plants respond to adverse conditions with the hope of improving tolerance of plants to environmental stress (Joseph *et al*., 2010). Likewise, sea water at 10% and 25% caused noticeable reduction in almost all growth criteria of root, shoot and flag leaf which was consistent with the progressive alteration in water relations (RWC & SWD) , protein and nucleic acids (DNA and RNA) contents of tested varieties during grain filling. Furthermore, degree of leaf succulence and degree of leaf sclerophylly were severely affected by seawater stress in both wheat cultivars. The magnitude of reduction was more obvious at higher salinity levels than the lower one particularly in Gemmieza-9 (Aldesuquy *et al*., 2012).

Irrigation is the most important factor in determining bread wheat (*Triticum aestivum* L.) growth and yield. Many investigators indicated that there was different response of wheat cultivars to water stress. The model prediction gave good agreement with actual yield, for two varieties over both growing seasons. Results, also, indicated that the yield of both varieties was reduced under deducting 20 % of irrigation water by 8.62 and 8.76 % for Sakha 93 and Giza 168, each in turn. Furthermore, using saline water for irrigation; reduced wheat yield by 4.14 and 4.38 % for Sakha 93 and Giza 168, respectively. Water consumptive use under total irrigation was reduced by 18.54 and 11.64% for both growing seasons, respectively, under saving 20 % of total water irrigation (Samiha Ouda, 2007). Sakha 93 was more tolerant to water stress than Giza 168, where yield reduction under skipping irrigation at milk stage where 14.2 and 34.5 % for Sakha 93 and Giza 168, consecutively. Whereas, skipping irrigation at maturity stage reduce grain yield by 12.9 and 24.3% for Sakha 93 and Giza 168, in series (Ouda *et al.,* 2007).

The present study was carried out to determine the individual and the combined effect of salinity and water stress on wheat growth, yield and its components and evaluate the best wheat cultivar under the different salinity levels and water stress.

Materials and Methods

A pot experiment was conducted, in greenhouse at Institute of Plant Nutrition, University of Hohenheim, Stuttgart, Germany during season 2010. The soil of the experimental pot was clay loam and PH=8.2. A randomized complete block design (RCBD) with four blocks were followed where four salinity levels (NaCl) occupied the main plots, whereas water stress traits were allocated in the sub plots and three wheat cultivars (Sakha 93, Gemmieza 7, and Giza 168 were distributed randomized in the sub –sub plots. Four salts levels (control (0), 50, 100 and 150 mM NaCl) in the soil were applied. The salinity levels of 50, 100 and 150 mM NaCl in soil solution were equivalent to an electrical conductivity of 8, 13 and 17 dSm^{-1}, respectively, which were measured at the beginning of the experiment. During the period of the experiment, the electrical conductivity at each salinity level slightly decreased due to the uptake of salt by plants. At the end of the experiment, an electrical conductivity was changed to 5, 9 and 13dSm^{-1}, respectively. The final water content (26% on dry soil basis) was achieved by adding tap water to each pot. The salinity levels was applied at the amount of the soil and mixed the soil completely before wheat plants seeding. 16 seeds were sown in each pot on the 1st of October. 4 weeks after sowing, the seedlings were thinned to 10 per pot. The water stress levels were applied in 3 levels normal irrigation (every day), shortage of irrigation (delay 4 and 8 days delay). The N, P, K and Mg were applied before wheat seeding as 3.1 g from NH_4NO_3, 1.5 g from $Ca(H_2PO_4)_2H_2O$, 2.1 g K_2SO_4 and 1.0 g from $MgSO_4$ per pot. During the experiment, the pots were weight daily and the water loss was replaced by adding tap water when total amount of water lost to avoid suffering either drought in the normal irrigation or flooding. Salt tolerance and water stress of crops may vary with their growth stage. Therefore, the measurement was carried out at vegetative, reproductive and grain maturity stages. Plants from each pot were harvested after 60 days in high salinity (150 mM NaCl) treatments and in other salinity treatments after 105days. Vegetative growths of wheat plants are characterized as plant height and leaf area were recorded. Leaf area measured according to the method described by Radford (1967) from this equation, LA = K (L x B), where: LA= leaf area (cm^2), K= Constant (0.75), L= leaf length (cm), B = Maximum leaf width (cm). The total fresh weight was determined, after that the samples were dried until the constant weight to determine the total dry weight. When plants were in the reproductive stage, three plants from each pot were harvested. Plants were separated into leaves with stacks. Shoots fresh weight and dry weight were determined as above. All plants from each pot were harvested. Na and Cl concentration in shoots were determined.

Data were statistically analyzed as randomized complete block (RCBD) design experiments, using the RCBD model as obtained by CoStat 1998-2005.Means were compared according to Fisher test at (p=0.05) least significant difference (LSD) to estimate the significant differences among treatments (Steel and Trrie, 1982).

Results and Discussion

Levels and the various studied characters (i.e. germination %, plant height (cm), plant leaf area (cm^2), and shoot weights); main while, it was proportional relationship with Na^+ and Cl^- contents. However the obtained results will be presented as follows:

1- Germination percentage:

Generally, data of table (1) indicated that there was a reverse relationship between the salinity. However increasing salinity levels from 0 to 150 mM NaCl caused reduction in germination %, whereas 150 mM NaCl had high decreasing in germination % as compared with control treatment, followed by 100 mM and 50 mM NaCl, but control had the highest values from germination %. As for cultivars' factor, there was significant difference among the three wheat cultivars as affected negatively by increasing salinity levels on germination %. Obtained data declared that Sakha 93 cultivar seemed to be more tolerant than the other two cultivars; whereas, it had the highest germination %. Meanwhile, Giza 168 cv. more sensitive to salt stress which it had the lowest germination %. While, "Gemmieza 7" was moderate for salt tolerant.These results were in good harmony with those obtained by Datta *et al., (*2009); Bahrani and Hagh Joo (2012) and Kandil *et al.* (2012).

2- Plant height (cm):

The effect of salinity and water stress on wheat plant height depicted in Table (1), declared that there was significant difference among the three levels from salinity (50, 100 and 100 mM NaCl) reduced plant height as compared with control level. For instance, control level (0.0 mM NaCl) resulted in the highest mean value of plant height. Concerning the effect of water stress on wheat plant height, increasing in irrigation period (after 8 days) had significant reduction of plant height followed by irrigation after 4 days as compared with normal irrigation which had longest plant height. Also, the cultivar "Sakha 93" had the tallest plants under greenhouse condition while "Giza 168" cultivar had the shortest height. However, there was no significant difference between both cultivars Sakha 93 and Gemmieza 7 in this parameter under study conditions. These results are in conformity with those obtained by Aldesuquy *et al*., 2012.

3- Plant leaf area (cm^2):

The data was obtained in Table (1), there was significant difference among the three levels from salinity (control (0), 50 and 100 NaCl) on leaf area and 100 mM NaCl reduced plant height as compared with other levels from salinity. 0 mM NaCl had highest leaf area. The effect of water stress on leaf area had highly significant. DeLay irrigation 8 days had the lowest leaf area followed by irrigation after 4 days as comparison with normal irrigation which had biggest area. Sakha93 had the highest value from leaf area while Giza 168 had smallest area. There was no significant difference between Sakha 93 and Gemmieza 7 in leaf area. There was significant interaction effect between salinity and water stress. Similar findings have been reported by many authors (El-Hendawy *et al*., 2004 and Amel Tammam *et al*., 2008).

4- Shoots' weight (fresh and dry):

Table (1) shows effect of salinity and water stress on fresh and dry weight of shoots, there was significant difference between the three salinity levels (control (0), 50 and 100 NaCl) and 100 mM NaCl reduced fresh and dry weight of shoots as compared with other salinity levels. The highest weights of fresh and dry were recorded with control treatment. Delay irrigation 8 days had significant reduction of shoots weight (fresh and dry) followed by irrigation after 4 days as comparison with normal irrigation which had heaviest weight. Sakha93 had the heaviest weight of shoots (fresh and dry). Giza 168 had the lowest fresh and dry weight. There was no significant difference between Sakha 93 and Gemmieza 7 in fresh and dry weight.

5- Na^+ and Cl^- concentrations:

The effect of salinity and water stress on Na and Cl concentration showed in Table (1), there was significant difference among the three levels from salinity (control (0), 50 and 100 NaCl) and 100 mM NaCl increased Na and Cl concentration as compared with other levels from salinity. The highest concentration of Na and Cl in shoots was obtained from control treatment. Increasing in irrigation period (8 days delay) had significant increasing of Na and Cl concentration followed by irrigation after 4 days as comparison with normal irrigation which had lowest Na and Cl concentration. Sakha93 had lowest value of Na and Cl concentration in shoots. Giza 168 had lowest Na and Cl concentration. There was no significant difference between Sakha 93 and Gemmieza 7 in Na and Cl concentration. These results were in agreement with those of many authors (Ruan, 2007, Amel Tammam *et al*., 2008, Gurmani *et al*., 2009, Ghogdi *et al*., 2012, and Shamsi and Kobraee, 2013) and explain the reason of this effect.

Table 1: Germination %, plant height, and leaf area, shoots weight (fresh and dry), and Na and Cl concentration in shoots of three Egyptian wheat cultivars as affected by salinity and water stress.

Treatments	Germination %	Plant height (cm)	Plant leaf area (cm^2)	Shoot weight		Na concentration mg g^{-1} DM	Cl concentration mg g^{-1} DM
				Fresh (g)	Dry (g)	Shoots	Shoots
	Salinity (S)						
0 mM NaCl	98.9 a	34.1 a	53.0 a	13.3 a	5.8 a	2.00 c	2.90 c
50 mM NaCl	87.3 b	32.1 b	42.9 b	12.8 a	5.3 b	49.7 b	47.1 b
100 mM NaCl	76.6 c	22.5 c	24.4 c	10.1 b	3.1 c	58.5 a	68.9 a
150 mM NaCl	72.6 d	-	-	-	-	-	-
Water stress (W)							
Normal irrigation	-	32.8 a	56.8 a	13.1 a	5.3 a	31.7 c	35.7 c
Delay 4 days	-	28.6 b	38.7 b	11.8 b	4.8 b	35.5 b	38.4 b
Delay 8 days	-	25.2 c	24.9 c	11.2 b	4.2 c	43.1 a	44.8 a
Wheat cultivars (C)							
Sakha 93	86.0 a	31.5 a	44.5 a	13.3 a	5.4 a	42.6 a	36.8 b
Gemmieza 7	84.3 a	31.1 a	42.2 a	12.2 b	4.9 a	37.3 b	38.1 b
Giza 168	81.2 b	26.1 b	33.7 b	10.8 c	3.9 b	33.4 c	44.1 a
Interactions (x)							
S x W	-	**	**	N.S	**	**	N.S
S x C	N.S	N.S	N.S	N.S	N.S	N.S	N.S
W x C	-	N.S	N.S	N.S	**	N.S	N.S
S x W x C	-	N.S	N.S	N.S	N.S	N.S	N.S

Means values in the same column marked with the same letters are not significantly difference at 0.05 level of probability (Duncan΄s, p<0.05). N.S. = not significant. ** = significant. - = Not applicable.

The interaction effect between salinity and water stress has significant. For example, there was interaction effect between salinity levels and water stress on plant height, leaf area and shoots dry weight; whereas the highest mean values resulted from 0 mM NaCl and normal irrigation but the lowest values was obtained from 100 mM and delay irrigation 8 days, as shown in Figure (1, 2 and 3). Also, there was significant interaction effect between water stress and cultivars on shoots dry weight. Sakha 93 under normal irrigation recorded the highest weight of dry shoots but Giza 168 under delay irrigation 8 days gave the lowest dry weight, Figure (4). While, there was interaction effect between salinity and water stress on Na content in shoots. The lowest Na content in shoots was resulted from 0 mM NaCl and normal irrigation. The highest Na content shoots was obtained from 100 mM and irrigation after 8 days Figure (5).

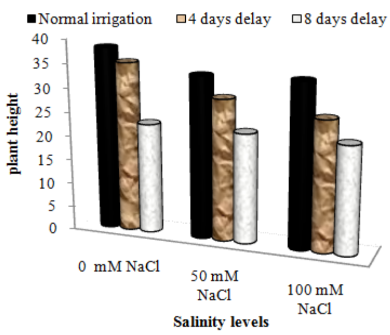

Fig. 1: Means of wheat plant height as affected by salinity and water stress.

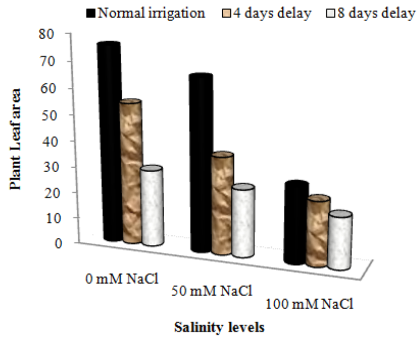

Fig. 2: Means of wheat leaf area as affected by salinity and water stress.

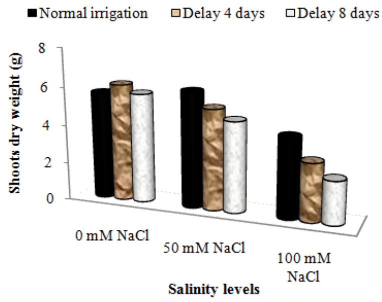

Fig. 3: Means of shoots dry weight as affected by salinity and water stress.

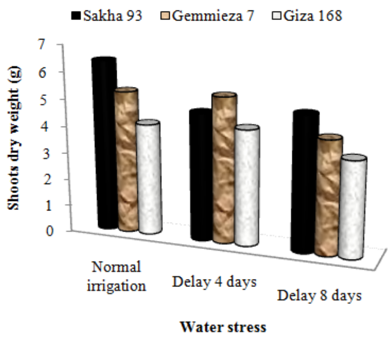

Fig. 1: Means of shoots dry weight of three wheat cultivars as affected by water stress.

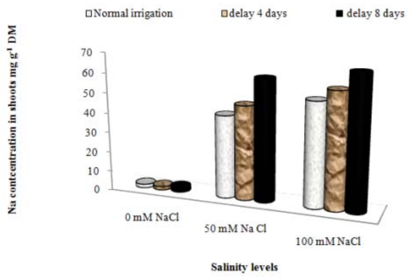

Fig. 5: Means of Na concentration in shoots as affected by salinity and water stress.

Data in Table (2) show that there were significant differences between the tested three wheat cultivars on the studied characters; i.e., plant height, leaf area (cm^2), and shoots fresh and dry weights at highest level of salinity NaCl (150 mM), whereas, the wheat cultivars "Sakha93" and "Gemmieza 7" had the highest the values of various studied characters. On the contrary, "Giza 168 cv." had the lowest ones. There was no significant difference between both cultivars "Sakha 93 and Gemmieza 7" in general. Meanwhile, the cultivar "Giza 168 cv." had highest concentration from Na and Cl in the shoots. "Sakha 93" cultivar had lowest Na and Cl content. There was no significant difference between Sakha 93 and Gemmieza 7 in Na and Cl concentration. These may explain why growth is slowed under salt stress and water stress (El-Hendawy *et al*., 2004, Datta *et al*., 2009, Bahrani and Hagh Joo, 2012 and Kandil *et al*., 2012).

Table 2: Plant height, leaf area, fresh weight, dry weight, Na and Cl concentration in shoots of three Egyptian wheat cultivars as affected by salinity stress.

Characteristics							
Salinity	Cultivars	Plant height (cm)	Leaf area (cm^2)	Fresh weight (g)	Dry weight (g)	Na concentration in shoots (mg g^{-1} DM)	Cl concentration in shoots (mg g^{-1} DM)
150 NaCl	Sakha 93	12.2 a	14.8 a	4.6 a	3.0 a	46.9 b	61.4 b
	Gemmieza7	11.3 a	12.3 a	4.5 a	2.7 a	51.8 b	69.5 b
	Giza 168	8.2 b	7.2 b	3.4 b	2.1 b	76.7 a	95.5 a

- Means values in the same column marked with the same letters are not significantly difference at 0.05 level of probability (Duncan's, p<0.05). - N.S. = not significant. - ** = significant.

Based upon the presented results, discussion could be provided as follow:

In general, germination percentage was decreased with increasing salinity up to 8 dS m NaCl. The decrease in radicle length was more pronounced as compared to root in all NaCl salt treatments; however this decrease was more prominent in Dez cultivar than others. Great inhibition in root length was also recorded in Yavarous. Inia, Kavir and Chamran cultivars indicated the highest salt tolerance, while Dez, Vinak, Cross Adl and Star cultivars showed the lowest ones. In general, it can be concluded that to select cultivars for better salt stress tolerance at seedling stage coleoptile and root elongation may be used as breeding criterions. More vigorous cultivars like Inia and Kavir could be considered as plant materials which are useful to breeders for future development of salt tolerant wheat cultivars (Bahrani and Hagh Joo, 2012). Na^+ content in all the genotypes and in both stages were increased. Bahar showed the highest Na+ content and the most reduction in yield, so it can be considered as more salt sensitive than Tajan genotype (Ghogdi *et al*., 2012).

Salinity concentrations significantly varied in all germination parameters under study except shoot dry weight character. Increasing salinity concentrations from 0 to 14 dSm^{-1} gradually decreased average of germination and seedling characters. It could be concluded that for maximizing wheat germination percentage and seedling parameters under salinity stress are recognized by using Sakha 93, Sakha 94 and Gemmeza 10 cultivars with increasing salinity concentrations levels up to 14 dS m^{-1}. Among the cultivars under investigation Sakha 93 and Sakha 94 cultivars appeared to be more tolerant to salinity at germination stage compared with other cultivars (Kandil et *al*., 2012). Increasing concentration of NaCl solution resulted in gradual reduction in seed germination and suppression of early seedling growth in all wheat cultivars. However, pronounced differences regarding salinity tolerance were observed among three wheat cultivars. Millat-2011 recorded least (11-40%) suppression in final germination percentage at different salinity levels as compared to 10-86% and 19-72% reduction observed for AARI-2011 and Sehar-2006, respectively. Millat-2011 also suffered less reduction in seedling dry biomass (21-43%) than 29-97% and 14-86% recorded for AARI-2011 and Sehar-2006, respectively. Millat-2011 appeared superior to Sehar-2006 and AARI-2011 due to its better germination and early seedling growth even at high salinity levels. Millat-2011 may tolerate moderate levels of salinity and may be tried for its field appraisal for cultivation on marginal salt affected lands (Hussain *et al*., 2013). The negative effect of salinity on plant was due increasing Na+ content in the leaves .The most this traits was observed at the Chamran cultivar but the highest sodium content belonged to Shahryar cultivar. The most tolerant and stable was Chamran cultivar that had highest yield on salinity level of 16 dSm^{-1} to other cultivars (Shamsi and Kobraee, 2013).

Environmental stress, especially drought stress, can play an important role in the reduction of the plant growth stage, specifically during germination in arid and semi arid regions. Results indicated significant differences among cultivars, and drought stress levels. In all traits, a significant decrease was observed with increase in stress level (Jajarmi, 2009). Water stress significantly reduced the plant height of all 25 wheat varieties. The varieties Sarsabz and Kiran-95 showed significantly good performance than other wheat varieties in control as well as at terminal drought stress (Mirbahar *et al.*, 2009). Fourteen wheat cultivars were grown under well watered and natural drought conditions. Morphological traits were measured at anthesis and yield, yield components and quality traits were evaluated at ripening time (Kiliç and Yağbasanlar, 2010). Water stress caused reduction in leaf relative water contents, water potential, osmotic potential, turgor potential, growth and yield components of both the wheat cultivars. Consecutive stresses at both growth stages caused severe reduction in yield and yield components in both cultivars of wheat (Akram 2011). Stress was imposed by withholding irrigation at three different growth stages of plant i.e., vegetative, anthesis and vegetative + anthesis (Khan and Naqvi, 2011). Highly significant differences among means of wheat varieties in all physiological and yield traits. Almost all varieties showed their best adaptation under stressed environment however Hashim-8 and Zam-04 behaved exclusively (Khakwani *et al*., 2012). Significantly highest germination stress tolerance index recorded in Lasani-2008 and lowest was recorded in Auqab-2000 under water stress. Dry matter percentage was recorded significantly highest in pasban-90 while the lowest dry matter percentage was observed in auqab-2000. FSD-2008 gained maximum plant height and was recorded minimum in Inqilab-91. Relative saturation deficit was significantly highest in Auqab-2000 while the significantly lowest relative saturation deficit was recorded in case of Lasani-2008. It was concluded from the results that Lasani-2008 performed better under drought and Auqab-2000 was recorded most drought sensitive variety (Raza *et al*., 2012). Large differences between the studied cultivars in both leaf elongation and drying of the second leaf, and these differences were largely in agreement with the available information about the behavior of the cultivars under drought in the field (Monica David, 2013). Most of growth characters, grain yield and its components of Sakha93 cultivar were greater than Giza 168 under both stressed and non – stressed conditation; this cultivar could be adapted to heat and water stress more than other one in relation to its genetic stability under unfavorable condition and its positive response to late sowing date. Water consumptive use means by Sakha 93 was higher than those of Giza 168 under all water stress levels; superiority was recorded for 10 day interval (Eman El-Sarag and Ismaeil, 2013).

Conclusion:

Giza 168 and Gemmieza7 cultivars were the sensitive parameters, which related to overall growth reduction under salt and water stress. Giza 168 cultivar of wheat was classified as salt and drought susceptible, whereas Sakha 93 as salt and drought tolerant based on various physiological and growth parameters appraised in the present study.

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