5 *Egypt. J. Agron.* **Vol. 45**, No. 3, pp. 271 - 286 (2023)

Egyptian Journal of Agronomy
http://agro.journals.ekb.eg/

Performance of Some Egyptian Bread Wheat Cultivars under Saline Soil Conditions at North Delta of Egypt

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SALINITY poses a significant threat to crop growth and yield, including wheat. This study, conducted at El Hamarawey farm at Sakha Agriculture Research Station in Egypt during the 2020/2021 and 2021/2022 wheat growing seasons, aimed to assess ten Egyptian bread wheat cultivars (Misr 1, Sakha 93, Sakha 95, Giza 168, Giza 171, Gemmaiza 9, Gemmaiza 11, Sids 13, Sids 14, Shandaweel 1) in both normal and saline soils. Employing a randomized complete block design with four replicates, the study examined various traits including heading date, maturity, plant height, flag leaf area, yield and its components, chlorophyll, and proline. Under saline soil conditions, a significant decrease in most traits was observed, with notable variations among wheat cultivars. Sakha 95 excelled in plant height, flag leaf area, grain yield, and chlorophyll a, b, and a + b, while Sakha 95 and Sids 14 demonstrated superior performance in 1000-grain weight, and Shandaweel 1 exhibited superiority in the number of grains/spike and proline content. A positive and highly significant correlation was found between grain yield and the number of spikes/m², number of grains/spike, and chlorophyll a and a + b, with significant correlations with the number of days to heading and maturity, 1000-grain weight, and chlorophyll b. Gemmiza 9, Shandaweel 1, Gemmeiza 11, Misr 1, and Sakha 93 emerged as highly salt-tolerant genotypes under investigation.

Keywords: Egyptian bread wheat *(Triticum aestivum* L.), salinity stress, yield and its component and correlation coefficient.

Introduction

Wheat stands as a crucial crop in both Egypt and on a global scale, and this is evident as Egypt is one of the largest wheat importers globally. It is not only the largest importer but also the biggest wheat consumer and bread eater per capita in the world. In 2021, Egypt's wheat production reached approximately nine million metric tons, representing a 1.12 percent increase from the previous year. Wheat is a crucial source of stable food in both urban and rural societies and plays a significant role in human nutrition. The estimated annual cultivated area for wheat in Egypt during the 2021/2022 season was about 3.6 million feddans (fed = 4200 m^2), with total production exceeding 9 million tons. Wheat holds strategic importance, impacting national economies worldwide (Yadav *et al.,* 2018).

Any reduction in wheat yield due to biotic or abiotic factors can have damaging effects on global food security. The increasing global population raises concerns about food production, and salt-affected soil, along with water shortage and nutrient deficiency, is a major limitation to wheat production (Mujeeb-Kazi *et al.,* 2019). Salinity is a significant stressor that negatively affects the growth and yield of various crops, including wheat, posing a considerable environmental threat to agriculture and food supply (Munns, 2002; Flowers, 2004). Soil salinization is a

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Received 2/3/2024; Accepted 29/6/2024
DOI: 10.21608/agro.2024.270930.1418

critical abiotic stress factor leading to reduced crop growth and productivity (Roychoudury *et al.,* 2008).

To enhance wheat production in Egypt, Enhancing the salt tolerance of wheat genotypes proves to be a financially efficient strategy, particularly for impoverished farmers in developing nations, when juxtaposed with alternative management techniques like soil surface salt leaching or gypsum application. (Pervaiz *et al.,* 2002). Approximately 35% of Egypt's agricultural soils have high salinity, with the majority located in the Nile Delta, including its north central, eastern, and western regions (Karajeh *et al.,* 2011).

Shabala and Munns (2017) discovered that salinity inhibits plant growth through water deficit, specific ion toxicity, and nutrient ion imbalance in two phases. The first phase occurs rapidly and depends on external salt concentration rather than salt in tissues, leading to growth inhibition due to water deficit or osmotic stress. The second phase is slower to appear and results from internal salt damage, with the degree of reduction dependent on the rate of leaf damage and dryness.

Egypt's current wheat yield falls short of meeting human requirements. To address the disparity between consumption and production, wheat cultivation has extended to recently reclaimed fields. However, the significant impact of salinity stress in the Egyptian North can drastically reduce wheat growth and yield, making crop farming unprofitable (Mujeeb-Kazi *et al.,* 2019, Zeeshan *et al.,* 2020).

Selecting the right wheat variety for the specific environment is crucial, especially in the presence of biotic and abiotic stress. Wheat breeders strive to develop suitable varieties for their respective environments, considering the severe weather fluctuations occurring globally. Increasing the genetic diversity of wheat varieties allows breeders to choose suitable environmental conditions, particularly with the rising percentage of lands affected by salinity, high temperatures, disease severity, and rapid transmission between regions. Developing tolerant plant materials utilizing existing genetic reservoirs has demonstrated to be a comparatively efficient and economical tactic for tackling salinity issues in salt-impacted regions, thereby aiding in augmenting wheat production (Ragab and Kheir, 2019). Thus, this research was proposed to study performance of some Egyptian bread wheat cultivars under saline soil Conditions at North Delta of Egypt.

Materials and Methods

The field experiments were conducted at El Hamrawey farm at Sakha Agriculture Research Station Egypt, during the two seasons 2020/21 and 2021/22 wheat growing season which had a part of area affected by salinity. The main objective of this investigation was to assess the performance of certain wheat cultivars under normal soil and salt-affected soil conditions. The studied wheat genotypes were obtained from the Wheat Research Section, Field Crops Research Institute, Agricultural Research Center, Giza, Egypt. The wheat cultivars used in the study included Misr 1, Sakha 93, Sakha 95, Giza 168, Giza 171, Gemmeiza 9, Gemmeiza 11, Sids 13, Sids 14, and Shandaweel 1. These cultivars were allocated to two separate sites for the trials: one for control soil and the other for salinity soil. The experimental site also considered seasonal variation in soil conditions. The names and pedigrees of the wheat cultivars are provided in (Table 1). The wheat cultivars were arranged in a randomized complete block design (RCBD) with four replicates in each soil state. The experimental unit area was 4.2 m^2 (3.5×1.2 m) with 6 rows spaced 20 cm apart. Sowing dates were on November 29th and December 1st in the two growing seasons, respectively. Proper irrigation, fertilization, weed control, and fungicides were applied at the recommended times following standard practices. Cultivation in land affected by salts differs from cultivation in pots, as it is challenging to control the percentage of salinization in saline land. For this reason, the land affected by salinity was selected for the study in both seasons. The land was divided into 60 plots, and soil samples were taken from the middle of each plot to analyze the percentage of salinity.

Among the 60 plots, 40 plots with EC values ranging between 6.8 to 7.5 were chosen, and they were further divided into four semi-homogeneous replicates based on salinity concentration (6.8-7.0, 7.1-7.3, 7.31-7.5, and 7.51-7.7). The distribution of items within each replicate was random, considering the similarity of salinity levels in the land. Thus, the experiment was conducted in an area with a salinity range of 6.8-7.7, and this experimental error was taken into account. It was observed that salinity increased from the irrigation source to the drainage source. The replicates were vertically distributed

TABLE 1: Name, pedigree and selection history of wheat cultivars.

wheat cultivars	Pedigree	Selection history
Misr 1	OASIS/SKAUZ//4*BCN/3/2*PASTOR	CMSS00Y01881T-050M-030Y-030M-030WGY-33M-0Y-0S.
Sakha 93	SAKHA92/TR810328	S.8871-1S-2S-1S-0S.
Sakha 95	PASTOR // SITE / MO /3/ CHEN / AEGILOPS SQUARROSA (TAUS) // BCN /4/ WBLL1.	CMSA01Y00158S-040POY-040M-030ZTM-040SY-26M-0Y-0SY-0S.
Giza 168	MRL/BUC//SERI	CM93046-8M-0Y-0M-2Y-0B-0SH.
Giza 171	SAKHA 93/GEMMEIZA 9	GZ 2003-101-1GZ-4GZ-1GZ-2GZ-0GZ.
Gemmeiza 9	ALD "S" / HUAC // CMH 74A. 630 / SX	GM 4583-5GM-1GM-0GM.
Gemmeiza 11	BOW"S"/KVZ"S"//7C/SER182 /3/GIZA168/ SAKHA 61	GM7892-2GM-1GM-2GM-1GM-0GM.
Sids 13	KAUZ"S"//TSI/SNB"S"	ICW94-0375-4AP-2AP-030AP-0APS-3AP-0APS-050AP-0AP-0SD.
Sids 14	BOW "S" / VEE"S" // BOW"S" / TSI/3/ BANI SEWEF 1	SD293-1SD-2SD-4SD-0SD.

based on salinity concentration. After the first irrigation, soil samples were collected, and the electrical conductivity coefficient was measured to determine the salinity concentration in the soil.

Prior to soil preparation, physical and chemical analyses were performed for each experimental site. Surface and subsoil samples were collected at depths of 0-25 cm and 25-50 cm during the two growing seasons.

Studied characters:

a- Physiological characters:

1- At the heading stage, flag leaves samples were randomly taken from each plot to determine flag leaf area and chlorophyll a and b. The total chlorophyll (mg l^{-1}) was estimated using the spectro-photometric method according to Moran (1982).

2- Proline content (mg g^{-1} fresh weight) was measured following the method of Bates *et al*., (1973). The absorbance was measured at 520 nm in a spectrophotometer, and the proline content was calculated in mgg^{-1} (Fresh weight) according to Ritchie and Nguyen (1990).

b- The agronomic characters:

1- Heading date, maturity date, plant height (cm), flag leaf area (cm^2), number of fertile tillers (m^2), 1000 grain weight, number of grains $spike^{-1}$, and grain yield (ard fed^{-1}), (one ardab (ard) of wheat =150 kg).

To evaluate the salinity tolerance of the investigated wheat cultivars, the stress susceptibility index (SSI) was determined based on grain yield. The SSI was calculated using the method of Fischer and Maurer (1978) as the differences in the results obtained for stress (salt-affected soil) and non-stress (normal soil) conditions with the following equations:

SSI = (1 - MGYS/MSYP)/SI. Where; SI = Salinity Stress Intensity = 1 - MYS/MYP

MGYs is the grain yield of each wheat cultivar under salt-affected soil.

MGYp is the grain yield of each wheat cultivar under normal soil.

MYs is the mean (MGYS) of all wheat cultivars under salt-affected soil.

MYp is the mean (MGYp) of all wheat cultivars under normal soil.

Statistical analysis:

All obtained data were statistically analyzed using the analysis of variance (ANOVA) for the randomized complete blocks design (RCBD) with four replications for each experiment (soil types). A combined analysis was performed between soil

TABLE 2: Some soil physical and chemical analyses for fertile and salt-affected soil in two experimental at both seasons.

Soil State	Sample Depth (cm)	Soil	PH	EC ds m^{-1}	Cation meq l^{-1}				Anion meq l^{-1}		
					Ca^{++}	Mg^{++}	Na^{+}	K^{+}	HCO3⁻⁻	CL^{-}	SO4⁻⁻
					Site 1 (2020/21)						
control Soil	0 – 25	Clayey soil	8.2	2.6	6.4	5.0	7.0	0.29	2.1	10.4	45.8
	25 - 50		8.5	2.5	10.9	6.7	11.8	0.33	2.5	12.9	47.9
					Site 2 (2021/22)						
	0 – 25	Clayey soil	7.4	1.55	5.3	4.5	8.9	0.33	2.5	6.8	31.7
	25 - 50		8.3	2.40	9.5	5.9	9.3	0.39	3.2	9.8	49.1
					Site 1 (2020/21)						
Salinity soil	0 – 25	Clayey soil	9.4	7.4	42.4	49.6	60.5	1.6	2.9	115.0	94.6
	25 - 50		9.5	8.4	59.1	59.9	74.2	1.8	3.1	88.0	100.0
					Site 2 (2021/22)						
	0 – 25	Clayey soil	8.7	8.8	38.9	30.2	49.6	0.34	3.1	57.9	75.6
	25 - 50		8.5	9.5	41.9	26.9	55.7	0.56	4.4	66.6	87.6

types and seasons after conducting a homogeneity test error mean squares between soil types and seasons, as described by Gomez and Gomez (1984) using the «MSTAT-C» Computer Software Package. Means of the treatments were compared using the least significant difference (LSD) method at a 5% level of probability, as described by Snedecor and Cochran (1980).

Results and Discussion

The analysis of variance revealed significant variations attributed to years for plant height, number of tillers/m^2, grain yield, chlorophyll a+b, and proline content. Highly significant differences were observed for flag leaf area and chlorophyll a. Salt concentrations showed highly significant variation for all studied traits except for the parameters under consideration include the number of days to heading, plant height, flag leaf area and chlorophyll b, where significant variation was observed. Cultivars had highly significant effects on all studied traits. The interactions between year and soil were significant for plant height and flag leaf area, and highly significant for chlorophyll a+b and proline content. The interaction between year and wheat cultivars showed highly significant variation for plant height and flag leaf area. The interaction between wheat cultivars and soil salinity had highly significant variation for the parameters assessed consist of the number of tillers/m^2, number of grains/spike, and grain yield, chlorophyll a, b, a+b, and proline content, and significant variation for plant height and thousand grain weight. The interaction among years x soil salinaty x wheat cultivars was highly significant for chlorophyll a and chlorophyll a+b (Table 3 and 5).

The variance attributed to salt soil concentrations exhibited the highest values compared to other sources of variation, signifying its primary contribution to the total variance. Ragab and Taha (2016) reported similar findings, which were consistent with those of Hussain *et al*., (2015) and Hagras *et al*., (2018). Conversely, Asli and Zanjan (2014) noted insignificant variation due to genotypes × salinity interaction for the number of kernels per spike, while Nasab *et al*., (2014) reported insignificant genotypes × salinity interaction for grain yield. The coefficients of variation ranged from 2.25 to 11.36 for the number of days to heading and chlorophyll b, respectively (Table 3).

Combined data over two years showed significant and highly significant effects for plant height and flag leaf area, respectively. The initial season exhibited greater values for plant height, flag leaf area, number of fertile tillers m^{-2}, grain yield, chlorophyll a+b, and proline content, with chlorophyll a being particularly noteworthy. Plant height and flag leaf area measured 93.1 cm and 38.5 m^2, respectively, during the first season, while the number of fertile tillers, number of grain spike^{-1}, and grain yield also displayed significant differences, chlorophyll a, chlorophyll a+b, and proline content, the second season recorded (289.1, 50.9, 16.19,9.19, 11.82, and 0.28), respectively (Tables 3, 4 and 5).

Combined data over two soil sites in Table 3, 4 and 5 revealed significant variation for The parameters assessed include the number of days to heading, plant height, flag leaf area, and chlorophyll b. In normal soil conditions, these

TABLE 3: Mean squares of years, salt concentrations, bread wheat genotypes, and their interactions for heading date, maturity date, plant height, flag leaf area, number of tillers m^{-2}, number of grain spike^{-1}, 1000 grain weight, grain yield, chlorophyll a, b, a+b and proline yield and its components in 2020/2021 and 2021/2022 growing seasons.

Source	Df	HD	MD	PLH	FLA	TILL	G/S
				2020/2021			
Year	1	66.38	10.651	3774.52*	2243.371**	15378.97*	90.376
y x R	4	1361.1*	366.39	5906.27	1109.953	34176.38	187.913
Soil	1	8479.**	4734.4**	5736.2*	989.441*	655917.**	6947.0**
y x S	1	290.63	33.867	119.341	38.973	4657.387	30.502
Error a	4	201.531	69.931	1479.18	264.247	8360.821	1247.63
Cul	9	1245.**	771.89**	621.5**	107.972**	192621.**	347.7**
y x cul	9	5.81	97.365	258.956	46.607**	1666.249	40.362
S x cul	9	64.719	149.8	80.847	12.756	78038.3**	246.5**
Cul x S x y	9	304.017	30.065	109.129	17.541	30694.11	48.187
Error b	72	4.222	18.012	7.104	1.261	426.307	6.039
CV%		2.25	2.94	8.05	6.1	7.43	4.92

				2021/2022			
Source	**Df**	**TGW**	**GY**	**CHL A**	**CHL B**	**CHL A+B**	**PROL**
Year	1	15.48	48.228*	15.073**	1.706	26.923*	0.005*
y x R	4	260.244	107.177	2.488	7.83	17.005	0.018*
Soil	1	3157.4**	2056.9**	495.52**	15.258*	684.68**	0.226**
y x S	1	43.464	14.606	0.013	0.005	0.035	0.00
Error a	4	359.961	26.219	0.207	9.117	7.759	0.002
Cul	9	683.79**	604.05**	131.40**	73.935**	398.99**	0.089**
y x cul	9	68.934	5.225	1.031	0.409	1.753	0.00
s x cul	9	180.238*	244.728**	15.351**	4.161**	33.017**	0.028**
Cul x S x y	9	140.318	10.553	2.759**	0.092	3.393**	0.018
Error b	72	9.973	1.337	4.506	5.853	0.136	0.00
CV%		7.86	7.43	2.8	11.36	3.25	5.82

HD=heading date, MD= maturity date, PLH= plant height, FLA= flag leaf area, G/S=number of grain/spike, TGW=1000 grain weight, GY=grain yield, CHLA=chlorophyll a, CHLB=chlorophyll b, CHLA+B=chlorophyll a+b and PROL=prolin

measured (99.8, 94.4, 39.1, and 2.87), respectively. Highly significant variation was observed for the number of days to maturity, number of fertile tillers m^{-2}, number of grains spike^{-1}, 1000 grain weight, and grain yield, chlorophyll a, chlorophyll a+b, which recorded (150.9, 351.7, 57.6, 45.3, 19.69, 10.87 and 13.74), respectively. For proline content, salinity soil recorded (0.32) compared with normal soil, which recorded (0.23).

Varietal Differences:

Combining data from Tables 3, 4, and 5 showed noticeable differences between wheat varieties in all traits studied. Gemmeiza 9 exhibited the longest duration for both days to heading and days to maturity, recorded at 98.3 and 147.7 days, respectively. On the other hand, Sakha 95 had the tallest plants and the largest flag leaf area (91.0 cm and 37.7 m^2), respectively without significant differences with Misr1, Sids 14, and Shandaweel 1. Conversely, Sakha 93 had the shortest plants and the narrowest flag leaf area compared to other cultivars across the years and soil conditions.

There was a highly significant variation among wheat cultivars for the number of tillers m^{-2}. Sakha 95 had the highest number of fertile tillers (343.3) compared to the other cultivars, while Gemmeiza 11 had the lowest number of fertile tillers (206.6). Additionally, Shandaweel 1 recorded the highest number of grains spike^{-1} (52.9) without significant differences with Misr 1, Sakha 95, and Giza 171. Conversely, Gemmeiza 9 displayed the fewest grains spike^{-1}, amounting to (46.8).

TABLE 4: Means of combined data for number of days to heading, number of days to maturity, plant height (cm), flag leaf area (cm^2), number of fertile tillers (m^2) and number of grain $spike^{-1}$ as affected by the two seasons, soil site wheat cultivars and their interaction

Year (Y)	NO. days to heading	No. days to maturity	Plant height (cm)	Flag leaf area (cm^2)	No fertile tillers (m^2)	No. grain $spike^{-1}$
2020/21	92.2	144.3	93.1	38.5	266.4	49.1
2021/22	90.7	144.9	81.9	33.9	289.1	50.9
F test	NS	NS	*	**	*	NS
Salinity levels (S)						
Normal soil	99.8	150.9	94.4	39.1	351.7	57.6
Salinity soil	83.0	138.3	80.6	33.3	203.8	42.4
F test	*	**	*	*	**	**
Wheat cultivars (c)						
Misr 1	93.9	144.2	89.9	37.1	297.5	50.7
Sakha 93	86.8	138.1	84.5	34.9	262.7	48.6
Sakha 95	91.9	142.9	91.0	37.7	343.3	51.0
Giza 168	89.1	145.6	87.1	36.0	261.8	48.6
Giza 171	87.7	145.2	85.6	35.4	305.4	50.5
Gemmeiza 9	98.3	147.7	85.6	35.4	220.4	46.8
Gemmeiza 11	89.3	145.4	86.4	35.8	206.6	49.7
Sids 13	91.0	146.9	85.4	35.3	269.7	49.0
Sids 14	93.6	146.1	89.3	37.0	315.6	52.0
Shandaweel 1	92.6	143.9	90.4	37.4	294.3	52.9
F test	**	**	**	**	**	**
LSD	11.67	3.45	2.2	0.91	16.8	2
Interaction						
Y X S	NS	NS	*	*	NS	NS
Y x c	NS	NS	**	**	NS	NS
S x C	NS	NS	*	NS	**	**
Y x S x C	NS	NS	NS	NS	NS	NS

**, * and NS indicated $P< 0.01$, 0.05 and not significant, respectively.

Sakha 95 and Sids 14 varieties produced significantly higher 1000 grain weight of (42.7) without significant differences with other cultivars, except for Giza 168, Gemmeiza 9, and Sids 13, which recorded the lowest values for 1000 grain weight. Sakha 95 was superior in grain yield (19.22 ard fed^{-1}) and significantly differed from other cultivars. On the other hand, Gemmeiza 11 had the lowest grain yield (11.57 ard fed^{-1}) over the years and soil conditions. Sakha 95 and Misr 1 recorded the highest values for chlorophyll a, b, and a+b (10.37, 10.29, 3.74, 3.64, 14.11, and 13.92, respectively), while Shandaweel 1 recorded the highest value for proline content (0.32) and Gemmeiza 11 recorded the lowest value (0.23).

The application of salinity significantly decreased plant height, grain yield, and yield components. Similar reductions in grain yield and yield components due to salinity were noted by Saqib *et al*., (2004).

Interaction Effects:

Interaction between year and soil site:

Data in Table 6 indicated the significant effects of interaction between year and soil on plant height and flag leaf area, and highly significant effects on chlorophyll a+b and proline content of the ten wheat cultivars. In the first season with control soil, the tallest plants (101.0 cm) and widest flag leaf area (42 m^2) were recorded. In the second season with control soil, the highest chlorophyll

TABLE 5: Mean of combined 1000 grain weight, grain yield (ard fed^{-1}), chlorophyll a, chlorophyll b chlorophyll a+b and proline content as affected by the two seasons, soil site wheat cultivars and their interaction.

	1000 grain weight	Grain yield (ard fed^{-1})	Chlorophyll a	Chlorophyll b	Chlorophyll a+b	Proline content
Year (Y)						
2020/21	40.6	14.92	8.48	2.39	10.87	0.27
2021/22	39.8	16.19	9.19	2.63	11.82	0.28
	NS	*	**	NS	*	*
Salinity levels (S)						
Normal soil	45.3	19.69	10.87	2.87	13.74	0.23
Salinity soil	35.1	11.41	6.81	2.15	8.96	0.32
	**	**	**	*	**	**
Wheat cultivars (c)						
Misr 1	40.2	16.66	10.29	3.64	13.92	0.30
Sakha 93	41.2	14.71	8.16	1.93	10.10	0.26
Sakha 95	42.7	19.22	10.37	3.74	14.11	0.30
Giza 168	37.1	14.66	7.89	1.96	9.86	0.26
Giza 171	41.9	17.11	8.66	2.00	10.67	0.28
Gemmeiza 9	37.2	12.34	7.59	1.63	9.22	0.24
Gemmeiza 11	42.0	11.57	7.31	1.51	8.82	0.23
Sids 13	36.0	15.10	8.87	2.48	11.34	0.26
Sids 14	42.7	17.67	9.70	3.10	12.80	0.29
Shandaweel 1	41.0	16.48	9.54	3.10	12.64	0.32
F test	**	**	**	**	**	**
LSD	2.57	0.94	0.20	0.23	0.30	0.01
Interaction						
Y X S	NS	NS	NS	NS	**	**
Y x c	NS	NS	NS	NS	NS	NS
S x C	*	**	**	**	**	**
Y X S x C	NS	NS	**	NS	**	NS

**, * and NS indicated P< 0.01, 0.05 and not significant, respectively.

a+b (14.19) was recorded, while proline content was (0.32 and 0.31) in the second and first season with salinity soil, respectively.

Interaction between year and wheat cultivars:

Data depicted in Table 7 revealed the interaction effects between growing seasons and wheat cultivars. Sakha 95, Sids 14 and Shandaweel 1 were recorded the tallest plants in both growing seasons, with heights of (98.0, 97.3 and 96.1cm) respectively, in the first season. As for flag leaf area, Sakha 95, Sids 14 and Shandaweel exhibited the highest values in the first season (42.6, 42.3 and 41.8) Table 7.

Interaction between wheat cultivars and soil sit:

Data presented in Table 8 reveals the interaction effects between soil sit and wheat cultivars over the two years. Sakha 95 exhibited the tallest plants (97.7 cm) under non-saline soil without significant differences with Misr 1, Giza 168, Sids 14, and Sahndaweel 1. Under non-saline soil, Sakha 95 also recorded the highest number of tillers m^{-2} (458.8), while Sids 14 recorded the highest number of grains spike^{-1} (61.7) without significant differences with Sakha 95 and Giza 171. Additionally, Sids 14 had the heaviest 1000 grain weight (48.1) without significant differences with Sakha 93, Sakha 95, and Shandaweel 1 under

TABLE 6: Mean of plant height, flag leaf area, chlorophyll a+b and proline content as affected by interaction between year and soil.

year	Salinity levels (S)	Plant height	Flag leaf area (m^2)	Chlorophyll a + b	Proline content
2020/21	Normal soil	101.0	42.0	13.28	0.22
	Salt soil	85.2	35.1	8.47	0.31
2021/22	Normal soil	87.8	36.2	14.19	0.24
	Salt soil	76.0	31.6	9.45	0.32
	F test	*	*	**	**
	LSD	0.41	5.83	0.09	0.06

**and * indicated P< 0.01, 0.05 respectively.

TABLE 7: Plant height and flag leaf area as affected by interaction between years and wheat cultivars.

Trait / Year	plant height		flag leaf area	
	2020/21	2021/22	2020/21	2021/22
Misr 1	93.2	86.7	40.6	33.7
Sakha 93	87.5	81.5	38.1	31.7
Sakha 95	98.0	84.0	42.6	32.7
Giza 168	92.5	81.7	40.2	31. 8
Giza 171	90.8	80.3	39.5	31.3
Gemmeiza 9	91.2	80.0	39.7	31.1
Gemmeiza 11	93.2	79.7	40.6	31.0
Sids 13	91.6	79.3	39.8	30.9
Sids 14	97.3	81.3	42.3	31.6
Shandaweel 1	96.1	84.7	41.8	32.9
F test	**		**	
LSD	2.65		1.12	

** indicated P< 0.01

non-saline soil. Sakha 95 emerged as the superior cultivar under non-saline soil, producing a grain yield of 25.69 ard fed^{-1} Furthermore, Sakha 95 recorded the highest values for chlorophyll a, b, and a + b (12.82, 4.40, and 17.21, respectively) under non-saline soil. Conversely, Shandaweel 1 recorded the highest value for proline content (0.40) under saline soil (Table 8).

Interaction between year, soil sit and wheat cultivars:

Data presented in Table 9 shows the significant interaction effects between year, soil sit, and wheat cultivars. In the second season, Sakha 95 recorded the highest values under normal soil in the second season for chlorophyll a and a + b were highly significant (13.82 and 18.44, respectively) under non-saline soil

Correlation coefficient:

The correlation coefficients between grain yield and agronomic traits are presented in Table 10. The traits that showed the highest correlation with grain yield were the number of fertile tillers m^{-2}, number of grains $spike^{-1}$, and chlorophyll a and a+b. Additionally, the number of days to heading and maturity, 1000 grain weight, and chlorophyll b had significant correlations with grain yield.

In a study conducted by Afiuni and Mahlouji (2006), they also identified a correlation between different traits and wheat grain yield under salinity

TABLE 8: Mean of plant height, number of fertile tillers m^{-2} , number of grain spike^{-1}, 1000 grain weight, Grain yield, chlorophyll a, b a+b and prolin content as affected by soil sit and wheat cultivars.

Traits	plant height		No. fertile tillers m^{-2}		Grain spike^{-1}		1000 grain weight	
Soil site	Normal soil	salty soil	Normal soil	salty soil	Normal soil	salty soil	Normal soil	salty soil
Cultivars								
Misr 1	95.9	83.9	365.0	230.1	56.0	45.4	42.4	38.1
Sakha 93	92.0	77.0	326.3	199.1	56.2	41.1	48.0	34.5
Sakha 95	97.7	84.3	458.8	227.8	59.6	42.5	47.8	37.6
Giza 168	95.6	78.6	334.4	189.2	55.5	41.8	41.7	32.4
Giza 171	92.4	78.7	405.2	205.7	59.7	41.3	46.5	37.3
Gemmeiza 9	92.4	78.7	256.5	184.2	52.3	41.3	42.9	31.5
Gemmeiza 11	93.4	79.4	249.8	163.5	58.2	41.3	47.3	36.7
Sids 13	91.7	79.2	361.4	178.0	57.4	40.6	40.9	31.1
Sids 14	97.1	81.5	415.5	215.7	61.7	42.3	48.1	37.2
Shandaweel 1	96.0	84.8	343.8	244.8	59.4	46.3	47.7	34.3
F test	**		**		**		*	
LSD	3.06		23.8		2.23		3.36	

** indicated P< 0.01.

TABLE 8: cont.

Traits	grain yield		chlorophyll a		chlorophyll b		chlorophyll a +b		proline content	
Soil site	Normal soil	salty soil	Normal soil	salty soil	Normal soil	salty soil	Normal soil	salty soil	Normal soil	salty soil
Cultivars										
Misr 1	20.44	12.88	11.96	8.62	3.82	3.46	15.77	12.08	0.24	0.37
Sakha 93	18.27	11.15	10.30	6.03	2.44	1.42	12.74	7.45	0.22	0.29
Sakha 95	25.69	12.76	12.82	7.92	4.40	3.09	17.21	11.01	0.27	0.34
Giza 168	18.73	10.60	10.03	5.75	2.16	1.77	12.19	7.52	0.23	0.30
Giza 171	22.69	11.52	10.87	6.46	2.41	1.59	13.28	8.05	0.24	0.32
Gemmeiza 9	14.37	10.32	9.71	5.46	1.98	1.28	11.69	6.74	0.21	0.27
Gemmeiza 11	13.99	9.15	9.21	5.41	1.88	1.14	11.09	6.55	0.20	0.26
Sids 13	20.24	9.97	11.23	6.50	2.87	2.09	14.09	8.59	0.22	0.31
Sids 14	23.27	12.08	11.88	7.52	3.63	2.57	15.51	10.09	0.25	0.33
Shandaweel 1	19.25	13.71	10.70	8.38	3.08	3.13	13.78	11.51	0.24	0.40
F test	**		**		**		**		**	
LSD	1.33		0.41		0.42		0.60		0.01	

** indicated P< 0.01.

stress. Correlation coefficients were calculated among various traits and grain yield, revealing that the grain filling period and the number of spikes m^{-2} exhibited the strongest correlation with grain yield. Additionally, the number of spikes m^{-2} and the number of kernels spike^{-1} showed relatively high direct effects on grain yield. Overall, the grain filling period, number of spikes m^{-2}, and number of kernels spike^{-1} emerged as the most influential traits on grain yield in their investigation.

TABLE 9: Mean of chlorophyll a and chlorophyll a + b as affected by interaction between year, soil and cultivars.

Trait	chlorophyll a				chlorophyll a+ b			
Year	2020/21		2020/21		2020/21		2020/21	
Soil site	Normal soil	salt soil	Normal soil	salt soil	Normal soil	salt soil	Normal soil	salt soil
Cultivars								
Misr 1	11.69	8.36	12.22	8.88	15.29	11.66	16.26	12.49
Sakha 93	9.82	5.61	10.78	6.45	12.16	6.86	13.32	8.05
Sakha 95	11.82	7.74	13.82	8.09	15.99	10.69	18.44	11.32
Giza 168	9.71	5.50	10.35	6.01	11.81	7.16	12.57	7.88
Giza 171	10.59	6.03	11.14	6.89	12.90	7.47	13.66	8.63
Gemmeiza	9.45	5.04	9.98	5.88	11.40	6.25	11.98	7.23
Gemmeiza 11	9.02	5.01	9.40	5.81	10.86	6.09	11.31	7.01
Sids 13	11.05	6.09	11.40	6.92	13.83	8.04	14.36	9.14
Sids 14	11.68	7.10	12.08	7.93	15.07	9.49	15.95	10.68
Shandaweel 1	10.42	7.91	10.97	8.85	13.48	10.96	14.07	12.05
F test	**				**			
LSD	0.41				0.6			

Stress susceptibility index (SSI)

The Salinity Susceptibility Index (SSI) was measured following the method proposed by Fischer and Maurer (1978). This index offers a more thorough assessment of a cultivar's reaction to salinity stress in contrast to a basic representation of yield under stress as a percentage of yield under non-stress conditions. Cultivars with an SSI value less than one (<1) are considered stress-tolerant, while those with an SSI greater than one (>1) are deemed susceptible. The SSI results for the ten investigated wheat cultivars are shown in Table (11).

Among the cultivars, Gemmiza 9, Shandawel 1, Gemmeiza 11, Misr 1, and Sakha 93 exhibited SSI values ranging from (0.670 to 0.927) indicating that they are highly salt-tolerant genotypes. The remaining genotypes, namely Giza 168, Sids 14, Giza 171, Sakha95 and Sids 13, had SSI values ranging from (1.033 to 1.207), signifying that they are susceptible wheat cultivars.

These results are consistent with the findings of Ragab and Taha (2016), Maha *et al.,* (2017), Hagras *et al.,* (2018), and Ragab and Kheir (2019), supporting the notion that certain wheat cultivars exhibit varying levels of tolerance to salinity stress.

Discussion

Saline soils hinder plant growth because of osmotic stress, ionic toxicity, and diminished capacity to absorb crucial minerals (Zeeshan *et al*., 2020), impacting various physiological and biochemical processes associated with the growth and development of plants.

Saqib *et al*., (2004) noted a significant decrease in plant height, grain yield, and yield components under salinity conditions. The reduction in grain yield and yield components due to salinity. Bacilio *et al*., (2004) discovered that under salinity stress, the flag leaf area in wheat was markedly reduced. Oraby *et al.,* (2005) demonstrated a decrease in the mean days to heading under salinity conditions, along with a significant reduction in the number of kernels panicle^{-1}. Ashraf and Harris (2005) estimated that salinity could lead to a yield loss of approximately 20%. El-Hendawy *et al.,* (2005) highlighted that the impact of salinity on tiller number and the number of kernels spike^{-1}, particularly during early growth stages, has a more pronounced effect on final grain yield compared to yield components in later stages. Tareq *et al.,* (2011) reported reductions of up to 8% in spike length, 3% in spike weight, 37% in filled spikelets plant^{-1}, 20% in total spikelets plant^{-1}, and 10% in test weight under stress conditions, resulting in a 16% decrease in total grain weight per plant. Turki *et al.,* (2012) suggested that the decrease in grain yield due to salinity may be attributed to reduced photosynthetic capacity, leading to decreased starch synthesis and accumulation

TABLE 10: Correlation between wheat cultivars and number of days to heading and maturity, plant height, flag leaf area, number of fertile tillers m^{-2}, number of grain spike^{-1}, 1000 grain weight, chlorophyll a, b and a+b and proline content.

traits	grain yield	heading date	maturity date	plant height	flag leaf area	No. tillers	grain spike^{-1}	1000 grain weight	Chloro-phyll a	Chloro-phyil b	Chloro-phyll a+b	proline
grain yield	1	*0.669	*0.617	0.329	0.222	**1	**0.787	*0.691	**0.897	*0.636	**0.875	-0.421
heading date		1	**0.814	0.427	0.362	*0.669	*0.677	*0.610	**0.754	0.413	*0.697	*-0.679
maturity date			1	0.397	0.307	*0.618	*0.631	0.481	*0.686	0.301	*0.610	*-0.621
plant height				1	**0.962	0.329	*0.544	0.336	0.474	0.151	0.404	-0.359
flag leaf area					1	0.222	0.407	0.288	0.335	0.079	0.277	-0.328
No. tillers						1	**0.787	*0.691	**0.897	*0.636	**0.875	-0.421
Grain spike^{-1}							1	*0.605	**0.811	0.364	**0.724	-0.531
1000 g. w.								1	*0.695	0.397	*0.647	-0.548
chlorophyll a									1	0.705	**0.974	-0.427
chlorophyll b										1	*0.846	-0.085
chlorophyll a+b											1	0
proline												1

r 0.05=0.552, r 0.1=0.683

TABLE 11: Salinity susceptibility index (SSI) values based on grain yield for the ten bread wheat genotypes under salinity soil.

Wheat cultivars and genotypes	Grain yield under normal soil	Grain yield under salinity soil	Reduction	redaction%	SSI	Description	Rank
Misr 1	20.44	12.88	7.55	36.96	0.879	T	4
Sakha 93	18.27	11.15	7.12	38.98	0.927	T	5
Sakha 95	25.69	12.76	12.93	50.33	1.197	S	9
Giza 168	18.73	10.60	8.13	43.42	1.033	S	6
Giza 171	22.69	11.52	11.18	49.25	1.171	S	8
Gemmeiza 9	14.37	10.32	4.05	28.18	0.670	T	1
Gemmeiza 11	13.99	9.15	4.84	34.56	0.822	T	3
Sids 13	20.24	9.97	10.27	50.75	1.207	S	10
Sids 14	23.27	12.08	11.19	48.09	1.144	S	7
Shandaweel 1	19.25	13.71	5.55	28.81	0.685	T	2

in the grain. They also observed a decrease in thousand kernel weight (TKW) across all 10 varieties and accessions regardless of the species, with variations in response to salt stress closely linked to genetic diversity among these species. Ahmad *et al.,* (2013a) noted that salinity stress induced early maturity in wheat, resulting in reduced crop height and leaf area. Abd El-Hamid *et al.,* (2020) and Farhat *et al.,* (2020) reported a decrease in chlorophyll content (both a and b) under salt stress conditions. Additionally, Abd El-Hamid *et al.,* (2020) highlighted proline as an osmotic adjustment component, typical in plant responses to salt stress. El-Shintinawy and Elshourbagy (2001) highlighted proline as a crucial protein with a significant role in salt stress tolerance, noting its notably high levels in wheat induced by salt-responsive genes to shield the plant from salinity effects. Additionally, proline serves as an osmotic adjustment component, a typical response in plants subjected to salt stress (Abd El-Hamid *et al.,* 2020). The Physiological importance of proline accumulation in plants has been assigned a role as a cyto-solute, as a convenient source of energy, as a protective factor for cytoplasmic enzymes.

Rania *et al.,* (2022) observed that salinity inhibits the flag leaf area, which is crucial for grain filling and overall plant development. Farouk (2011) and Khataar *et al.,* (2018) further noted that the reduction in flag leaf turgidity and area, along with diminished assimilate synthesis, ultimately impacts the yield potential of the plant. Salinity stress affects the responsiveness of some physiological characteristics such as relative water content and chlorophyll content, as according previous research (Dehnavi *et al.,* 2017).

Other researchers have studied into it, reported an increase in response to saline circumstances for other physiological characteristics such as proline concentration (Abd El-Hamid *et al.,* 2020). In general, wheat has been found to be moderately resistant of salinity (Asif *et al.,* 2020). Stress from salinity induces morphological, physiological, biochemical, and molecular changes in plants. Under salinity stress, there were generally decreasing effects on agronomic and morphologic characteristics

Abbas *et al.,* (2013) reported that the yield components were significantly reduced due to salinity stress. Hamam and Negim (2014) reported a maximum reduction in the number of tillers per plant, followed by grain weight plant^{-1}. They observed decreases in the number of tillers plant^{-1}, biomass, days to heading, number of kernels spike^{-1}, 1000-kernel weight, and grain yield under salinity treatments compared to the control group. Salinity levels of 25, 50, 75, and 100 mM NaCl resulted in reductions in grain yield by 14.57%, 29.59%, 42.80%, and 55.78%, respectively, compared to the control treatment. Farooq *et.al*., (2015) emphasized that soil salinity poses a global challenge, leading to decreased plant growth and yield, and in severe instances, complete crop failure. Ragab and Taha (2016) documented that escalating salt concentrations resulted in a notable decrease in plant height, biological yield, grain yield, straw yield, the number of kernels per spike and kernel weight at the adult plant stage. Farhat *et al.,* (2020) reported that Sakah 95, Misr 3, and Sids 14 were suitable cultivars for moderately salt affected soils. Maha *et al.,* (2020) reported significant variations in all agronomical traits (including plant height, number of days to heading, number of spikes, number of grains spike^{-1}, thousand grain weight and grain yield) as well as physiological traits, influenced by salinity levels, cultivars, and their interaction. However, the number of grains spike^{-1} was not affected by the interaction. Ahmed *et al.,* (2021) noted that Egyptian varieties, sids1, sids12, sids13, and Gemmiza12, exhibited maximum values for grain spike^{-1}, spike length, and spike weight, respectively. Rania *et al.,* (2022) highlighted Misr 3 as superior to Sids 14 in all studied characteristics except for flag leaf area, relative water content and plant height. Ragab and Taha (2016) discovered strong and positive correlations between biological yield (under salt-affected soil) and the number of spikes pot^{-1}, as well as biological and straw yields per pot at the adult-plant stage. Through stress tolerance index analysis, among the nine studied cultivars, Misr 2 was classified as a salt-tolerant cultivar, while Gemmeiza 3 and Sids 12 were categorized as salt-sensitive cultivars. Saline soils constrain plant growth due to osmotic stress, ionic toxicity, and reduced mineral uptake capabilities (Zeesha *et al.,* 2020), impacting various physiological and biochemical processes associated with plant growth and development.

Salinity conditions significantly reduced plant height, grain yield, and yield components. Similar reductions in grain yield and yield components due to salinity were observed in the study by Saqib *et al.,* (2004). Bacilio *et al.,* (2004) also found that salinity stress led to a significant decrease in flag leaf area in wheat. Days to heading were also reduced under salinity conditions (Oraby *et al.,* 2005), and the number of kernels panicle^{-1} significantly decreased under salinity stress. It is estimated that salinity can cause up to 20% potential yield losses (Ashraf and Harris, 2005).

El-Hendawy *et al.,* (2005) emphasized that salinity's influence on tiller number and the number of kernels per spike, occurring during early growth stages, has a more significant effect on final grain yield compared to yield components in later stages. Additionally, Tareq *et al.,* (2011) demonstrated reductions in yield component traits such as spike length, spike weight, filled spikelet plant^{-1}, total spikelet plant^{-1}, and test weight under stress conditions, ultimately leading to a 16% decrease in total grain weight plant^{-1}.

The decrease in grain yield due to salinity may be attributed to a reduction in photosynthetic capacity, leading to decreased starch synthesis and accumulation in the grain (Turki *et al*., 2012). Turki *et al.,* (2012) also observed a decrease in total kernel weight across all 10 varieties and accessions, regardless of the species, with the response to salt among the varieties and accessions closely linked to genetic diversity among the species. Soil salinity adversely affected various morphological characteristics of wheat plants, including plant height and chlorophyll content, as noted by Ahmad *et al.,* (2013a), who observed that early maturity of wheat due to salinity stress resulted in reduced crop height and leaf area. The chlorophyll content (both a and b) of leaves serves as an indicator of the photosynthetic potency of plant tissues, which was decreased under salt stress conditions (Abd El-Hamid *et al.,* 2020 ; Farhat *et al.,* 2020). Additionally, proline, as noted by Abd El-Hamid *et al.,* (2020), serves as an osmotic adjustment component and is a typical response in plants exposed to salt stress. El-Shintinawy and Elshourbagy (2001) revealed that proline plays an essential role in salt stress tolerance and was significantly increased in wheat, indicating its induction by salt-responsive genes to protect the plant from the influence of salinity. Proline accumulation in plants has been assigned various physiological importance, such as acting as a cytosol-solute, a convenient source of energy, and a protective factor for cytoplasmic enzymes.

The flag leaf is a crucial part of the plant, playing a significant role in grain filling. However, salinity inhibits flag leaf area, as highlighted by Rania *et al*., (2022), impacting flag leaf turgidity, assimilate synthesis, and ultimately, yield potential, as noted by Farouk (2011) and Khataar *et al.,* (2018).

Salinity stress affects the responsiveness of some physiological characteristics, such as relative water content and chlorophyll content, as observed in previous research (Dehnavi *et al.,* 2017). Other researchers have also reported an increase in proline concentration in response to saline conditions for other physiological characteristics (Abd El-Hamid *et al.,* 2020). In general, wheat has been found to be moderately resistant to salinity (Asif *et al.,* 2020). Salinity-induced stress causes morphological, physiological, biochemical, and molecular changes in plants, resulting in overall decreasing effects on agronomic and morphologic characteristics.

Abbas *et al.,* (2013) reported that yield components were significantly reduced due to salinity stress, with the number of tillers plant^{-1} experiencing the maximum reduction, followed by grain weight plant^{-1}. Hamam and Negim (2014) reported that salinity treatments decreased the number of tillers per plant, biomass, days to heading, number of kernels spike^{-1}, 1000-kernel weight, and grain yield compared to the control. Salinity levels of 25, 50, 75, and 100 mM NaCl resulted in reductions in grain yield by 14.57%, 29.59%, 42.80%, and 55.78%, respectively, compared to the control treatment.

Farooq *et al.,* (2015) emphasized that soil salinity is a global issue leading to decreased plant growth and yield, and in severe cases, complete crop failure. Ragab and Taha (2016) reported that increasing salt concentrations caused a significant decrease in plant height, biological yield, grain yield, straw yield, number of kernels spike^{-1}, and kernel weight at the adult plant stage. Farhat *et al.,* (2020) identified Sakah 95, Misr 3, and Sids 14 as suitable cultivars for moderately salt-affected soils. Maha *et al.,* (2020) observed notable variations in all agronomical and physiological traits affected by salinity levels, cultivars, and their interaction, except for the number of grains spike^{-1}, which remained unaffected by the interaction. Additionally, Ahmed *et al.,* (2021) noted that Egyptian varieties sids1, sids12, sids13, and Gemmiza12 exhibited maximum values for grain per spike, spike length, and spike weight, respectively. Rania *et al*., (2022) highlighted that Misr 3 outperformed Sids 14 in all studied characteristics, except for flag leaf area, relative water content, and plant height. Ragab and Taha (2016) reported strong and positive correlations between biological yield under salt-affected soil and the number of spikes per pot, as well as biological and straw yields per pot at the adult-plant stage.

Abd El-Hamid *et al*., (2020) indicated that significant decrease for most studied characteristics by soil salinity. Results based on cluster analysis indicated that Sakha 95 and Giza171 exhibited the highest grain yield under both conditions, moderate values for both yield reduction ratio and stress susceptibility index especially for Sakha 95, moderate values of physiological characters and protein content. There was insignificant difference in grain yield between Misr 3, Sakha 95 and Giza 171 under soil salinity. Also, Line 4, Line 10 and Misr 3 recorded lowest values for yield reduction ratio and stress susceptibility index, maximum values for physiological characters and moderate values for quality characters.

El-hawary *et al*., (2022) recorded that the three cultivars; Misr 3, Sakha 95 and Giza 171 exhibited the highest grain yield under the three conditions with lowest grain yield reduction under both water deficit and soil salinity conditions indicating their good ability to tolerant difficult growing conditions. ELKOT *et al.,* (2023) reported that the traits were varied significantly in their values for most traits in the two seasons under normal and saline soil. 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 Giza171followed 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.

Conclusion:

It could notable that Gemmiza 9, Shandaweel 1, Gemmeiza 11, Misr 1, and Sakha 93 emerged as highly salt-tolerant genotypes under this investigation. These cultivars were recommended to sowing under saline soil condition at North Delta region.

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