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Evaluation of Eight Bread Wheat Cultivars for Soil Salinity Tolerance

Ahmed F. Elkot#, Zainab A.A. ElRashidy, Mokhtar M.M. Gab Alla

Wheat Research Department, Field Crops Research Institute, Agricultural Research Center (ARC) 12619, Giza, Egypt.

SOIL salinity is the major global limitation to wheat production. Thus, eight Egyptian bread wheat cultivars were evaluated under normal and saline soil conditions during two consecutive seasons 2020/2021 and 2021/2022 at the experimental farm of Sakha Agricultural Research Station, Kafr Elsheikh, Egypt, eight wheat cultivars were arranged at Latin square design. The objective was to evaluate eight Egyptian wheat cultivars under the effects of salinity stress on yield and its components characteristics. The studied traits were days to heading, days to maturity, grain filling period, grain filling rate, plant height, biological yield, harvest index and grain yield and its components. The behavior of tested wheat cultivars were different under normal and saline condition due to the effect of soil salinity and the tolerance of the tested wheat cultivars. The studied traits were varied significantly in their values for most traits in the two seasons. All mean values of the studied traits decreased under the saline conditions. Generally, at normal soil the genotypic main effect plus genotype by traits analysis revealed that the best genotypes in studied traits was Giza 171 followed by Sids 14 and Shandweel 1, and the lowest genotypes for all studied traits was Sids 12 under saline soil conditions, the best genotypes in most traits were Giza 171, Sids 14, Gemmieza 12 then Misr 1 and Sids 12 was the lowest genotypes for all studied traits. The current investigation revealed that the bread wheat cultivars Giza171 was the best tested cultivar for all traits under normal soil and soil salinity condition. The wheat cultivar Giza 171 can be recommended to be cultivated in salinity effected soil and north delta.

Keywords : Salinity, Wheat (*Triticum aestivum* L.), Yield, Yield components.

Introduction

Globally, climate change and warming have direct effected on wheat crop yield and quality by intensifying the frequency and extent of different stresses. Wheat is the strategic cereal crop in Egypt and worldwide, it contributes a significant part of daily calories and protein intake (EL Sabagh et al., 2021; Kizilgeci et al., 2020). Among the strategic cereals crops, wheat is the most staple cereal crop in Egypt with total annual production of about 10 million tons in 2021-2022 growing season from an average of 1.5 million hectares (FAO, 2023). Moreover, the productivity of wheat in Egypt (7.5t/ha) is among the highest in the world (FAO, 2023). However, there is a huge gap between local production and demand for consumption leading to the importation of about 10.6 million tons of wheat during 2022.

Salt stress affects 20% of global cultivable land and is increasing continuously owing to the change in climate and anthropogenic activities (Arora, 2019). Moreover, Chartres & Noble (2015)

#Corresponding author email: ahmed.elkot@arc.sci.eg
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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.

This huge gap between production and consumption lead to increase the wheat-cultivated area in the newly reclaimed lands in Egypt. Currently, rising soil salinity has been a major problem in the soils of Egypt in the most of the newly reclaimed land located in west and east of Delta and west of the Nile Valley in Upper Egypt, are suffering from salinity stresses (Karajeh et al., 2011). Around 30 to 40% of the soils of the Nile delta classified as salt-affected soils (Yassin et el., 2019; Hammam & Mohamed, 2020; Masarmi et al., 2023).

Salinity stress on yield and grain quality are often most important during the growth stages, wheat tillering stage, and plant height and number of spikes per meter square (Tadesse et al., 2018). Moreover, Soil salinity effect the plant growth by increasing osmotic stress, ion toxicity, and nutritional imbalance or a combination of these factors which effect the plant growth, physiological and biochemical metabolism in wheat crop and reduce the biological and grain yield (Ashraf & Harris, 2004; Genedy & Eryan, 2022; Ashraf et al., 2023).

In general, wheat is stated to be moderately tolerant to salinity (Asif et al., 2020). Soil Salinity problems require sustainable management strategies, including; identifying and further developing crop cultivation practices adapted to saline conditions, enhanced drainage systems in the salinity effected soils, developing salt-tolerant wheat varieties and exchanging knowledge and transferring practical and adaptive solutions. Development of tolerant wheat materials through exploring the available genetic resource is one the most effective strategy to cope with salinity challenging and developing new wheat cultivars tolerant to salinity stress in Egypt, which is relatively low-cost and environmentally friend strategy (Ragab & Kheir, 2019).

To ensure high wheat yield under saline conditions, breeding efforts for improving salinity tolerance of wheat cultivars is one of the most important breeding targets especially with increasing the agricultural land through establishing national mega projects to reclaim and cultivate new lands in new delta (Ragab & Kheir, 2019; Volkov & Beilby, 2017).

Through the breeding programs, a few salt-tolerant bread wheat cultivars have been developed and cultivated in different countries for example Sakha 8 in Egypt, KLR1-4 and KLR 19 (India), LU-26S and SARC-1 (Pakistan) (Munns et al., 2006) but these cultivars no longer used due to the high susceptibility to wheat rusts diseases.

Stress tolerance indices (STI's) were widely used as simple mathematical equations that quantify and compare the grain yields under stressed and non-stressed conditions to differentiate the tolerant/sensitive genotypes. There are various stress tolerance indices such as stress susceptibility index "SSI", (Fischer & Maurer, 1978), a larger value of SSI represent relatively more sensitivity to stress, thus smaller values of SSI are favored.

This current investigation was aimed to: (1) evaluate the performance of eight Egyptian wheat cultivars under normal and saline soil condition, (2) understand the effects of salinity stress on some agronomic traits, yield and its components of wheat cultivars under this study, (3) find out salt-tolerance cultivars for cultivation in saline soil in Egypt.

Materials and Methods

Two years field experiment was conducted on the experimental farm of Sakha Agricultural Research Station, Kafr Elsheikh, Egypt, in two consecutive wheat growing seasons of 2020/2021 and 2021/2022.

The experimental materials consisted of selected eight Egyptian wheat cultivars obtained from Wheat Research Department, Filed Crops Research Institute, Agricultural Research Center, Egypt. The details of Name and pedigree of the selected bread wheat cultivars are shown in Table 1.

The experiments were conducted under two different conditions: normal soil (N) at the 2nd Nattaf farm (2.04 EC) and salt affected soil (S) at El-Hamrawy farm (8.66 EC), Sakha Agricultural Research station. The soil analysis of the two locations was carried out at the Laboratories of Soil Research Department, Sakha Agricultural Research Station, Agricultural Research Center, Kafrel sheikh, Egypt (Table 2). The meteorological data for the two growing seasons were obtained from The Central Laboratory for Agricultural Climate (Tables 3, 4).

Experimental design

The selected eight wheat cultivars were arranged in Latin Square Design with eight rows, eight column and eight wheat cultivars under normal (N) and saline (S) conditions. The area of the experimental unite was 4.8 m^2. Each plot consisted of eight rows, 4 m long and 0.2 m apart. The sowing dates in the two locations of normal and stress condition were 23 and 28 November in the two successive seasons respectively. All recommended agricultural practices were applied as recommended for wheat crop.

Statistical analysis

The recorded data included earliness characters, i.e. days to heading (DTH) and days to maturity (DTM), grain filling period (d) (GFP = DTM-DTH), grain filling rate (g/d) (GFR = GY/GFP) and the agronomic data including grain yield and its attributes which were recorded as follows: plant height (PH) in cm, number of spikes/ m^{-2} (SPM^{-2}), number of kernels $spike^{-1}$ (KSP^{-1}), 1000-kernel weight (1000-KW, g), biological yield BY (ton/fad), harvest index (H% = (GY/BY)*100), grain yield (ton/fad) (faddan= 4200 m^2) and Stress susceptibility index (SSI) was estimated according to Fischer & Maurer (1978) as:

SSI = (1 - Yd/Yp)/D.

where: Yd = mean yield under saline soil, Yp = mean yield under normal soil = potential yield, D = salinity stress intensity = 1 - (mean Yd of all genotypes/mean Yp of all genotypes).

The obtained data were analyzed using SPSS, (IBM crop, 2020) (Version 27.0). The results of Levene test (Leven, 1960) proved the homogeneity of separate error variances for all studied traits that permits to apply combined analysis.

TABLE 1. Name, pedigree and selection history of the eight selected Egyptian wheat cultivars

Cultivar	Pedigree and selection history
Gemmiza 12	TUS /3/ SARA / THB // VEE CMSS97Y00227S-5Y-010M-010Y-010M-2Y-1M-0Y-0GM
Sids 1	HD 2172 / PAVON “S” // 1158.57/ MAYA 74 “S” S 46-4SD-2SD-1SD-0SD
Sids 12	BUC//7C/ALD/5/MAYA74/ON//1160.147/3/BB/GLL/4/CHAT”S”/6/MAYA/ VUL//CMH74A.630/4*SX SD7096-4SD-1SD-1SD-0SD
Sids 14	SW8488*2/KUKUNA CGSS01Y00081T-099M-099Y-099M-099B-9Y-0B-0SD
Misr 1	OASIS/SKAUZ//4*BCN/3/2*PASTOR CMSS00Y01881T-050M-030Y-030M-030WGY-33M-0Y-0S
Misr 2	SKAUZ/BAV92 CMSS96M03611S-1M-010SY-010M-010SY-8M-0Y-0S
Giza 171	SAKHA 93/GEMMEIZA 9 Gz2003-101-1Gz-4Gz-1Gz-2Gz- 0Gz
Shandweel 1	SITE/MO/4/NAC/TH.AC//3*PVN/3/MIRLO/BUC CMSS93B00567S-72Y-010M-010Y-010M-3Y-0M-0HTY-0SH

TABLE 2. Soil analysis for normal soil (2nd Nattaf Farm) and salt-affected soil (Elhamrawy Farm) during 2020-2021 and 2021/2022 seasons

Location	Season	Soil depth (cm)	Soil structure	ECdsm^{-1}	Soluble anions MeqL^{-1}			Soluble captions MeqL^{-1}			
					Hco_3^{-}	Cl^{-}	So_4^{--}	Ca^{++}	Mg^{++}	Na^{+}	K^{+}
2nd Nattaf Farm	2020/21	0-30	Clay	2.03	3.13	8.16	9.16	5.54	3.89	10.48	0.27
		30-60	Clay	1.48	2.62	4.84	7.39	3.41	2.43	8.64	0.32
	2021/22	0-30	Clay	2.05	3.24	9.01	8.41	5.52	3.95	10.98	0.3
		30-60	Clay	1.52	2.85	5.03	7.75	3.98	2.35	8.87	0.29
ElHamrawy Farm	2020/21	0-30	Clay	8.62	4.12	37.06	48.36	25.41	17.52	46.05	0.51
		30-60	Clay	6.51	3.21	28.02	34.34	10.73	10.73	41.74	0.39
	2021/22	0-30	Clay	8.76	4.03	38.96	46.98	24.48	16.86	47.89	0.61
		30-60	Clay	6.59	3.36	31.66	34.58	14.25	11.15	41.58	0.51

TABLE 3. The monthly metrological parameters at Sakha Agricultural research station during 2020/2021growing season

Month	T2M	TMIN	TMAX	TDEW	RH2M	RAIN	WIND	SRAD
November	19.95	15.79	25.76	12.55	65.1	27.5	2.25	11.73
December	16.53	11.73	23.48	8.88	64.8	1.3	2.01	11.15
January	15	9.95	22.05	8.01	67.07	11.8	2.5	11.16
February	14.74	9.73	22.25	7.68	68.21	39.9	2.19	14.06
March	15.85	10.3	23.35	8.27	65.65	53.6	2.67	18.54
April	19.96	12.09	29.84	8.28	56.22	0.5	2.88	24.44
May	26.63	17.87	37.14	10.51	46.37	0	2.81	27.6
Average and Sum	18.38	12.49	26.27	9.17	61.92	19.23	2.47	16.95

TABLE 4. The monthly metrological parameters at Sakha Agricultural Research station during 2021/2022 growing season

Month	T2M	TMIN	TMAX	TDEW	RH2M	RAIN	WIND	SRAD
November	21.5	16.5	28.57	13.72	66.33	29.7	2.25	12.33
December	14.94	10.87	20.51	8.93	69.89	12.4	2.59	8.76
January	11.5	6.96	17.6	5.89	71.22	51.9	2.48	10.82
February	13.06	7.98	19.9	7	70.13	12.5	2.35	14.68
March	13.64	8.18	20.78	6.13	65.33	31.8	2.79	17.99
April	21.62	13.43	31.45	7.81	52.18	0.7	3.01	21.71
May	24.76	16.8	33.86	10.81	51.23	5.3	3.2	24.2
Average and Sum	17.29	11.53	24.67	8.61	63.76	20.61	2.67	15.78

T2M Temperature Average at 2 Meters (°C), TMIN minimum temperature at 2 Meters, (°C), TMAX maximum temperature at 2 Meters (°C), TDEW, ew/Frost Point at 2 Meters (°C), RH2M Relative Humidity % Average at 2 Meters, RAIN Precipitation (mm), Wind Speed at 2 Meters (m/s), SRA Solar Radiation (MJ/m^2/day)

Results

The means of all studied characters across the two seasons for the normal and saline soils were presented in Tables 5-8.

In Table 5, the mean values of days to heading (DTH) ranged from 97.38 to 86.63 days for Sids12 and from 108.13 to 95.50 days for Misr2 under normal and soil salinity conditions, respectively. Days to maturity (DTM) ranged from 148.75 to 130.94 days for Sids 12 and from 155.94 to 138.63 days for Misr 2 under normal and soil salinity conditions, respectively. The longest grain filling period GFP's (51.38 days) were for Sids12 and Giza171 (51.31 days), while Misr2 had the shortest GFP (47.81 days) under the normal conditions. Under saline conditions Shandweel 1 and Giza171 had 45.00 and 44.44 day, respectively, while the longest GFP's (42.63 and 42.50 day) were for Sids 1 and Sids14, respectively

The highest grain filling rate (GFR) was observed by Misr 1 (67.99) under normal conditions and for Giza 171 (54.42) under saline conditions, while Sids 12 had the lowest rates (21.07 and 15.35) under both conditions, respectively. In case of plant height, Misr 2 produced the highest plants with 121.56 and 110.94 cm, and Sids 12 gave the shortest plants of 100.63 and 89.06 cm, under both conditions, respectively (Table 6).

The number of spikes/m^2 (SPM^2) went in the range from 220.13 with Sids 12 to 420.81 with Misr 2 under normal conditions. The same trend was also observed under saline condition, the number of spikes/ m^2 was ranged from 171.88 with Sids 12 to 340.63 with Misr 2.

The data in Table 7 revealed that, under the respective conditions the highest numbers of kernels/spike (KSP^{-1}) were observed with Shandaweel 1 (84.15) and Giza 171 (60.19), while the lowest numbers were with Sids 1 (58.08) and Misr 2 (40.29).

The highest 1000 kernel weight (1000-KW) was Giza 171 under two conditions with value 53.79 and 46.71, respectively, while the lowest one was Misr 2 with 39.12 and 27.67 under the respective two conditions.

The data in table 7 also showed that biological yield (BY) of the tested cultivars ranged from 4.53 or 3.01 ton/faddan in Sids 12 to 9.61 or 6.24 ton/faddan in Giza 171 under normal or saline conditions, respectively.

The mean values of the harvest index (HI%) ranged from 26.83% with Sids 1 to 36.02% with Sids 14 under normal conditions, and from 22.46% with Sids 12 to 38.94% with Giza 171 under saline conditions. (Table 8).

TABLE 5. Mean performance of the days to heading, days to maturity and grain filling period (day) as affected by salinity conditions and genotypes

Cultivar	Days to heading (days)		Days to maturity (days)		Grain filling period (day)	
	Normal	Salinity	Normal	Salinity	Normal	Salinity
Gemmeiza 12	103.19	90.06	151.38	133.94	48.19	43.88
Sids 1	106.63	94.38	155.38	137.00	48.75	42.63
Sids 12	97.38	86.63	148.75	130.94	51.38	44.31
Sids 14	106.00	94.38	155.06	136.88	49.06	42.50
Misr 1	103.06	91.19	151.69	135.06	48.63	43.88
Misr 2	108.13	95.50	155.94	138.63	47.81	43.13
Giza 171	104.31	92.63	155.63	137.06	51.31	44.44
Shandweel 1	104.44	92.19	155.19	137.19	50.75	45.00
Mean	104.14	92.12	153.63	135.84	49.48	43.72
F test	**	**	**	**	**	**
Lsd 0.05	1.62	2.84	1.46	2.25	1.06	1.68

TABLE 6. Mean performance of number of grain filling rate (g/day), plant height (cm) and number of spike/m^2 as affected by salinity conditions and genotypes

Cultivar	Grain filling rate (g/day)		Plant height (cm)		Number of Spikes/m^2	
	Normal	Salinity	Normal	Salinity	Normal	Salinity
Gemmeiza 12	57.98	32.34	112.19	102.19	358.25	305.63
Sids 1	44.19	37.06	115.63	106.25	414.06	313.13
Sids 12	21.07	15.35	100.63	89.06	220.13	171.88
Sids 14	67.24	38.91	119.38	107.50	378.88	317.34
Misr 1	67.99	38.31	107.50	101.88	400.44	319.06
Misr 2	57.69	27.22	121.56	110.94	420.81	340.63
Giza 171	66.95	54.42	117.81	109.38	370.69	326.41
Shandweel 1	55.71	31.04	117.19	106.56	366.75	329.84
Mean	54.85	34.33	113.98	104.22	366.25	302.99
F test	**	**	**	**	**	**
Lsd0.05	4.31	4.71	3.46	4.21	34.83	26.55

TABLE 7. Mean performance of number of kernels/spike, 1000 kernel weight and biological yield (ton/fad) as affected by salinity conditions and genotypes

Cultivar	Number of spikes/m^2		1000 kernel weight		Biological yield (ton/fad)	
	Normal	Salinity	Normal	Salinity	Normal	Salinity
Gemmeiza 12	68.81	52.06	43.67	33.36	8.38	4.61
Sids 1	58.08	41.66	39.89	34.02	8.07	5.50
Sids 12	81.78	52.86	47.01	28.53	4.53	3.01
Sids 14	77.41	53.04	50.94	40.67	9.18	5.22
Misr 1	59.68	46.05	44.74	32.24	9.28	5.57
Misr 2	68.55	40.29	39.12	27.67	8.82	4.92
Giza 171	74.85	60.19	53.79	46.71	9.61	6.24
Shandweel 1	84.15	50.61	40.63	27.70	8.51	5.11
Mean	71.66	49.59	44.97	33.86	8.30	5.02
F test	**	**	**	**	**	**
Lsd 0.05	12.02	9.42	8.60	5.47	0.42	0.51

TABLE 8. Mean performance of harvest index % and grain yield (ton/fad) as affected by salinity conditions and genotypes

Cultivar	Harvest index %		Grain yield (ton/fad)	
	Normal	Salinity	Normal	Salinity
Gemmeiza 12	33.89	30.78	2.79	1.42
Sids 1	26.83	28.48	2.16	1.57
Sids 12	27.22	22.46	1.09	0.68
Sids 14	36.02	31.36	3.28	1.64
Misr 1	35.45	30.42	3.31	1.69
Misr 2	31.23	23.78	2.76	1.17
Giza 171	35.64	38.94	3.41	2.43
Shandweel 1	33.49	27.04	2.83	1.38
Mean	32.47	29.80	2.70	1.50
F test	**	**	**	**
Lsd 0.05	2.51	5.14	0.25	0.20

The cultivar Giza 171 gave the highest grain yield (GY) of 3.41 and/or 2.43 ton/faddan under the two respective conditions. On the other hand, Sids 12 gave the lowest ones of 1.09 and/or 0.68 ton/faddan, respectively.

The effect of seasons, soil treatments and cultivars interaction

The estimates of the studied traits under the normal and saline conditions in the two seasons were demonstrated from Tables 9 - 12. For days to heading (DTH), Sids 12 was the earliest cultivar and Misr 2 was the latest one in two seasons under normal and saline conditions. For days to maturity (DTM) also Sids 12 was the earliest cultivar and Misr 2 was the latest one in the two seasons under normal and saline conditions.

For the grain filling period (GFP) the two wheat cultivars Shandweel 1 and Sids 12 were having the longest grain filling period under normal conditions in the first season and Misr 2 had the shortest grain filling period, while Shandaweel 1 and Giza171 having the longest grain filling period and Misr 1 had the shortest grain filling period under soil saline in the first season. Likewise, in the second season Giza 171 and Shandaweel 1 were having the longest grain filling period and Gemmeiza 12 had the shortest grain filling period under normal condition while, Shandaweel 1 and Gemmiza 12 were having the longest filling period and Misr 2 had the shortest grain filling period under soil saline conditions (Table 9).

For the grain filling rate (GFR) in the first season under normal and soil saline conditions Giza171 and Sids 14 had the highest rates, while, Sids 12 had the lowest rates under normal and soil saline conditions. In the second season under normal conditions, Misr1 and Gemmiza 12 had the highest tested cultivars and under soil saline conditions Giza171 and Misr1 were the highest cultivars, while, Sids 12 had the lowest rates under normal and soil saline conditions. (Table10).

For plant height (PH), data in table 10 revealed that, in the first season, both cultivars Sids 14 and Misr 2 were the tallest plants under normal conditions with 126.88cm, while, Misr 2 was the tallest one under saline conditions with 112.50 cm, while, Sids 12 had the shortest one with (104.38 and 90.00 cm) under normal and saline conditions, respectively. However, in the second season Misr 2 produced the tallest plants under the respective conditions with 116.25 and 109.18 cm, Sids 12 produced the shortest plants under the respective conditions with 96.88 and 88.13 cm.

For the number of spikes/ m^2 (SPM^{-2}), the wheat cultivars Sids 12 showed the lowest number of spikes/ m^2 under normal and soil saline conditions in the two seasons, while Misr 2 showed the highest number of spikes/ m^2 in the first season in normal and saline conditions. In the second season the two wheat cultivars Sids 1 and Misr 2 had the highest number of spikes/ m^2 in normal and saline soil. However, in the two years of experiment under normal and saline conditions Sids 12 showed the lowest number of spikes/ m^2 among the tested eight wheat cultivars.

For the number of kernels/spike (KSP^{-1}), Sids 1 showed the lowest number of kernels/spike among the tested wheat cultivars and Shandweel 1 showed the highest number of kernels / spike under normal condition in two seasons, while under saline condition in two seasons Giza 171 showed the highest number of kernels / spike among the tested eight wheat cultivars (Table 11).

For 1000 kernel weight (1000-KW), the cultivar Giza 171 showed the highest value of 1000 kernel weight under normal and saline conditions in the two consecutive seasons, while, Misr 2 had the lowest value of 1000 kernel weight under normal and saline conditions in two seasons (Table11).

The biological yield (BY) data showed that the wheat cultivar Giza 171 had the highest biological yield among the tested wheat cultivars under normal and saline conditions in the first season. In the second season Misr 1 showed the highest biological yield under normal conditions, while Giza171 showed the highest biological yield among the tested wheat cultivars under saline condition (Table 11).

For the harvest index (HI%), in the first season Giza171 showed the highest harvest index under normal condition while, Sids 14 showed the highest harvest index under salinity condition. In the second season under normal condition Misr 1 showed the highest harvest index while, Giza171 showed the highest harvest index under salinity condition (Table 12).

TABLE 9. Mean performance of days to heading, days to maturity and grain filling period (day) as affected by interactions among seasons, salinity conditions and genotypes

Cultivar	Days to heading (days)				Days to maturity (days)				Grain filling period (day)			
	2020/2021		2021/2022		2020/2021		2021/2022		2020/2021		2021/2022	
	Normal	Salinity	Normal	Salinity	Normal	Salinity	Normal	Salinity	Normal	Salinity	Normal	Salinity
Gemmeiza 12	103.25	90.13	103.13	90.00	151.88	129.00	150.88	138.88	48.63	38.88	47.75	48.88
Sids 1	107.50	93.50	105.75	95.25	154.75	131.88	156.00	142.13	47.25	38.38	50.25	46.88
Sids 12	97.13	88.38	97.63	84.88	146.25	128.38	151.25	133.50	49.13	40.00	53.63	48.63
Sids 14	107.63	94.25	104.38	94.50	154.13	132.75	156.00	141.00	46.50	38.50	51.63	46.50
Misr 1	104.25	91.00	101.88	91.38	152.63	131.25	150.75	138.88	48.38	40.25	48.88	47.50
Misr 2	109.00	94.13	107.25	96.88	154.75	134.50	157.13	142.75	45.75	40.38	49.88	45.88
Giza 171	106.13	91.88	102.50	93.38	155.00	132.75	156.25	141.38	48.88	40.88	53.75	48.00
Shandweel 1	105.50	91.63	103.38	92.75	154.75	132.63	155.63	141.75	49.25	41.00	52.25	49.00
Mean	105.05	91.86	103.23	92.38	153.02	131.64	154.23	140.03	47.97	39.78	51.00	47.66
F test	**	**	**	**	**	**	**	**	**	**	**	**
Lsd 0.05	2.17	3.25	2.41	4.66	1.91	3.45	2.23	2.88	1.45	1.73	1.54	2.87

TABLE 10. Mean performance of grain filling rate (g/day), plant height (cm) and number of spikes/m2 as affected by interactions among seasons, salinity conditions and genotypes

Cultivar	Grain filling rate (g/day)				Plant height (cm)				Number of spikes/m^2			
	2020/2021		2021/2022		2020/2021		2021/2022		2020/2021		2021/2022	
	Normal	Salinity	Normal	Salinity	Normal	Salinity	Normal	Salinity	Normal	Salinity	Normal	Salinity
Gemmeiza 12	55.63	32.65	60.33	32.03	116.88	104.38	107.50	100.00	359.38	273.13	357.13	338.13
Sids 1	37.58	39.19	50.80	34.93	117.50	107.50	113.75	105.00	403.75	251.56	424.38	374.69
Sids 12	20.61	16.17	21.53	14.54	104.38	90.00	96.88	88.13	271.13	188.75	169.13	155.00
Sids 14	74.92	44.08	59.55	33.73	126.88	108.75	111.88	106.25	403.38	243.75	354.38	390.94
Misr 1	59.69	34.67	76.29	41.96	111.88	104.38	103.13	99.38	422.13	259.38	378.75	378.75
Misr 2	55.53	29.44	59.85	25.01	126.88	112.50	116.25	109.38	435.38	306.88	406.25	374.38
Giza 171	75.84	50.57	58.07	58.27	122.50	111.25	113.13	107.50	392.38	282.19	349.00	370.63
Shandweel 1	53.79	32.66	57.63	29.41	123.13	108.13	111.25	105.00	376.63	295.94	356.88	363.75
Mean	54.20	34.93	55.51	33.74	118.75	105.86	109.22	102.58	383.02	262.70	349.48	343.28
F test	**	**	**	**	**	**	**	**	**	**	**	**
Lsd 0.05	9.29	6.51	5.23	6.79	5.17	6.48	4.60	5.38	69.69	41.03	56.19	33.71

TABLE 11. Mean performance of number of kernels/spike, 1000- kernel weight (g) and biological yield (ton/fad) as affected by interactions among seasons, salinity conditions and genotypes

Cultivar	Number of spikes/m²				1000 kernel weight				Biological yield (ton/fad)			
	2020/2021		2021/2022		2020/2021		2021/2022		2020/2021		2021/2022	
	Normal	Salinity	Normal	Salinity	Normal	Salinity	Normal	Salinity	Normal	Salinity	Normal	Salinity
Gemmeiza 12	66.38	50.00	71.25	54.13	38.80	29.24	43.67	33.36	9.26	4.47	7.49	4.75
Sids 1	55.64	39.60	60.51	43.73	35.01	29.89	39.89	34.02	8.16	4.60	7.98	6.40
Sids 12	79.34	50.81	84.21	54.90	42.14	24.40	47.01	28.53	5.97	3.43	3.09	2.59
Sids 14	74.98	50.85	79.85	55.23	46.07	30.49	50.94	40.67	10.43	3.91	7.93	6.53
Misr 1	57.24	43.99	62.11	48.11	39.87	28.11	44.74	32.24	9.19	4.86	9.38	6.28
Misr 2	66.11	38.23	70.99	42.35	34.24	23.54	39.12	27.67	8.60	4.66	9.05	5.19
Giza 171	72.41	58.13	77.29	62.25	48.92	42.59	53.79	46.71	10.60	5.55	8.62	6.93
Shandweel 1	81.71	48.55	86.59	52.68	35.76	23.57	40.63	27.70	8.65	4.68	8.36	5.54
Mean	69.23	47.52	74.10	51.67	40.10	28.98	44.97	33.86	8.86	4.52	7.74	5.52
F test	**	**	**	**	**	**	**	**	**	**	**	**
Lsd 0.05	17.00	13.33	17.00	13.32	8.60	5.30	8.60	5.47	0.68	0.76	0.48	0.68

TABLE 12. Mean performance of harvest index (%), grain yield/fad (ton/fad) as affected by interactions among seasons, salinity conditions and genotypes.

Cultivar	Harvest index %				Grain yield (ton/fad)			
	2020/2021		2021/2022		2020/2021		2021/2022	
	Normal	Salinity	Normal	Salinity	Normal	Salinity	Normal	Salinity
Gemmeiza 12	29.24	28.71	38.54	33.23	2.70	1.27	2.88	1.56
Sids 1	21.80	32.83	31.85	25.45	1.78	1.51	2.55	1.62
Sids 12	17.17	19.31	37.28	31.34	1.02	0.64	1.16	0.71
Sids 14	33.36	49.04	38.68	23.70	3.48	1.70	3.07	1.58
Misr 1	31.19	28.85	39.70	31.99	2.89	1.40	3.72	1.99
Misr 2	29.53	25.57	32.92	22.39	2.54	1.19	2.98	1.15
Giza 171	34.91	37.44	36.36	40.59	3.71	2.06	3.12	2.80
Shandweel 1	30.81	28.74	36.18	26.12	2.65	1.33	3.01	1.43
Mean	28.50	31.31	36.44	29.35	2.59	1.39	2.81	1.61
F test	**	**	**	**	**	**	**	**
Lsd 0.05	4.07	8.10	2.93	6.33	0.44	0.25	0.24	0.30

For the grain yield (GY), in the first season Giza 171 showed the highest grain yield under normal and salinity conditions while, in the second season Misr1 showed highest grain yield under normal conditions and Giza171 showed the highest grain yield under salinity condition. On the other hand, Sids 12 produced the lowest grain yield under the two respective conditions and seasons (Table 12).

Salinity tolerance

Susceptibility index

In Table 13 the data showed that the susceptibility index (SSI) established on grain yield for the tested cultivars in the two seasons Sids 1 then Giza 171 followed by Sids 12 had SSI values below unity for over all seasons, while the values of SSI above unity belonged to Misr 1 then Gemmieza 12, Sids 14 and Misr 2 as on average of the two seasons.

This figure divide into four sections the best cultivars that exists in top right section and the lowest cultivars exists in top left section according that Fig. 1 illustrated the means of all tested wheat cultivars of all studied traits under normal condition at two seasons, it indicated the best genotypes in most traits were Giza 171, Sids 14 then Shandweel 1, and the lowest genotype in all traits under study was Sids 12.

This figure divide into four sections the best cultivars that exists in top right section and the lowest cultivars exists in top left section, according to Fig. 2 in salinity conditions under two seasons, the best genotypes in most traits under study were Giza 171, Sids 14, then Misr 1 and Sids 12 was the lowest genotypes for all studied traits.

Discussion

In the current investigation, the salt affected soil is characterized by moderate to high salinity levels EC in the range between 6.51 and 8.76 dsm^{-1} (Rhoades et al., 1999) in El-Hamrawy farm which represent the saline soil, while under normal condition in 2nd Nattaf farm EC in the range of 1.48 to 2.05 dsm^{-1} (Tables 2). In the current study, the tested eight wheat cultivars were varied in their values for most of the studied traits in the first and second season. This might happened be due to the change of the environmental factors like temperature, relative humidity and the interaction between the cultivars and environmental factors. These results were similar to results obtained by Darwish et al. (2017), Farhat et al (2019, 2020) and Abd El-Hamid et al. (2020), (Table 3). All studied traits were decreased under saline soil conditions, as shown in Tables 5-8 these results were similar to Shabala & Munns (2017), Farhat et al. (2020) and Masarmi et al. (2023). They indicated that the salinity could 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 depend on the rate of leaf injury as shown in Tables 5-8.

The means of days to heading and days to maturity reduced under salinity conditions as well as a significant reduction in the number of kernels/ spike and number of spikes /m^2. Therefore, grain yield was decreased under salinity conditions. These results are similar to those reported in the previous studies (El-Hendawy et al., 2005; Ragab & Kheir, 2019; Abd El-Hamid et al., 2020; Ghonaim et al., 2020; Moghadam et al., 2020; Ashraf et al., 2023). They reported that salinity could decrease spike fertility and translocation of assimilates to the grains of wheat, that might be led to the reduction of grain yield under salinity conditions.

TABLE 13. Estimates of a salinity stress susceptibility index based on grain yield for the studied genotypes in the two seasons

Cultivar	2020/2021	2021/2022	Over all
Gemeiza 12	1.10	1.06	1.08
Sids 1	0.20	0.82	0.49
Sids 12	0.73	0.84	0.78
Sids 14	1.08	1.10	1.09
Misr 1	1.05	1.08	1.07
Misr 2	1.07	1.43	1.24
Giza 171	0.94	0.23	0.60
Shandweel 1	1.02	1.22	1.12

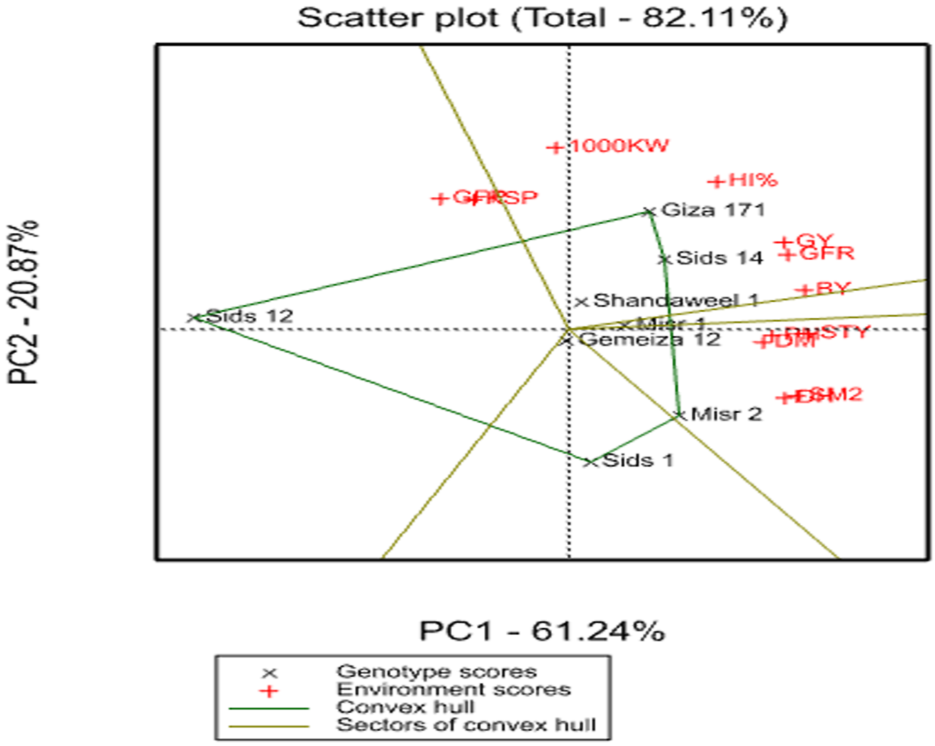

Fig. 1. Means of genotypes for studied traits under normal conditions at two seasons

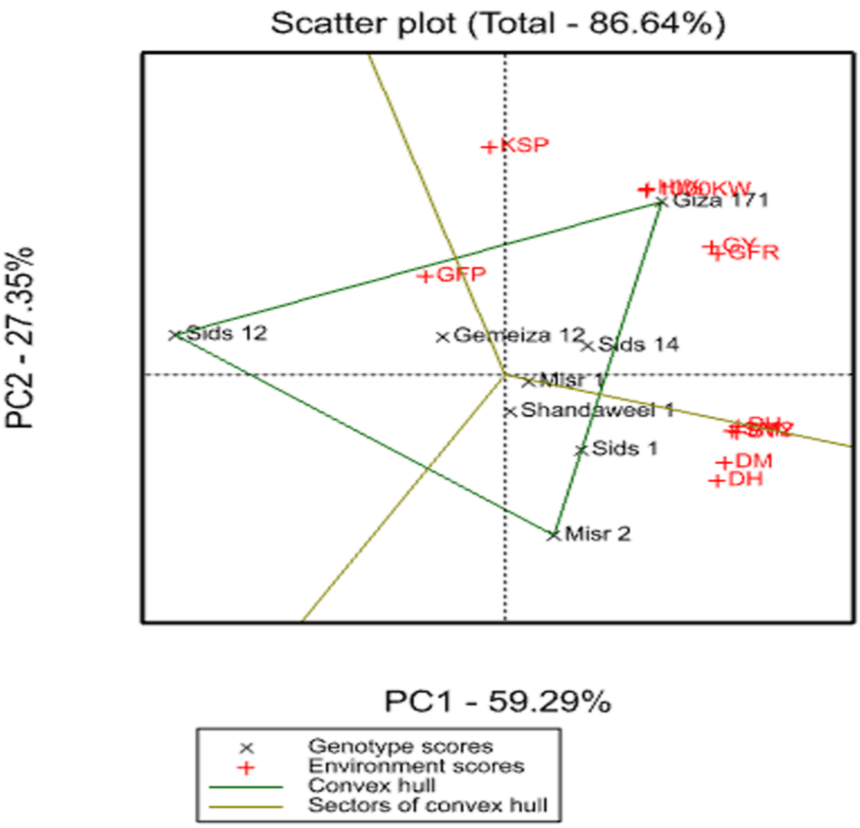

Fig. 2. Means of genotypes for studied traits under saline conditions at two seasons

Likewise, results in Tables 9-12 showed that the highest decrease in the studied traits were observed in the sensitive wheat cultivars. This was matching with the results obtained by Darwish et al. (2017), Abd El-Hamid et al. (2020) and Farhat et al. (2019, 2020), their results showed that the effect of temperature and soil salinity during grain filling period resulted in reduced grain growth and shortening the period for normal grain development and grain filling rate was reduced according to short grain filling period and therefore affect grain yield.

The SSI values for evaluated cultivars 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. As shown in Table 13 the mean SSI over two seasons appeared to be a suitable selection index to distinguish the resistant cultivar for salinity tolerance. The bread wheat cultivars showed low values of these indices would be more tolerant to soil salinity stress as reported by Hamam & Negim (2014), Farhat et al. (2020) and Darwish et al. (2023). These results showed that Sids1, Giza171 and Sids 12 were considered tolerant wheat cultivars respectively. These results agree with those obtained by Darwish et al. (2017), Hagras et al. (2018) and Abd El-Hamid et al. (2020). They reported that Giza 171 was moderate soil salinity tolerance.

The Genotype by trait (GT) analysis reported by Feroz et al. (2017) and Farhat et al. (2020) as screening tool to identify the salt tolerant wheat cultivar. The GT method illustrates together the grain yield superiority and relative tolerant wheat cultivars to the studied stress expressed with the most stability under the studied environments, however, Giza 171 was showed superiority among all tested cultivars in most of the traits like 1000-kernel weight (1000- KW) , grain yield(GY), biological yield (BY) and harvest index (HI %). However, Giza 171 showed lower grain filling period (GFP) and higher grain filling rate (GFR) which indicate that, Giza171 the most stable and tolerant cultivars among testes wheat cultivars under soil salinity conditions and similar results reported by Abd El-Hamid et al. (2020). These results reflect the genetic background of the wheat cultivars that derived from the salinity tolerant parent Sakha93.

Conclusion

The present study showed the effect of soil salinity in different wheat cultivars and the results concluded the decrees of important agronomic traits like grain yield and biological yield and some other traits under salinity condition. However, the results showed the superiority of wheat cultivar Giza 171 was the best genotypes at two seasons under normal and saline soil condition. GT analysis could facilitate testing of different genotype for relative tolerance of salinity and grain yield superiority at the main time.

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تقييم ثمانية اصناف من قمح الخبز لتحمل الملوحة فى التربة

أحمد فوزى القط، زينب احمد عباس الرشيدى، مختار مراجع مختار
قسم بحوث القمح- معهد بحوث المحاصيل الحقلية - مركز البحوث الزراعية- الجيزة- مصر.

تٌعد ملوحة التربة من أهم معوقات إنتاج القمح على المستوى العالمي. ولذلك تم تقييم ثمانية اصناف من قمح الخبز تحت ظروف التربة العادية والتربة الملحية خلال موسمى 2021/2020 و2022/2021 فى محطة بحوث سخا- كفر الشيخ- مصر فى تصميم المربع اللاتينى . كان الهدف من الدراسة هو معرفة تأثير اجهاد الملوحة على الصفات التى تم دراستها ومعرفة افضل الاصناف تحت ظروف الأراضى المتأثرة بالملوحة.

الصفات المدروسة كانت عدد الأيام من الزراعة حتى طرد السنابل، عدد الأيام من الزراعة حتى النضج الفسيولوجى، مدة امتلاء الحبوب، معدل امتلاء الحبوب، ارتفاع النبات، عدد السنابل فى المتر المربع، عدد الحبوب فى السنبلة، وزن الالف حبة، المحصول البيولوجى، دليل الحصاد و محصول الحبوب/فدان. اختلفت نتائج الموسمين معنويا وكذلك كانت قيم متوسطات الصفات تحت ظروف التربة الملحية أقل من التربة العادية وكذلك كانت الأصناف الأفضل تحت ظروف التربة العادية هى جيزة 171، سدس 14 و شندويل 1 وكانت أقل الأصناف سدس 12. أفضل الأصناف تحت التربة الملحية كانت جيزة 171، سدس 14 و مصر 1 وأيضا كان أقلهم سدس 12.