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AGRONOMIC AND PHYSIOLOGICAL STUDIES ON SOME EXOTIC AND LOCAL BREAD WHEAT GENOTYPES UNDER SALINE SOIL CONDITIONS IN NORTH DELTA REGION

W.Z.E. Farhat[1], M.T. Shehab-Eldeen[1] and Rania A. Khedr[2]
1. Wheat Research Department, Field Crops Research Institute, ARC, Egypt
2. Crops physiology Res. Dept., Field Crops Res. Inst., ARC, Egypt, wayosha@yahoo.com

ABSTRACT

Soil salinity is the major global limitation to wheat production. Thus, ten bread wheat exotic lines and local cultivars were studied under normal and moderate saline soil conditions during 2017/18 and 2018/19 growing seasons. the objective was to understand the effects of salinity stress on some agronomic and physiological characters and to estimate some selection indices for salt tolerance in wheat. The studied characters were plant height and grain yield and its components in addition to relative water content, contents of chlorophyll a and b, proline and malondialdehyde and catalase activity in the flag leaves. The two seasons and saline conditions behaved differently. Besides, sufficient genetic variability among the studied genotypes was detected. Moreover, the variance due to saline conditions was the most important comparing to the other sources. Most of studied characters were higher in their mean values in the second season than the first one. All mean values of the studied characters decreased under the saline conditions, except for proline and malondialdehyde contents and catalase activity. Genotypic main effect plus genotype by environment interaction (GGE) Biplot analysis revealed that Line 2, Sakha 95, Misr 3 and Sids 14 had high yielding ability and relative tolerance under salinity conditions. Based on correlation coefficients, the high values of relative water content, chlorophyll, proline contents and catalase activity in addition to the low value of malondialdehyde content may be used as physiological selection criteria for salt tolerance screening of wheat genotypes.

Key words: ***Wheat, Triticum aestivum L., Salinity, Stress tolerance index, GGE biplot, ICARDA.***

INTRODUCTION

Wheat is a main cereal crop in Egypt and worldwide. Next to water shortage and nutrient deficiency, soil salinity is the major global limitation to wheat production (Mujeeb-Kazi *et al* 2019). About 35 % of the cultivated soils in Egypt suffers from a relatively high salinity level and the majority of these soils are found in the Nile Delta (north central region and its eastern and western sides) (Karajeh *et al* 2011). Moreover, Chartres and Noble (2015) reported that about 100 Mha of soil (approximately 11% of the world’s irrigated land) have turned saline due to irrigation with water containing salts.

From the several strategies to increase wheat production in the salt-affected areas, the development of tolerant plant materials using available genetic resources has been a relatively effective and low-cost means to face the salinity challenging (Ragab and Kheir 2019). In general, wheat is stated to be moderately tolerant to salinity (Asif *et al* 2020). In this respect, the latest breeding efforts have achieved a few salt-tolerant cultivated wheats, for example the genotypes KLR1-4 and KLR 19 (in India), LU-26S and SARC-1 (in Pakistan) and Sakha 8 (in Egypt) (Munns *et al* 2006). Unfortunately, the former cultivars have not been extensively accepted by farmers because of other agronomic limitations. It is necessary, subsequently to continue breeding for improved salinity tolerance of wheat.

Salinity stress induces morphological, physiological, biochemical, and molecular changes in plants. At the level of agronomic and morphological characters, decreasing effects were observed in general under the salinity stress (Darwish *et al* 2017, Ragab and Kheir 2019, Abd El-Hamid *et al* 2020 and Morsy *et al* 2020).

The previous studies reported decreasing response of some physiological characteristics such as relative water content and chlorophyll content due salinity stress (Tang *et al* 2015, Dehnavi *et al* 2017, Abd El-Hamid *et al* 2020, Zeeshan *et al* 2020). On the other hand, other researchers stated increasing response under the saline conditions for other physiological characters like proline and malondialdehyde content and catalase activity (Tang *et al* 2015, Dehnavi *et al* 2017, Abd El-Hamid *et al* 2020 and Zeeshan *et al* 2020).

Several stress indices have been proposed to screen genotypes for salinity tolerance. The stress susceptibility index (Fischer and Maurer 1978) is commonly used by researchers to estimate the tolerance of genotypes for salinity stress (Ragab and Kheir (2019), Abd El-Hamid *et al* 2020 and Morsy *et al* 2020).

Genotypic main effect plus genotype by environment interaction (GGE) consists of a set of graphs that allow visualization of the patterns in a dataset from different angles (Yan *et al* 2007). GGE biplot analysis has been mainly used to analyze data from multi-environment variety trials and other types of data that can be organized a two-way table. Biplot analysis appeared as a valuable screening tool to identify the slat tolerant wheat genotypes due to its graphical nature (Feroz *et al* 2017).

The relationship among the physiological characters and stress tolerance indices must be determined to understand which traits are the most important contributors to salinity tolerance (Zhu *et al* 2016 and Negrão *et al* 2017).

Therefore, this study was performed to: (1) understand the effects of salinity stress on some agronomic and physiological characters of wheat, (2) screen some exotic lines and local cultivars of bread wheat to improve salt tolerance through prebreeding programs, (3) facilitate the ranking of genotypes for salt tolerance using multiple parameters simultaneously and (4) estimate the relations of salt tolerance with the agronomic and physiological characters to determine reliable multiple selection indices for salt tolerance in wheat.

MATERIALS AND METHODS

One hundred and thirty-three bread wheat lines had been selected during a training visit to ICARDA’s research station at Marchouch near Rabat, Morocco in 2014. The selected entries were preliminary screened during 2015/2016 growing season against rusts at Sakha Agricultural Research Station Farm (Egypt; 38°52′N 65°48′E). Only five lines were selected based on their tolerance to the three wheat rusts and forwarded to the current study. The selected five lines plus five Egyptian cultivars i.e., Misr 2, Misr 3, Sakha 95, Gemmeiza12 and Sids 14 (Table 1) were evaluated under two saline conditions in 2017/18 and 2018/19 seasons.

The two saline conditions were normal soil at 2nd Nattaf Farm and salt affected soil at El-Hamrawy Farm. The soil analysis was performed at the Laboratory of Soil Research Department of Sakha Agricultural Research Station. The soil type was clay in the two farms, and EC values ranged from 2.45 to 2.95 dsm^{-1} for the normal soil and from 6.1 to 8.72 dsm^{-1} for the saline soil at 0-30 and 30-60 cm depth in the two seasons. According to Sakha meteorological station, the average minimum temperatures were 15.4 and 12.6 ^{0}C, while the average maximum temperatures were 27.8 and 25.8 ^{0}C during 2017/18 and 2018/19 seasons, respectively. In addition, the rainfall reached 78.34 and 73.10 mm and the averages of relative humidity were 62.73 and 68.68 % in the first and second season, respectively. All other cultural practices were applied according to the recommendations of the wheat department for the region. The used genotypes were evaluated separately in the two soils using the alpha Lattice design with four replications. The plots consisted of two rows with 2.5 m length and 30 cm apart.

Table 1. Names and pedigrees of the studied wheat genotypes.

Genotype	Pedigree	Selection history
Line 1	SERI.1B//KAUZ/HEVO/3/AMAD/4/KAUZ/KAPSW	AISBW05-0180-3AP-0AP-0AP-1AP -0SD
Line 2	DEBEIRA/4/KAUZ//ALTAR 84/AOS/3/KAUZ	ICW05-0597-9AP-0AP-0AP-2AP -0SD
Line 3	SERI.1B//KAUZ/HEVO/3/AMAD/4/FLAG-2	ICW06-00141-15AP/0KUL-0DZ/0AP-0DZ/0AP-1AP-0AP
Line 4	SERI.1B//KAUZ/HEVO/3/AMAD/4/PFAU/MILAN	ICW06-00151-8AP-0AP -1 SD
Line 5	VEE/NAC//REBWAH-19	ICW06-00354-1AP-0AP -1 SD
Misr 2	SKAUZ / BAV92	CMSS96M03611S-1M-010SY-010M-010SY-8M-0Y-0S
Misr 3	ATTILA*2/PBW65*2/KACHU	CMSS06Y00582T-099TOPM-099Y-099ZTM-099Y-099M-10WGY-0B-0EGY
Sakh95	PASTOR // SITE / MO /3/ CHEN / AEGILOPS SQUARROSA (TAUS) // BCN /4/ WBLL1.	CMA01Y00158S-040POY-040M-030ZTM-040SY-26M-0Y-0SY-0S.
Gemmeiza 12	OTUS /3/ SARA / THB // VEE	CMSS97Y00227S-5Y-010M-010Y-010M-2Y-1M-0Y-0GM
Sids 14	Bow''s''/Vee''s''//Bow's'/Tsi/3/BANI SUEF 1	SD293-1SD-2SD-4SD-0SD

The agronomic characters studied were plant height (cm), no. spikes m^{-2}, no. kernels $spike^{-1}$, 1000-kernel weight (g) and grain yield (kg m^{-2}). For the physiological characters, flag leaves samples were randomly taken from each plot at heading stage to estimate photosynthetic pigments of chlorophyll a and b (mg L^{-1}) according to Moran (1982), proline content (mg g^{-1} fresh weight,) according to Bates *et al* (1973), relative water content (%) according to Ritchie and Nguyen (1990), activities of catalase (μmol min^{-1} g^{-1} protein) by the method of Chance and Maehly (1955) and Malondialdehyde content (nmol g^{-1} fresh weight) by the method of Heath and Packer (1968). Stress susceptibility index (SSI) was estimated according to Fischer and Maurer (1978) as: SSI = $(1 - Y_d/Y_p)/D$. Where: Y_d = mean yield under saline soil, Y_p = mean yield under normal soil = potential yield, D = salinity stress intensity = 1 - (mean Y_d of all genotypes/mean Y_p of all genotypes). The means of the studied genotypes were used to perform the genotype and genotype by environment interaction GGE biplot using GenStat 18 (Payne *et al* 2017).

The analysis of studied characters was achieved based on alpha lattice design using the GenStat 18, and the accuracy of alpha lattice was not higher than randomized complete block design (RCBD). Therefore, the analysis of variance was performed according to RCBD. Combined analysis across the two saline conditions in the two seasons was performed when the assumption of errors homogeneity cannot be rejected (Levene 1960). Seasons were random, while the saline conditions and genotypes were fixed. Spearman rank correlation was also calculated using GenStat 18.

RESULTS

Analysis of variance

Combined analysis of variance for the studied characters are shown in Tables 2 and 3. Significant (p value < 0.05 or 0.01) effects of seasons, saline soil treatments and genotypes were observed for all the studied characters. Mean squares due to season, saline treatment and genotype interaction effects were significant for all characters, except the interaction of season x saline treatment for 1000-kernel weight, chlorophyll b, catalase activities and malondialdehyde content, season x genotype for 1000-kernel weight, chlorophyll b, proline and catalase activity, saline treatment x genotype for No. spikes m^{-2} and 1000-kernel weight, and season x saline x genotypes for No. spikes m^{-2} and 1000-kernel weight, relative water content, chlorophyll a and b and catalase activity.

Table 2. Analysis of variance for the plant height and grain yield and its components across the two seasons, salinity conditions and studied wheat genotypes.

SOV	df	PH	SM	KS	KW	GY
Season (Y)	1	11730.63**	243386**	27.97*	1065.02**	1.2**
Salinity (S)	1	13140.63**	1173690.5**	204.26**	3378.24**	5.95**
Y x S	1	3422.5**	26103.58**	5.47	89.4**	0.25**
Reps/S/Y = Error (a)	12	91.980	1643.390	4.580	6.010	0.005
Genotypes (G)	9	481.32**	10295.87**	145.66**	261.59**	0.35**
Y x G	9	38.61*	1890.67*	1.21	56.75**	0.07**
S x G	9	36.81*	1381.65	1.81	26.79**	0.04**
Y x S x G	9	45.07**	759.24	1.52	12.12*	0.05**
Pooled error b	108	16.050	898.110	1.820	5.130	0.002
Total	159					
CV %		4.40	6.52	3.48	4.03	7.02

PH = plant height (cm), SM = No. spikes m^{-2}, KS = No. kernels $spike^{-1}$, KW = 1000-kernel weight (g) and GY = grain yield (g m^{-2}).

Table 3. Analysis of variance for the physiological characters across the two seasons, salinity conditions and studied wheat genotypes.

SOV	df	RWC	Chl a	Chl b	PRO	CAT	MDA
Season (Y)	1	119.64**	50.74**	1.38**	0.03**	186.9121**	0.03**
Salinity levels (S)	1	1560.71**	703.38**	222.46**	0.46**	298.65**	0.48**
Y x S	1	5.04*	3.56**	0.06	0.11**	1.17	0.002
Reps/S/Y = Error (a)	12	0.830	0.070	0.070	0.001	3.770	0.001
Genotypes (G)	9	31.14**	7.03**	2.66**	0.03**	231.39**	0.01**
Y x G	9	4.68**	0.14*	0.03	0.0001	0.05	0.0005**
S x G	9	2.63*	0.96**	0.41**	0.004**	14.62**	0.01**
Y x S x G	9	2.19	0.11	0.01	0.001**	1.28	0.001**
Pooled error b	108	1.150	0.060	0.020	0.0001	1.150	0.0001
Total	159						
CV%		1.34	2.25	3.94	5.46	5.34	3.27

RWC = relative water content (%), Chl a = chlorophyll a, Chl b = chlorophyll b, PRO = proline content, CAT = activities of catalase, MDA = malondialdehyde content.

Mean performance

Data in Table 4 display the means of all studied characters across the two saline conditions and seasons. The values of plant height ranged from 85.3 cm for Line 1 to 101.3 cm for Sids 14. Besides, the number of spikes m^{-2} went in the range from 419.0 spikes in Line 4 to 506.3 spikes in Line 2. The lowest 1000-kernel weight was 34.2 g in Line 3, while the highest weight was 43.1 g in Sakha 95 and Sids 14. The number of kernels spike^{-1} varied from 49.0 (Line 4) to 63.3 (Line 1) kernels. Moreover, the grain yield ranged from 0.398 kg m^{-2} in Line 4 to 0.873 kg m^{-2} in Line 2 and 0.848 kg m^{-2} in Sakha 95.

Table 4. The mean performance of the studied characters as affected by season, salinity condition and genotype.

Name	PH	SM	KW	KS	GY	RWC	Cha	Chb	PRO	CAT	MDA
Line 1	**85.3**	**447.1**	**35.7**	**63.3**	**0.578**	**80.2**	**9.29**	**3.62**	**0.274**	**17.7**	**0.257**
Line 2	**92.2**	**506.3**	**37.0**	**54.1**	**0.873**	**81.8**	**11.29**	**4.84**	**0.400**	**24.0**	**0.185**
Line 3	**88.4**	**465.4**	**34.2**	**56.1**	**0.605**	**78.6**	**9.95**	**3.41**	**0.271**	**16.0**	**0.266**
Line 4	**85.6**	**419.3**	**37.7**	**49.0**	**0.398**	**79.0**	**10.14**	**4.01**	**0.250**	**16.5**	**0.277**
Line 5	**87.5**	**444.1**	**39.2**	**53.4**	**0.593**	**78.5**	**10.33**	**3.70**	**0.268**	**15.8**	**0.275**
Misr 2	**99.1**	**465.0**	**37.3**	**53.6**	**0.651**	**80.7**	**10.61**	**3.99**	**0.292**	**22.2**	**0.278**
Misr 3	**89.7**	**465.0**	**41.7**	**60.5**	**0.792**	**81.2**	**10.80**	**4.17**	**0.306**	**24.7**	**0.226**
Sakha 95	**94.1**	**480.9**	**43.1**	**58.5**	**0.848**	**80.6**	**11.48**	**3.79**	**0.278**	**22.1**	**0.248**
Gemmeiza12	**88.1**	**430.2**	**39.2**	**57.1**	**0.599**	**78.4**	**10.40**	**3.65**	**0.266**	**16.8**	**0.280**
Sids 14	**101.3**	**473.1**	**43.1**	**56.0**	**0.775**	**82.1**	**11.09**	**4.19**	**0.299**	**24.6**	**0.234**
Mean	**91.1**	**459.6**	**38.8**	**56.2**	**0.671**	**80.1**	**10.54**	**3.94**	**0.290**	**20.1**	**0.253**
LSD$_{0.05}$	**2.8**	**21.0**	**0.9**	**1.6**	**0.033**	**0.8**	**0.17**	**0.11**	**0.011**	**0.8**	**0.008**

PH = plant height (cm), SM = no. spikes m^{-2}, KS = no. kernels spike^{-1}, KW = 1000-kernel weight (g), GY = grain yield (g m^{-2}), RWC = relative water content percent, Cha = chlorophyll a (mg L^{-1}), Chb = chlorophyll b (mg L^{-1}), PRO = proline (mg g^{-1} fresh weight), CAT = catalase (µmol min^{-1} g^{-1} protein) and MDA = content of malondialdehyde (nmol g^{-1} fresh weight).

The leaf relative water content varied from 78.4% in Gemmeiza12 to 82.1% in Sids 14. In addition, the concentrations of chlorophyll a extended from 9.29 mg L^{-1} in Line 1 to 11.48 mg L^{-1} in Sakha 95, while chlorophyll b fluctuated from 3.41 mg L^{-1} in Line 3 to 4.84 mg L^{-1} in Line 2. Moreover, free proline contents in flag leaves were in the range of 0.25 mg g^{-1} fresh weight in Line 4 and 0.40 mg g^{-1} fresh weight in Line 2. Besides, activity of catalase, a scavenger of H_2O_2 outside the chloroplasts, jumped from 15.8 µmol min^{-1} g^{-1} protein in Line 5 to 24.7 µmol min^{-1} g^{-1} protein in Misr 3. Finally, the content of malondialdehyde differed from 0.185 nmol g^{-1} fresh weight to 0.280 nmol g^{-1} fresh weight in Line 2 and Gemmeiza12.

The effect of season and genotype interaction

The means of all studied characters across the two saline conditions in the two seasons are revealed in Tables 5-6. The averages of all genotypes in 2018/19 were significantly (Table 2 and 3) greater than those in 2017/18 under normal and saline conditions for all characters, except for proline and malondialdehyde contents.

Table 5. The mean performance of the plant height and grain yield and its components as affected by season and genotype.

Name	PH		SM		KW		KS		GY	
	1st	2nd	1st	2nd	1st	2nd	1st	2nd	1st	2nd
Line 1	75.0	95.6	395.0	499.2	35.3	36.1	62.4	64.3	0.546	0.610
Line 2	81.3	103.1	491.3	521.3	36.3	37.8	52.6	55.6	0.751	0.996
Line 3	79.4	97.5	438.3	492.5	33.9	34.6	49.2	63.1	0.540	0.670
Line 4	75.6	95.6	377.5	461.0	37.5	37.9	48.3	49.6	0.283	0.513
Line 5	78.8	96.3	395.0	493.1	38.9	39.5	49.8	56.9	0.383	0.802
Misr 2	92.5	105.6	425.4	504.6	37.0	37.5	52.8	54.4	0.633	0.670
Misr 3	82.5	96.9	425.0	505.0	40.9	42.4	58.4	62.7	0.637	0.946
Sakha 95	86.9	101.3	434.6	527.1	42.2	43.9	55.4	61.6	0.732	0.964
Gemmeiza12	79.4	96.9	388.3	472.1	39.0	39.3	54.4	59.9	0.595	0.604
Sids 14	94.4	108.1	435.8	510.4	42.9	43.3	52.6	59.5	0.745	0.805
Mean	82.6	99.7	420.6	498.6	38.4	39.2	53.6	58.7	0.585	0.758
LSD$_{0.05}$	3.9	4.1	34.9	24.2	1.5	1.2	2.3	2.3	0.048	0.047

1st = 2017/18 season, 2nd = 2018/19 season, PH = plant height (cm), SM = no. spikes m^{-2}, KS = no. kernels spike^{-1}, KW = 1000-kernel weight (g) and GY = grain yield (g m^{-2}).

The values of plant height went in the range from 75 and 95.6 cm in Line 1 to 94.4 and 108.1 cm in Sids 14 in the first and second season, respectively. Besides, the number of spikes m^{-2} ranged from 377.5 and 461.0 spikes in Line 4 to 491.3 and 527.1 spikes in Line 2 and Sakha 95 in the first and second season, respectively. In addition, the lowest and highest 1000-kernel weight were 33.9 and 34.6 g in Line 3 and 42.9 g in Sids 14 and 43.9 g in Sakha 95 in the first and second season, respectively. The number of kernels spike^{-1} varied from 48.3 and 49.6 kernels for Line 4 in the first season to 62.4 and 64.3 kernels for Line 1 in the second season. The lowest grain yield was 0.283 and 0.513 kg m^{-2} for Line 4 in the first season, while the highest values were 0.751 and 0.996 kg m^{-2} for Line 2 in the second season.

Table 6. The mean performance of the physiological characters as affected by season and genotype.

Name	**RWC**		**Cha**		**Chb**		**PRO**		**CAT**		**MDA**	
	1st	**2nd**	**1st**	**2nd**	**1st**	**2nd**	**1st**	**2nd**	**1st**	**2nd**	**1st**	**2nd**
Line 1	**79.4**	**81.0**	**8.56**	**10.02**	**3.50**	**3.74**	**0.281**	**0.267**	**16.64**	**18.77**	**0.267**	**0.248**
Line 2	**80.3**	**83.2**	**10.75**	**11.83**	**4.79**	**4.89**	**0.412**	**0.388**	**22.93**	**25.16**	**0.194**	**0.176**
Line 3	**77.1**	**80.0**	**9.45**	**10.45**	**3.32**	**3.49**	**0.287**	**0.256**	**14.86**	**17.11**	**0.277**	**0.254**
Line 4	**78.5**	**79.4**	**9.65**	**10.62**	**3.86**	**4.16**	**0.266**	**0.234**	**15.41**	**17.65**	**0.292**	**0.262**
Line 5	**78.0**	**79.1**	**9.77**	**10.89**	**3.58**	**3.81**	**0.282**	**0.254**	**14.72**	**16.87**	**0.289**	**0.262**
Misr 2	**80.6**	**80.7**	**10.05**	**11.17**	**3.91**	**4.07**	**0.308**	**0.276**	**21.16**	**23.31**	**0.306**	**0.250**
Misr 3	**80.5**	**81.9**	**10.07**	**11.53**	**4.02**	**4.31**	**0.319**	**0.292**	**23.80**	**25.68**	**0.233**	**0.218**
Sakha 95	**79.4**	**81.8**	**10.94**	**12.02**	**3.74**	**3.84**	**0.290**	**0.267**	**20.99**	**23.22**	**0.258**	**0.239**
Gemmeiza12	**76.7**	**80.1**	**9.91**	**10.90**	**3.55**	**3.74**	**0.282**	**0.250**	**15.72**	**17.96**	**0.290**	**0.270**
Sids 14	**81.8**	**82.4**	**10.61**	**11.58**	**4.16**	**4.23**	**0.315**	**0.282**	**23.51**	**25.63**	**0.247**	**0.222**
Mean	**79.2**	**81.0**	**9.98**	**11.10**	**3.84**	**4.03**	**0.304**	**0.277**	**18.97**	**21.14**	**0.265**	**0.240**
$LSD_{0.05}$	**0.9**	**1.2**	**0.25**	**0.23**	**0.16**	**0.15**	**0.011**	**0.019**	**1.09**	**1.06**	**0.011**	**0.011**

1st = 2017/18 season, 2nd = 2018/19 season, RWC = relative water content percent, Cha = chlorophyll a (mg L^{-1}), Chb = chlorophyll b (mg L^{-1}), PRO = proline (mg g^{-1} fresh weight), CAT = catalase (µmol min^{-1} g^{-1} protein) and MDA = content of malondialdehyde (nmol g^{-1} fresh weight).

The leaf relative water content had values from 76.7% in Gemmeiza12 and 79.1% in Line 5 to 81.8% in Sids 14 and 83.2 in Line 2 in the first and second season, respectively. Additionally, the concentration of chlorophyll a ranged from 8.56 and 10.02 mg L^{-1} for Line 1 to 10.94 and 12.02 mg L^{-1} for Sakha 95, while chlorophyll b ranged from 3.32 and 3.49 mg L^{-1} for Line 3 to 4.79 and 4.89 mg L^{-1} for Line 2 in the first and second season, respectively. The proline content ranged from 0.266 and 0.234 mg g^{-1} fresh weight in Line 4 to 0.412 and 0.388 mg g^{-1} fresh weight in Line 2 in the first and second season, respectively. Activity of catalase, started from 14.72 and 16.87 µmol min^{-1} g^{-1} protein for Line 5 and reached to 23.8 and 25.68 µmol min^{-1} g^{-1} protein for Misr 3 in the first and second season, respectively. The content of malondialdehyde was in the range of 0.194 and 0.176 nmol g^{-1} fresh weight for Line 2 and 0.306 nmol g^{-1} fresh weight for Misr 2 and 0.27 nmol g^{-1} fresh weight for Gemmeiza12 in the first and second season, respectively.

The effect of saline treatment x genotype interaction

The means of all studied characters across the two seasons for the same saline treatment are presented in Tables (7 and 8). The mean values of plant height ranged from 93.8 cm for Line 1 and Line 5 and 74.4 cm for Line 4 to 110.0 and 92.5 cm for Sids 14 under normal and soil salinity conditions, respectively. Besides, the number of spikes m^{-2} went in the range from 500.8 spikes for Gemmeiza12 and 327.5 spikes for Line 4 to 605.0 and 407.5 spikes for Line 2 under normal and soil salinity conditions, respectively. The lowest kernel weight was 34.9 and 33.6 g in Line 3, while the highest values were 44.2 g in Sakha 95 and 42.3 g in Sids 14 under normal and soil salinity conditions, respectively. The number of kernels $spike^{-1}$ varied between 51.3 and 46.6 kernels in Line 4 and 66.9 and 59.8 kernels in Line 1 under normal and soil salinity conditions, respectively. The lowest value of grain yield was 0.533 and 0.264 kg m^{-2} for Line 4, while the highest values were 1.122 kg m^{-2} for Sakha 95 and 0.656 kg m^{-2} for Line 2 under normal and soil salinity conditions, respectively.

The relative water content had values ranging from 81.40% in Line 3 and Gemmeiza12 and 75.3% in Line 5 to 85.20% in Line 2 and 79.6% in Sids 14 under normal and soil salinity conditions, respectively. The contents of chlorophyll a varied from 11.6 and 6.98 mg L^{-1} in Line 1 to 13.59 mg L^{-1} in Sakha 95 and 9.48 mg L^{-1} in Line 2, while chlorophyll b ranged from 4.51 mg L^{-1} in Line 3 and 2.16 mg L^{-1} in Line 1 to 6.05 and 3.64 mg L^{-1} in Line 2 under normal and soil salinity conditions, respectively.

Table 7. Mean performance of the plant height and grain yield and its components characters as affected by salinity conditions and genotypes.

Name	PH		SM		KW		KS		GY	
	N	S	N	S	N	S	N	S	N	S
Line 1	93.8	76.9	540.4	353.8	36.6	34.8	66.9	59.8	0.733	0.423
Line 2	101.9	82.5	605.0	407.5	38.7	35.4	59.9	48.4	1.091	0.656
Line 3	98.8	78.1	548.3	382.5	34.9	33.6	59.9	52.4	0.829	0.382
Line 4	96.9	74.4	511.0	327.5	39.0	36.4	51.3	46.6	0.533	0.264
Line 5	93.8	81.3	522.5	365.6	40.7	37.7	59.8	47.0	0.818	0.367
Misr 2	106.3	91.9	559.6	370.4	38.0	36.5	57.3	49.9	0.769	0.534
Misr 3	99.4	80.0	546.3	383.8	43.0	40.4	66.8	54.2	1.038	0.546
Sakha 95	104.4	83.8	570.5	391.3	44.2	41.9	63.2	53.7	1.122	0.574
Gemmeiza 12	96.9	79.4	500.8	359.6	40.3	38.0	62.0	52.2	0.783	0.416
Sids 14	110.0	92.5	548.3	397.9	43.9	42.3	60.6	51.5	0.926	0.624
Mean	100.2	82.1	545.3	374.0	39.9	37.7	60.8	51.6	0.864	0.479
LSD$_{0.05}$	3.9	4.1	32.5	27.3	1.5	1.1	2.4	2.2	0.051	0.044

N = normal condition, S = salinity condition, PH = plant height (cm), SM = no. spikes m^{-2}, KS = no. kernels spike^{-1}, KW = 1000-kernel weight (g) and GY = grain yield (g m^{-2}).

Table 8. Mean performance of the physiological characters as affected by salinity conditions and genotypes.

Name	RWC		Cha		Chb		PRO		CAT		MDA	
	N	S	N	S	N	S	N	S	N	S	N	S
Line 1	84.2	76.3	11.60	6.98	5.07	2.16	0.230	0.318	16.48	18.93	0.196	0.319
Line 2	85.2	78.3	13.09	9.48	6.05	3.64	0.327	0.472	22.03	26.06	0.134	0.237
Line 3	81.4	75.8	11.79	8.11	4.51	2.30	0.206	0.336	15.13	16.85	0.199	0.332
Line 4	82.2	75.8	12.48	7.80	5.12	2.90	0.195	0.305	15.89	17.17	0.207	0.347
Line 5	81.8	75.3	12.55	8.11	4.89	2.50	0.218	0.318	14.45	17.14	0.200	0.351
Misr 2	84.1	77.3	13.12	8.10	4.96	3.03	0.266	0.317	21.79	22.68	0.272	0.283
Misr 3	83.9	78.6	12.65	8.96	5.17	3.16	0.246	0.365	21.89	27.59	0.173	0.278
Sakha 95	83.6	77.6	13.59	9.36	5.12	2.46	0.219	0.338	21.25	22.96	0.192	0.305
Gemmeiza12	81.4	75.4	12.33	8.48	5.00	2.29	0.230	0.302	16.44	17.24	0.213	0.347
Sids 14	84.7	79.6	13.15	9.04	5.26	3.13	0.228	0.370	21.54	27.60	0.191	0.277
Mean	83.2	77.0	12.64	8.44	5.11	2.76	0.236	0.344	18.69	21.42	0.198	0.308
LSD$_{0.05}$	1.0	1.1	0.24	0.24	0.16	0.15	0.015	0.017	1.00	1.14	0.012	0.011

RWC = relative water content percent, Cha = chlorophyll a (mg L^{-1}), Chb = chlorophyll b (mg L^{-1}), PRO = proline (mg g^{-1} fresh weight), CAT = catalase (µmol min^{-1} g^{-1} protein) and MDA = content of malondialdehyde (nmol g^{-1} fresh weight).

Moreover, the proline contents ranged from 0.195 mg g^{-1} fresh weight in Line 4 and 0.302 mg g^{-1} fresh weight in Gemmeiza12 to 0.327 and 0.472 mg g^{-1} fresh weight in Line 2 under normal and soil salinity conditions, respectively. Furthermore, catalase activity varied from 0.134 µmol min^{-1} g^{-1} protein in Line 2 and 0.219 µmol min^{-1} g^{-1} protein in Misr 2 and reached to 0.246 µmol min^{-1} g^{-1} protein in Misr 2 and 0.351 µmol min^{-1} g^{-1} protein in Line 5 under normal and soil salinity conditions, respectively. The lowest content of malondialdehyde was 0.134 and 0.237 nmol g^{-1} fresh weight for Line 2, while the highest value was 0.272 mol g^{-1} fresh weight for Misr 2 and 0.351 mol g^{-1} fresh weight for Line 5 under normal and soil salinity conditions, respectively.

The effect of season x soil treatment x genotype interaction

The estimates of the studied characters under the two saline conditions in the two seasons are demonstrated in Tables (9 and 10).

Table 9. Mean performance of plant height and grain yield and its components as affected by interactions among seasons, salinity conditions and genotypes.

Name	**PH**				**SM**				**KW**			
	2017/18		**2018/19**		**2017/18**		**2018/19**		**2017/18**		**2018/19**	
	N	**S**	**N**	**S**	**N**	**S**	**N**	**S**	**N**	**S**	**N**	**S**
Line 1	**78.8**	**71.3**	**108.8**	**82.5**	**480.0**	**310.0**	**600.8**	**397.5**	**36.1**	**34.5**	**37.1**	**35.1**
Line 2	**85.0**	**77.5**	**118.8**	**87.5**	**587.5**	**395.0**	**622.5**	**420.0**	**37.8**	**34.8**	**39.6**	**36.0**
Line 3	**87.5**	**71.3**	**110.0**	**85.0**	**509.2**	**367.5**	**587.5**	**397.5**	**34.8**	**33.0**	**35.0**	**34.1**
Line 4	**82.5**	**68.8**	**111.3**	**80.0**	**445.0**	**310.0**	**577.1**	**345.0**	**38.8**	**36.3**	**39.3**	**36.5**
Line 5	**82.5**	**75.0**	**105.0**	**87.5**	**456.7**	**333.3**	**588.3**	**397.9**	**40.5**	**37.4**	**41.0**	**38.0**
Misr 2	**96.3**	**88.8**	**116.3**	**95.0**	**514.2**	**336.7**	**605.0**	**404.2**	**37.5**	**36.5**	**38.5**	**36.6**
Misr 3	**85.0**	**80.0**	**113.8**	**80.0**	**487.5**	**362.5**	**605.0**	**405.0**	**41.5**	**40.3**	**44.4**	**40.5**
Sakha 95	**92.5**	**81.3**	**116.3**	**86.3**	**509.2**	**360.0**	**631.8**	**422.5**	**42.7**	**41.8**	**45.8**	**42.0**
Gemmeiza 12	**83.8**	**75.0**	**110.0**	**83.8**	**452.5**	**324.2**	**549.2**	**395.0**	**40.2**	**37.9**	**40.5**	**38.1**
Sids 14	**96.3**	**92.5**	**123.8**	**92.5**	**493.3**	**378.3**	**603.3**	**417.5**	**43.5**	**42.3**	**44.3**	**42.3**
Mean	**87.0**	**78.1**	**113.4**	**86.0**	**493.5**	**347.8**	**597.1**	**400.2**	**39.3**	**37.4**	**40.5**	**37.9**
LSD$_{0.05}$	**4.2**	**6.7**	**6.7**	**5.1**	**52.0**	**49.1**	**41.6**	**26.8**	**2.6**	**1.7**	**1.8**	**1.5**

Table 9. Cont.

Name	KS				GY			
	2017/18		2018/19		2017/18		2018/19	
	N	S	N	S	N	S	N	S
Line 1	65.6	59.3	68.3	60.3	0.720	0.372	0.745	0.474
Line 2	57.8	47.5	62.0	49.3	0.912	0.590	1.269	0.723
Line 3	51.9	46.5	67.9	58.3	0.759	0.321	0.898	0.443
Line 4	51.1	45.5	51.5	47.8	0.382	0.184	0.683	0.343
Line 5	53.7	46.0	65.8	48.0	0.466	0.301	1.171	0.433
Misr 2	56.5	49.0	58.1	50.8	0.760	0.505	0.778	0.563
Misr 3	63.0	53.7	70.6	54.8	0.801	0.474	1.275	0.618
Sakha 95	59.1	51.7	67.4	55.8	0.906	0.558	1.338	0.590
Gemmeiza 12	58.8	49.9	65.3	54.5	0.777	0.414	0.790	0.418
Sids 14	57.0	48.3	64.2	54.8	0.894	0.597	0.958	0.652
Mean	57.4	49.7	64.1	53.4	0.738	0.432	0.990	0.525
$LSD_{0.05}$	3.2	3.4	3.6	2.9	0.060	0.076	0.084	0.046

PH = plant height (cm), SM = no. spikes m^{-2}, KS = no. kernels $spike^{-1}$, KW = 1000-kernel weight (g) and GY = grain yield (g m^{-2}).

Table 10. Mean performance of the physiological characters as affected by interactions among seasons, sowing dates and genotypes.

Name	RWC				Cha				Chb			
	2017/18		2018/19		2017/18		2018/19		2017/18		2018/19	
	N	S	N	S	N	S	N	S	N	S	N	S
Line 1	83.8	75.1	84.6	77.5	11.03	6.09	12.17	7.87	4.98	2.01	5.17	2.31
Line 2	84.4	76.2	85.9	80.4	12.69	8.80	13.49	10.16	6.01	3.57	6.09	3.70
Line 3	79.8	74.4	83.0	77.1	11.32	7.59	12.26	8.63	4.47	2.17	4.56	2.43
Line 4	82.0	75.1	82.4	76.5	12.26	7.04	12.69	8.55	4.92	2.79	5.32	3.01
Line 5	81.4	74.6	82.2	76.0	12.13	7.40	12.96	8.82	4.78	2.39	5.01	2.61
Misr 2	83.3	77.8	84.8	76.7	12.71	7.38	13.54	8.81	4.91	2.92	5.00	3.14
Misr 3	83.5	77.5	84.3	79.6	12.08	8.07	13.22	9.85	5.03	3.02	5.31	3.31
Sakha 95	83.0	75.8	84.2	79.3	13.19	8.69	13.99	10.04	5.09	2.39	5.16	2.52
Gemmeiza 12	79.8	73.6	83.0	77.2	11.86	7.95	12.81	9.00	4.93	2.17	5.06	2.42
Sids 14	84.4	79.1	84.9	80.0	12.94	8.28	13.36	9.80	5.30	3.02	5.23	3.23
Mean	82.5	75.9	83.9	78.0	12.22	7.73	13.05	9.15	5.04	2.65	5.19	2.87
$LSD_{0.05}$	1.3	1.3	1.6	1.9	0.37	0.35	0.32	0.33	0.27	0.20	0.20	0.23

Table 10. Cont.

Name	PRO				CAT				MDA			
	2017/18		2018/19		2017/18		2018/19		2017/18		2018/19	
	N	S	N	S	N	S	N	S	N	S	N	S
Line 1	0.273	0.289	0.186	0.348	15.44	17.84	17.52	20.02	0.197	0.336	0.194	0.302
Line 2	0.355	0.468	0.300	0.476	20.40	25.45	23.66	26.66	0.135	0.253	0.132	0.221
Line 3	0.247	0.327	0.166	0.346	13.89	15.84	16.36	17.86	0.219	0.335	0.179	0.330
Line 4	0.247	0.285	0.143	0.325	15.13	15.69	16.65	18.65	0.214	0.371	0.201	0.324
Line 5	0.259	0.306	0.177	0.331	13.29	16.15	15.62	18.12	0.212	0.365	0.188	0.337
Misr 2	0.295	0.320	0.238	0.315	20.62	21.70	22.95	23.67	0.300	0.311	0.245	0.255
Misr 3	0.290	0.348	0.203	0.382	20.84	26.75	22.93	28.43	0.175	0.291	0.172	0.265
Sakha 95	0.247	0.334	0.192	0.342	19.62	22.36	22.88	23.57	0.195	0.321	0.189	0.289
Gemmeiza12	0.270	0.293	0.189	0.312	15.21	16.22	17.68	18.25	0.230	0.350	0.196	0.344
Sids 14	0.280	0.350	0.175	0.390	20.78	26.24	22.31	28.95	0.193	0.301	0.190	0.254
Mean	0.276	0.332	0.197	0.356	17.52	20.43	19.86	22.42	0.207	0.323	0.188	0.292
$LSD_{0.05}$	0.018	0.014	0.024	0.032	1.53	1.61	1.37	1.69	0.021	0.011	0.012	0.019

RWC = relative water content percent, Cha = chlorophyll a (mg L^{-1}), Chb = chlorophyll b (mg L^{-1}), PRO = proline (mg g^{-1} fresh weight), CAT = catalase (µmol min^{-1} g^{-1} protein) and MDA = content of malondialdehyde (nmol g^{-1} fresh weight).

For plant height, Line 4 was the shortest genotype under saline condition in the two seasons, though Sids 14 and Misr 2 were the tallest genotype under most conditions. Besides, Line 4 showed the lowest number of spikes m^{-2} under saline conditions in the two seasons, however Line 2 and Sakha 95 revealed the highest number in the first and second season, respectively.

Additionally, Line 3 had the lowest weight of kernels under all conditions, but Sids 14 and Sakha 95 had the highest weight under most conditions. Moreover, Line 4 gave the lowest number of kernels spike^{-1}, however Line 1 had the highest number under most conditions. In the same time, Line 4 had the lowest grain yield under all conditions, whereas Line 2, Sids 14 and Sakha 95 were the best ones under most conditions.

Gemmeiza12 and Line 5 explored the lesser relative water content in the first season and second season, respectively, while Sids 14 and Line 2 had the highest values under most conditions. In addition, Line 1 gave the lowest chlorophyll a estimates under all conditions, although the highest estimates belonged to Sakha 95 under normal conditions and Line 2 under saline conditions in the two seasons. Also, the lowest chlorophyll b value belonged to Line 3 and Line 1 under normal and saline conditions, respectively in the two seasons, while Line 2 had the highest value under all conditions. Besides, the lowest proline content belonged to Line 4 under most conditions and the highest content was produced by Line 2 under all conditions. Also, the lowest activity of catalase was given by Line 4 and Line 5 under most conditions and the highest activity belonged to Misr 3 in the first season and Line 2 and Sids 14 in the second season. Finally, the lowest level of lipid peroxidation belonged to Line 2 under all conditions, while Misr 2 had the highest level under normal and salinity conditions in the first and second season, respectively.

Salinity tolerance

Salinity stress susceptibility index

Table (11) demonstrates salinity stress susceptibility index (SSI) established on grain yield for the genotypes under study in the two seasons. Misr 2 then Sids 14 followed by Line 2 and in the latter Line 1 had SSI values below unity for the mean of the two seasons, while the values of SSI above unity belonged to Line 3 then Line 4 as average of the two seasons.

Genotype main effect plus genotype x environment interaction (GGE) biplot for grain yield

Figure 1 visualizes the appropriate genotypes for the two saline conditions in the two seasons. The lines split the biplot into seven sectors and the four environments were grouped into three main sectors. The "which-won-where" pattern showed that Line 2 and Sids 14 were the vertex genotypes under saline conditions in the two seasons and normal condition in the first season. In addition, Sakha 95 was won under normal conditions in the second season followed by Misr 3.

Table 11. Estimates of a salinity stress susceptibility index based on grain yield for the studied genotypes in the two seasons.

Genotype	2017/2018	2018/2019	Mean
Line 1	1.16	0.76	0.96
Line 2	0.85	0.92	0.88
Line 3	1.39	1.07	1.23
Line 4	1.25	1.06	1.15
Line 5	0.83	1.34	1.08
Misr 2	0.79	0.58	0.69
Misr 3	0.98	1.10	1.04
Sakha 95	0.92	1.19	1.06
Gemmeiza 12	1.12	1.00	1.06
Sids 14	0.81	0.68	0.74

Reduction percentage and correlation

The means and ranges of reduction% due to salinity stress for the studied characters are listed in Table (12). The means of reduction were in the positive direction for all studied charcters except for porline content, catalase activity and content of Malondialdehyde. The least affected characters with the salinity stress were No. kernels spike^{-1} (0.05 and 0.06 %) and relative water content (0.08 and 0.07 %) in the firrst and second season, respectively.

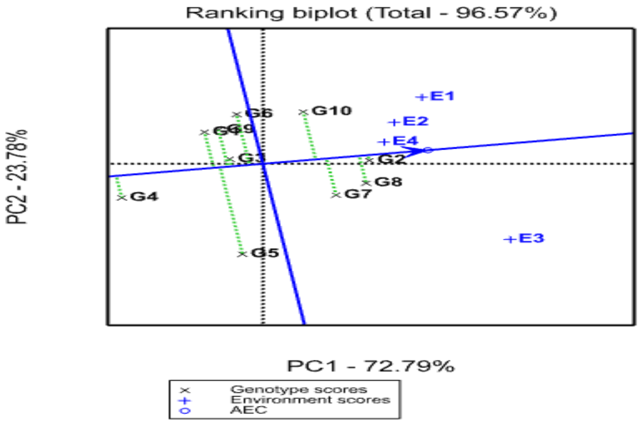

Fig. 1. Ranking the 10 genotypes based on their grain yiels across the normal and saline conditions in 2017/18 and 2018/19 seasons. E1 = normal in 2017/18, E2 = salinity in 2017/18, E3 = normal in 2018/19, E4 = salinity in 2018/19, G1 – G5 = Line 1 - Line 5, G6 = Misr 2, G7 = Misr 3, G8 = Sakha 95, G9 = Gemmeiza12 and G10 = Sids 14.

On the contrary, the most affected characters with salinity were grain yield (0.42 and 0.46%), chlorophyll b (0.48 and 0.45%), No. spikes m^{-2} (0.29 and 0.33%) and chlorophyll a (0.37 and 0.30%) in the first and second seasons, respectively. Moreover, the increasig in average were 0.20 and 0.08% for proline, 0.60 and 0.57% for malondialdehyde content and 0.16 and 0.13 5 by catalase activity the firrst and second season, respectively. The range of the reduction% was from -0.87 for malondialdehyde content in the first season to 0.63% for grain yield in the second season.

Spearman correlation coefficients (r) among the mean salinity susceptibility index and the studied characters under normal and saline conditions are presented in Table (12). There were significant (p value < 0.01 or 0.05) and high negative correlation coefficient among salinity susceptibility index and relative water content and catalase activity under the saline treatments and plant height and grain yield only under saline conditions. Also, salinity susceptibility index had moderate and insignificant correlations with No. spikes m^{-2}, chlorophyll b and proline contents under normal and saline conditions and with plant height and chlorophyll a content only under the normal conditions. The correlation coefficient for salinity susceptibility index was insignificant and varied from negative value under normal to positive value under salinity condition for malondialdehyde content.

Table 12. Means and ranges of reduction% due to salinity stress for the characters studied during 2017/19 (1st) and 2018/2019 (2nd) seasons in addition to Spearman correlation coefficient among means of susceptibility index and the studied characters under normal (N) and salinity (S) conditions across the two seasons.

Characters	Reduction%						Correlation coefficient	
	Mean		Range					
			Minimum		Maximum			
	1st	2nd	1st	2nd	1st	2nd	N	S
PH	0.10	0.24	0.04	0.17	0.19	0.30	-0.590	-.663*
SM	0.29	0.33	0.23	0.28	0.35	0.40	-0.470	-0.413
KS	0.05	0.06	0.02	0.03	0.08	0.09	-0.079	-0.274
KW	0.13	0.16	0.10	0.07	0.18	0.27	-0.177	-0.103
GY	0.42	0.46	0.33	0.28	0.58	0.63	-0.128	-.736*
RWC	0.08	0.07	0.06	0.06	0.10	0.10	-.832**	-.665*
Chl a	0.37	0.30	0.31	0.25	0.45	0.35	-0.488	-0.302
Chl b	0.48	0.45	0.40	0.37	0.60	0.55	-0.559	-0.489
PRO	-0.20	-0.86	-0.35	-1.27	-0.06	-0.32	-0.611	-0.496
CAT	-0.16	-0.13	-0.28	-0.30	-0.04	-0.03	-.796**	-.737*
MDA	-0.60	-0.57	-0.87	-0.84	-0.04	-0.04	-0.156	0.390

*** and** : Significant at 0.05 and 0.01 probability level, respectively.**

PH = plant height (cm), SM = no. spikes m^{-2}, KS = no. kernels $spike^{-1}$, KW = 1000-kernel weight (g), GY = grain yield (g m^{-2}), RWC = relative water content percent, Cha = chlorophyll a (mg L^{-1}), Chb = chlorophyll b (mg L^{-1}), PRO = proline (mg g^{-1} fresh weight), CAT = catalase (µmol min^{-1} g^{-1} protein) and MDA = content of malondialdehyde (nmol g^{-1} fresh weight).

DISCUSSION

The salt affected soil under this study is characterized with low to moderate salinity levels (EC in range of 6.1 to 8.72 dsm^{-1}), therefore had low heterogeniety. This have been confirmed by the value of coefficients of variation which ranged from 1.34 for relative water content to 7.02 for grain yield (Tables 2 and 3).

The error variances were proved to be homogeneous for the two seasons and saline soil treatments for all characters, so the combined analysis was performed across the two seasons and saline conditions. The analysis of variance indicated that the two seasons and the two saline conditions behaved differently and detected sufficient genetic variability among the studied genotypes. In addition, the significance of the given interactions revealed that the genotypes responded differently to saline conditions and seasons and the possibility to select of the most tolerant genotypes. Moreover, the variance due to saline conditions was most important related to the other sources. Similar results were recorded by Darwish *et al* 2017, Ragab and Kheir (2019) and Abd El-Hamid *et al* (2020).

The studied characters were higher in their values for most characters in the second season compared to the first one, confirming the seasonal changes effects. The high values of the studied characters may be due to the lower temperature and higher relative humidity in this season compared to the first one. These results are in line with Darwish *et al* (2017), Farhat *et al* (2019) and Abd El-Hamid *et al* (2020), who found that the high temperatures during grain filling resulted in reduced grain growth and shortening the period for normal grain development. Anyway, the study have been repeated in two seasons to provide more consistency of the results.

As shown in Tables 8 through 10, all studied characters were decreased under the studied saline conditions, except for proline and malondialdehyde contents and catalase activity**.** Shabala and Munns (2017) indicated that the salinity can inhibit the plant growth by water deficit, specific ion toxicity and nutrient ion imbalance in two phases. The first phase happens quickly and depends on salt external the plant rather than salt in tissues, and growth inhibition is due to water deficit or osmotic stress. The second phase takes time to appear, and results from inside salt injury and the reduction depends on the rate of leaf injury.

Most of agronomic characters were decreased under saline conditions and in general the highest decrease in these traits were observed in the sensitive genotypes. These results were similar to those reported in the previous studies (Ragab and Kheir 2019, Ghonaim *et al* 2020, Abd El-Hamid *et al* 2020, Moghadam *et al* 2020). El-Hendawy *et al* (2005) documented similar results and reported that salinity could decrease spike fertility and translocation of assimilates to the grain of wheat and barley. In addition, the growth inhibition under salinity stress due to cells shrinkage after few seconds or minutes, due to water loss by osmotic stress. After hours, cells recover their foremost size but the growth rates stay low, causing inferior growth amounts of leaf, shoot and root. After some weeks, it modifies the vegetative development and variations in reproductive development can be noticed (Shabala and Munns 2017).

Earlier investigation reveals that among plant responses to salinity, strategies that control ion uptake, transport, and balance, in addition to water potential, photosynthesis, cell division, osmotic adjustment, enzymatic activities, polyamine regulation and stress signaling contribute, with important roles, to salinity tolerance in plants (Shahid *et al* 2020).

Leaf relative water content reflects plant water status and it is used as a meaningful index for dehydration tolerance salinity stress (Dehnavi *et al* 2017 and Abd El-Hamid *et al* 2020). The present results were in agreement with Abd El-Moneim *et al* (2020) and Moghadam *et al* (2020), who revealed that relative water content decreased by increasing of salinity levels and it was higher in tolerant wheat cultivars than sensitive ones.

The chlorophyll content corresponds to the photosynthesis and the leaf injury, therefore, could be used to assess salt tolerance of genotype (Shabala and Munns 2017). As for our results, a marked perturbation in photosynthetic parameters along with reduced chlorophyll contents resulting from salinity stress were observed in wheat (Abd El-Hamid *et al* 2020 and Zeeshan *et al* 2020).

Plants encounter salt stress through accumulating high concentration of inorganic ions or de novo synthesizing low molecular weight organic solutes like proline for osmotic adjustments (Ashraf and Harris 2004). Our results are in harmony with those of Tang *et al* (2015) and Abd El-Hamid *et al* (2020), who reported that proline content increased under saline soil compared to normal soil.

Shabala and Munns (2017) reported that salinity stress causes generation of reactive oxygen species (ROS) and its extremely reactive and may cause cellular damage through lipid peroxidation as well as proteins and nucleic acids oxidation. Catalase is a major antioxidant enzyme protect cells against oxidative injury. The relationship between antioxidant activity and salinity stress tolerance seems to be highly complicated. While many papers stated a positive relation between antioxidant production in plant tissues and plant salinity tolerance, equivalent others exhibited no, or even negative, correlation between these two characters. Thus, it appears that increased antioxidant activity should be treated as a damage control mechanism rather than a trait directly conferring salinity stress tolerance. Our study supports earlier studies (Vighi *et al* 2017 and Moghadam *et al* 2020) that illustrated a higher activity of catalase in plants salt stress and the activities of these enzymes were again higher in the tolerant genotypes.

The membrane stability was reported as criterion of selection to differentiate salt tolerant and sensitive genotypes (Demiral and T€urkan 2005). Membrane integrity is subjected to reactive oxygen species-induced lipid peroxidation that produces malondialdehyde (MDA) when oxidized (Azevedo Neto *et al* 2006). In general, salt sensitive genotypes are more liable to lipid peroxidation in membranes as compared to the tolerant ones. Therefore, MDA index reflects membrane stability and could be used as a potential indicator of stress tolerance (Demiral and T€urkan 2005). The obtained results here are in line with those of Feki *et al* (2017), Ghonaim *et al* (2020) and Zeeshan *et al* (2020), who stated that MDA contents were significantly increased by the salt treatment, indicating enhanced lipid peroxidation. In general, in plants given salinity treatments, the MDA content was highest in the sensitive genotypes compared to the tolerant ones (Zeeshan *et al* 2020).

The salinity susceptibilty index (SSI) was calculated using the grain yield trait. The SSI values for genotypes stand for tolerant if were less than unity, for sensitive if were above unity and for moderate tolerant or sensitive if were equal or near to 1. Misr 2, Sids 14, Line 2 and Line 1 were considered tolerant genotypes, while Line 3 and Line 4 were sensitive ones and the other genotyps were moderately tolerant genotypes. However, tolerance and susceptibility indices are not ideal to characterize genotypes with high yield performance and high-stress tolerance under both environments (Thiry *et al* 2016). Therefore, Ragab and Kheir (2019) interested with the superiority of grain yield under the studied stress conditions in addition to the stress susceptibility index.

Biplot analysis was used by Feroz *et al* (2017) as screening tool to identify the slat tolerant wheat genotypes. The GGE biplot method illustrates together the grain yield superiority and relative tolerant genotype to the studied stress expressed with the most stability under the studied environments. Figure 1 depended on the average environment coordination (AEC) method (Yan *et al* 2007). In this method, an average environment is defined by the average PC1 and PC2 scores of all environments, represented by a small circle. A line with single arrow passes through the biplot origin and the average environment (small circle) and is referred to as (average environment axis) or AEA. The arrow pointes to higher mean performance for the genotypes. The line perpendicular to AEA and passes through the biplot origin pointed to higher performance variability or less stability in both direction (grand mean) (Yan *et al* 2010). A longer projection to the AEC ordinate regardless as the direction, represents a greater tendency of the GEI of a genotype, which means that it is more variable and less stable across environments or vice versa (Kaya *et al* 2006). Consequently, the genotypes Line 2> Sakha 95> Misr 3> Sids 14 were more stable as well as high yielding. Our resluts are in line with Ragab and Kheir (2019). They recommended that the bread wheat cultivars Misr 2 and Sakha 95 might be suitable for moderate salt affected soils.

The rank correlation was used in place of Pearson coefficient of correlation because the salinity susceptibility index (SSI) cannot be assumed to be normally distributed (Darwish *et al* 2017 and Morsy *et al* 2020). The relation between SSI and grain yield was negative and only had high value under salinity, indicating the importance of grain yield under stress compared to the normal conditions and the high potential yield under non-stressed conditions does not necessarily result in high yield under the stressed salinity conditions and *vice versa* (Darwish *et al* 2017 and Morsy *et al* 2020). The relations of SSI were negative with the physiological characters except for malondialdehyde content under salinity conditions, indicating the role of high values of these characters for salinity tolerance, while the low value of malondialdehyde content was important under salinity conditions. Feki *et al* (2017) demonstrated that tolerance to salinity in wheat genotypes was associated with lower MDA contents and higher activities of antioxidant enzymes. Munns *et al* (2006) and Temel and Gozukirmizi (2015) found that the activities of antioxidant enzymes are strongly correlated with tolerance to salt-induced oxidative stress in wheat.

CONCLUSION

It could be concluded depending on this research that Line 1 might be introduced for advanced evaluation on the national level to confirm these results. Sakah95, Misr 3 and Sids 14 (the most recent cultivars bred by Agricultural Research Center) were suitable cultivars to be cultivated to moderate saline soils. GGE biplot analysis could facilitates testing genotypes for relative tolerance of salinity and grain yield superiority at the main time. High values of relative water content, chlorophyll, proline contents and catalase activity in addition to the low values of malondialdehyde contents may be used as physiological selection criteria for screening of salt tolerant wheat genotypes.

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دراسات محصولية وفسيولوجية على بعض تراكيب وراثية من قمح الخبز المستوردة والمحلية في ظروف التربة المالحة بمنطقة الدلتا

وليد ذكي اليماني فرحات[١]، مصطفى تاج الدين شهاب الدين[١]، رانيا أنور خضر[٢]

١. قسم بحوث القمح معهد بحوث المحاصيل الحقلية – مركز البحوث الزراعية مصر

٢. قسم بحوث فسيولوجيا المحاصيل معهد بحوث المحاصيل الحقلية – مركز البحوث الزراعية مصر

تُعد ملوحة التربة من أهم معوقات إنتاج القمح على المستوى العالمي. ولذلك تم تقييم عشرة سلالات وأصناف محلية ومستوردة من قمح الخبز تحت ظروف التربة العادية ومتوسطة الملوحة خلال موسمي الزراعة ٢٠١٧/١٨ و٢٠١٨/١٩. وكانت أهداف الدراسة هي تقدير تأثير إجهاد الملوحة على بعض الصفات المحصولية والفسيولوجية وتقدير بعض دلائل الانتخاب لتحمل الملوحة في القمح. وكانت الصفات المدروسة هي ارتفاع النبات ومحصول الحبوب ومكوناته بالإضافة إلى محتوى الماء النسبي، ومحتوى كل من الكلوروفيل أ وب والبرولين ومادة malondialdehyde، ونشاط الـ catalase في ورقة العلم. اختلفت نتائج الموسمين ومعاملتي الملوحة معنويا وكان هناك تباين معنوي بين التراكيب الوراثية المستخدمة. وكذلك كان التباين بسبب التربة المتأثرة بالملوحة الأكثر أهمية بالنسبة لمصادر التباين الأخرى. وأعطت الصفات المدروسة أعلى القيم في الموسم الثاني مقارنة بالموسم

الأول. وقد تناقصت متوسطات جميع الصفات المدروسة نتيجة للملوحة، باستثناء محتوى البرولين ومادة malondialdehyde ونشاط الـ catalase. وقد أظهر تحليل GGE Biplot أن سلالة القمح رقم ٢ ، والأصناف سخا ٩٥، مصر ٣ وسدس ١٤ كانت مرتفعة في محصول الحبوب بالإضافة للتحمل النسبي لظروف الملوحة تحت الدراسة. وبناء على معاملات الارتباط، فإن القيم المرتفعة من محتوى الماء النسبي والكلوروفيل ومحتوى البرولين ونشاط الـ catalase بالإضافة إلى القيم المنخفضة لمادة malondialdehyde يمكن استخدامها كدلائل انتخاب فسيولوجية لتحمل الملوحة في القمح.

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