International Journal of Research in Agronomy 2021; 4(1): 122-130

International Journal of Research in Agronomy

E-ISSN: 2618-0618
P-ISSN: 2618-060X

www.agronomyjournals.com
2021; 4(1): 122-130
Received: 03-01-2021
Accepted: 09-02-2021

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Evaluation of some barley genotypes under saline soil conditions

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Abstract
This study examined ten barley genotypes under both normal and saline soil environments at Sakha Agricultural Research Station, during two growing seasons 2019/2020 and 2020/2021. A randomized complete block design with four replications were used for each experiment. Some traits were recorded *i.e.* days to maturity, plant height (cm), spike length (cm), number of spikes m^{-2}, number of grains $spike^{-1}$, grain yield (t ha^{-1}), biological yield (t ha^{-1}), chlorophyll, K, Na content and K/ Na ratio. Analysis of variance for years, locations, genotypes and interaction were significant and highly significant for all studied traits. Results revealed that, the evaluated genotypes reveled a wide variation in salinity sensitivity. Line-1 and Line-6 gave the most desirable values of yield and related traits as well as physiological parameters under studied environments in both seasons, so we can recommend those genotypes under salinity conditions.

Keywords: Barley, salt stress, physiological traits, grain yield, salinity tolerance indices

Introduction
Barley (*Hordeum vulgare* L.) crop considered as the third crop after wheat and rice, which is planted under large environments. Barley is a major source of food today for a large number of people living in the salinity affected and semi arid areas of the world, where wheat and other cereals are less adapted among cereal crops, barley known as one of the main cereals that is tolerant to many environmental stresses in the world [1].
Among environmental stresses, salinity is a major factor that limits crop productivity and food security around our world [2]. Global climate change is accelerating the process of soil salinization. Thus, it is recommended to screen some salt-tolerant genotypes according to salinity tolerance related traits.
Recent program of breeding in many countries aimed to improve grain and straw yields under various environmental constrains. Soil salinity is a global problem that threatens crop growth and productivity and prevents the sustainable development of modern agriculture. The major causes of soil salinity are raising levels of groundwater with high salt content and poor-quality drainage and irrigation systems [3]. Salinity causes morphological, physiological and biochemical changes that interfere with plant growth and productivity [4].
Photosynthesis is one of the most basic physiological and bio-chemical process of plant's growth and productivity, but it is severely affected by soil salinity [5, 6]. Salt stress causes the excessive uptake of Na from root zone which creates osmotic and water stress to plants [7].
Breeding for salinity tolerance needs many steps *i.e.*, searching for genetic tolerant sources, evaluation and selected desirable materials under salinity stress conditions.
The objectives of the present investigation are mainly: evaluation of selected barley genotypes for high yielding and their tolerance to salinity stress.

Material and Methods
Ten six-row barley genotypes were selected for this study, including four local varieties (Giza 123, Giza 2000, Giza 129 and Giza 135) and six promising Egyptian lines i.e. 1, 2, 3, 4, 5 and 6 lines. The name of studied genotypes and their pedigree presented in Table 1.

Table 1: Name of the studied barley genotypes and their pedigree.

Genotype	Pedigree
Giza 123	Giza 117// FAO86
Giza 2000	Cr366-13-1/ Giza121
Giza 129	Deir Alla 106/ Cel//As46/Aths*2"
Giza 135	Zarza/Bermejo/4/ DS4931//Gloria-Bar/ Copal/3/Sen/5/Ayarosa"
Line 1	Lignee527/Chn-01// Gustoe/5/ Alanda-01/4/WI2291/3/Api/ CM67//L2966-69
Line 2	Apm/HC1905// Robur/3/ Arar/4/Baca'S'/3/AC253//CI 08887/ CI 05761
Line 3	Mr25-84/Att/3/Mari/Aths //Bc/4/ Aths/lignee686//ACSAD618
Line 4	C.C.89/3/ Alanda// Lignee527/Arar
Line 5	Rhn-03/Birta
Line 6	Rupee CI 04355 //80-5145 Hma -01

The studied genotypes of barley evaluated under two different field locations *i.e.*, normal soil at 1st Nattaf farm and El-Hamrawy farm as salt affected soil at Sakha Agricultural Research Station, Kafr El-Sheikh Governorate (31°07\\ N latitude and 30°57\\ E longitude) in two seasons 2019/20 and 2020/21. Soil analysis was done in 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 2.1 to 2.4 dsm^{-1} for the normal soil and from 8.6 to 10.7 dsm^{-1} for the saline soil at 0-30 cm depth in the two seasons (Table 2).

Table 2: Some soil mechanical and chemical analysis before sowing at 0-30 cm depth for Nattaf and El Hamrawy farm during 2019/2020 and 2020/2021 seasons.

Soil Properties	Normal		Saline soil	
	1st season	2nd season	1st season	2nd season
Mechanical analysis				
Sand	17.1	16.2	15.4	14.9
Silt	37.0	36.3	35.2	37.1
Clay	45.9	47.5	49.4	47.0
Chemical analysis				
PH	8.5	8.2	8.2	8.3
EC [soil past, $dS\ m^{-1}$]*	2.1	2.4	8.6	10.7
Na^{+}	14.4	14.8	60.7	65.2
K^{+}	0.3	0.5	0.8	0.9
Ca^{++}	4.6	5.3	26.3	25.5
Mg^{++}	2.5	2.0	13.9	15.1
$CO3^{--}$	0.0	0.0	0.0	0.0
$HCO3^{-}$	5.5	3.8	8.2	9.4
CL^{-}	10.1	15.0	47.5	49.8
$SO4^{--}$	6.2	3.8	46.0	47.5
$CaCo_3$ %	2.7	2.3	1.9	1.9
OM %	1.5	1.3	1.0	1.1

*Soil Electrical Conductivity (EC) and soluble ions were determined in saturated soil paste extract.

Meteoritical data during the two growing seasons for the site of experiments are shown in Table 3.

Table 3: Monthly mean air temperature (°C), relative humidity % and rainfall (mm/month) during the growing seasons 2019/20 and 2020/21 at the experimental site.

Month	AT °C 2019/20		AT °C 2020/21		RH %		Rainfall (mm)	
	Max.	Min.	Max.	Min.	2019/20	2020/21	2019/20	2020/21
December	21.7	10.7	22.8	12.0	63.5	67.7	27.9	5.4
January	18.4	8.4	21.6	10.3	68.9	68.1	38.4	13.5
February	20.8	8.6	21.8	10.0	66.0	68.4	14.3	33.3
March	24.6	10.3	22.3	10.7	59.5	67.1	30.8	0.6
April	27.3	12.5	28.2	12.0	56.3	60.3	0.0	0.1
May	33.0	15.7	35.8	17.9	50.5	50.0	0.0	0.0

All other cultural practices were applied according to the recommendations of the barely department for the region. The selected genotypes were evaluated in the two locations using the RCBD design with four replications. The plots area was 4.2 m^2 consisted of six rows with 3.5 m length and 20 cm apart. Sowing was done in the first of December in the two seasons.

The studied characters

The studied characters were: days to maturity, plant height (cm), spike length (cm), no. of spikes m^{-2}, no. of grains $spike^{-1}$, 1000-grain weight, grain yield ($t\ ha^{-1}$), biological yield ($t\ ha^{-1}$) and chlorophyll content (SPAD) in the second leaf according to Monge and Bugbe [8]. In addition, Na and K contents ($mg\ g^{-1}$ dw) in the third leaf were determined according to the methods described by Buresh *et al.* [9] and Chapman and Pratt [10] and K/ Na ratio also was calculated.

Salinity indices

Six salinity stress tolerance indices were calculated:

1. Stress tolerance (TOL) =YP-YS according to Fernandez **[11]**.
2. Mean cultivars productivity (MP) = (Yp+Ys)/2 according to Hossain *et al*. [12].
3. Yield reduction ratio (Yr) = 1- Ys/Yp according to Golestani and Assad [13].
4. Stress tolerance index (STI) = $(Yp + Ys)/ (\bar{Y}p)^2$ according to Fernandez [11].
5. Yield stability index (YSI) = Ys/Yp according to Bouslama and Schapaugh [14].
6. Yield index (YI) =$Ys/ \bar{Y}s$ according to Gavuzzi *et al.* [15].

Statistical Analysis

The analysis of variance was performed according to RCBD. Combined analysis performed when the assumption of errors homogeneity can't be rejected [16]. Seasons were random, while the environments and genotypes were fixed.

Results and Discussion

Analysis of Variance

The error variances were proved to be homogeneous for the two seasons and treatments for all traits, so the combined analysis was performed across the two seasons and saline conditions.

Mean squares for the studied traits under both normal and saline conditions in the two growing seasons are presented in Table (4). The variance due to years, locations and genotypes (Y, S, G) were significant at (0.01 or 0.05 probability levels) for all studied traits, except for grain yield, chlorophyll content, Na content and K content for years. Also, mean squares of interaction between the years and locations (Y x S) for plant height, spike length, no. of grains $spike^{-1}$, no. of spikes m^{-2}, 1000-grain weight, biological yield and Na/K ratio were significant. These findings indicate that the two seasons and the two environments behaved differently and detected sufficient genetic variation among the materials studied. The genotypes and years (G x Y) interaction were significant for all studied traits except for chlorophyll content, biological and grain yield. Genotypes and treatments (G x S) Interaction were significant for all the studied traits except for days to maturity. Genotypes and years and treatments (G x Y x S) interaction were significant for all studied traits except for days to maturity chlorophyll content, biological and grain yield. Accordingly, the genotypes responded differently to saline conditions and seasons and the possibility to select of the most tolerant genotypes.

Effect of seasons and saline conditions

As shown in Table 4 (a and b), all the traits studied were reduced to the salt conditions studied, except for the Na content. Shabala and Munns [17] reported that salinity can inhibit plant growth through water deficiency, specific ion toxicity and nutrient ion imbalance in two phases. The first phase occurs rapidly and is dependent on the outside salt of the plant rather than the salt in the tissues, and growth inhibition is due to lack of water or osmotic stress. The second stage takes time to appear, and results from an internal salt lesion and the reduction depends on the rate of foliar lesion.

Table 4 (a): The combined analysis of variance over years (Y), saline conditions (S) and genotypes (G) for all studied traits.

SOV	Df	Days to maturity	Plant height	Spike length	No. of grains/spike	No. of spikes/m^2	1000-grain weight
Years (Y)	1	549.55**	2554.99**	50.33**	609.19**	18689.52**	29.62**
Saline conditions(S)	1	205.96**	40114.07**	188.01**	11774.71**	367036.81**	610.01**
Y*S	1	0.02 ns	1251.04**	13.68**	406.06**	12362.69**	17.86*
Rep/(Y x S) = (Ea)	12	1.02	24.36	0.14	6.08	854.97	2.33
Geno (G)	9	39.60**	1284.16**	5.76**	126.44**	19688.98**	509.61**
G*Y	9	8.19**	107.44**	1.87**	39.01**	814.90*	67.82**
G*S	9	1.60 ns	248.92**	1.91**	53.97**	4724.47**	10.16**
G*Y*S	9	2.03 ns	99.18**	0.83**	55.15**	2913.08**	5.91*
Pooled Error)=(Eb)	108	1.23	22.31	0.29	15.54	666.64	2.81
Total	159						

Table 4 (b): The combined analysis of variance over years (Y), saline conditions (S) and genotypes (G) for all studied traits.

SOV	Df	Biological yield	Grain yield	chlorophyll content	Na content	K content	Na/K ratio
Years (Y)	1	12.58**	2.86ns	12.66 ns	6620.26 ns	15.82 ns	0.98 *
Saline conditions (S)	1	349.38**	60.80**	250.87**	1646989916.96**	97796.36**	12029.25**
Y*S	1	6.13*	0.64ns	2.99 ns	20878.62 ns	1190.45 ns	1.42 *
Rep/(Y x S) = (Ea)	12	0.91	1.09	3.15	61519.49	723.55	1.4
Geno (G)	9	21.99**	2.61**	43.84**	9007047.82**	44548.18**	206.18**
G*Y	9	1.25ns	0.07ns	2.72 ns	909360.28**	4279.28**	26.2**
G*S	9	2.10**	0.93**	6.89**	8411072.95**	13488.58**	193.96**
G*Y*S	9	1.17ns	0.18ns	2.71 ns	966474.34**	1305.25*	25.89**
Pooled Error) = (Eb)	108	0.78	0.13	1.67	69381.73	515.26	2.01
Total	159						

* and ** indicate significance at 0.05 and 0.01 levels, respectively.

The averages of all genotypes in 2019/2020 were significantly (Tables 5) greater than those in 2020/2021 under both conditions (normal and saline soil) for all studied characters, except for Na content under favorable conditions and K content under stress. In the first season high values were recorded and it may be due to the lower temperature and high rainfall in this season compared to the second one. Similar results were found by many researcher in their studies [18, 19, 20, 21].

Table 5: The mean performance of the studied traits as affected by season and saline conditions.

Treatments	**Days to maturity (day)**			**Plant height (cm)**			**Spike length (cm)**		
	1st season	**2nd season**	**Comb.**	**1st season**	**2nd season**	**Comb.**	**1st season**	**2nd season**	**Comb.**
Normal	130.19	126.47	128.33	102.76	100.36	101.56	8.99	7.29	8.14
Salt	127.9	124.22	126.06	76.69	63.1	69.9	6.24	5.7	5.97
Treatment LSD 0.05	0.56	0.55	0.35	2.64	2.76	1.7	0.19	0.22	0.13
Years x T LSD 0.05	--			2.4					
Treatments	No. of grain spike^{-1}			No. of spike m^{-2}			1000- grain weight		
	1st season	2nd season	Comb.	1st season	2nd season	Comb.	1st season	2nd season	Comb.
Normal	69.03	61.74	65.39	443.28	439.24	441.26	49.1	48.91	49
Salt	48.69	47.97	48.33	365.07	325.87	345.47	45.86	44.33	45.1
Treatment LSD 0.05	1.11	1.55	0.85	8.88	20.81	10.07	1.03	0.58	0.53
Years x T LSD 0.05	1.2			14.25					
Treatments	Biological yield (ton ha-1)			Grain yield (ton ha-1)			Chlorophyll content (spad)		
	1st season	2nd season	Comb.	1st season	2nd season	Comb.	1st season	2nd season	Comb.
Normal	11.02	10.87	10.94	4.29	4.14	4.22	48.47	47.62	48.04
Salt	8.46	7.50	7.98	3.18	2.79	2.99	45.69	45.4	45.55
Treatment LSD 0.05	0.26	0.69	0.33	0.22	0.78	0.36	1.07	0.86	0.61
Years x T LSD 0.05	0.46			--		0.17	--		
Treatments	Na content (mg g dry weight^{-1})			K content (mg g dry weight^{-1})			Na /K ratio		

	1st season	2nd season	Comb.	1st season	2nd season	Comb.	1st season	2nd season	Comb.
Normal	230.64	240.62	235.63	459.45	455.46	457.46	0.52	0.54	0.53
Salt	6670.24	6634.53	6652.39	404.55	410.64	407.59	17.80	16.90	17.35
Treatment LSD 0.05	82.21	173.43	85.45	4.76	20.26	9.27	0.41	0.81	0.40
Years x T LSD 0.05	120.85			--			0.57		

Interaction between the studied factors

Days to heading

Data presented in table 6 showed that, the earliest genotypes in maturity was barley cultivar Giza 123 under both normal (125.33 day) and saline soils (123.70 day). On the other direction, barley cultivar Giza 135 was the latest under normal condition (130.33 day) and saline soils (127.50 day) under combined. Then, Line 2 (130.06 day) under normal conditions and (126.73 day) under saline one as shown in (Table 6) under combined.

Table 6: Means days to maturity for the ten evaluated genotypes under both normal (N) and saline soil (S) conditions during 2019/2020 and 2020/2021 seasons.

Genotypes	Days to maturity (day)					
	1st season		2nd season		Comb.	
	Normal	Stress	Normal	Stress	Normal	Stress
Giza123	126.63	124.73	124.02	122.67	125.33	123.70
Giza2000	130.66	129.04	127.03	124.36	128.84	126.70
Giza129	127.67	123.67	124.33	122.33	126.00	123.00
Giza135	132.67	129.33	128.00	125.67	130.33	127.50
Line-1	131.30	130.04	127.68	123.67	129.49	126.85
Line-2	132.37	128.73	127.74	124.72	130.06	126.73
Line-3	129.68	127.42	126.33	125.00	128.01	126.21
Line-4	128.05	125.90	126.04	125.12	127.05	125.51
Line-5	131.55	130.46	126.53	123.80	129.04	127.13
Line-6	131.33	129.67	127.00	124.83	129.17	127.25
LSD 0.05	1.65	1.77	1.26	1.73	--	
LSD 0.05	1.68		1.49		1.10	

Plant height and spike length

In evaluating the diversity of salt tolerance degree morphological characterization is an essential step. Data of combined analysis revealed that line-1 and line-6 were the tallest genotypes under normal conditions, while line-1 was the tallest genotype under saline condition. Giza129 and Giza135 were the shortest ones under the two conditions (Table 7). It is noticeable that Line 5 showed a high values of plant height (110.78 cm) under normal environment, while it decreased sharply under saline environment (65.47 cm). Abu-El-lail *et al.* [22] recorded that, crop growth and productivity can be affected by salinity induced nutritional disorders. These results are in line with those reported by Pakniyat *et al.* [23].

Concerning salinity effect on spike length, the longest spike was expressed with Giza 123 (9.19 cm) while the shortest one was observed with line-2 (6.70 cm) under normal conditions. On the other direction, under saline soils line-6 recorded the longest spike (7.13 cm) while the shortest ones were recorded with line-5 (5.52 cm) as shown in Table 6. These results are in harmony with those reported by El-Wakeel *et al*. [24].

Table 7: Means values of plant height and spike length for the ten evaluated genotypes under both normal (N) and saline soil (S) environments during 2019/2020 and 2020/2021 seasons.

Genotypes	Plant height (cm)						Spike length (cm)					
	1st season		2nd season		Comb.		1st season		2nd season		Comb.	
	N	S	N	S	N	S	N	S	N	S	N	S
Giza123	102.15	78.57	104.67	60.00	103.41	69.29	10.42	7.05	7.96	5.84	9.19	6.45
Giza2000	110.23	82.17	103.03	63.33	106.63	72.75	9.18	5.92	6.91	5.47	8.05	5.70
Giza129	94.33	54.67	84.67	50.00	89.50	52.33	9.67	5.88	7.70	5.27	8.68	5.58
Giza135	91.33	51.67	87.67	47.67	89.50	49.67	8.33	5.64	6.70	5.52	7.52	5.58
Line-1	115.02	94.00	104.67	77.54	109.84	85.77	9.64	7.22	7.55	5.37	8.59	6.29
Line-2	106.71	85.67	93.17	64.52	99.94	75.09	7.02	5.71	6.38	5.60	6.70	5.66
Line-3	99.38	80.40	104.50	61.72	101.94	71.06	9.89	6.11	7.05	5.67	8.47	5.89
Line-4	97.16	83.08	96.39	70.33	96.78	76.71	7.05	5.74	7.01	6.08	7.03	5.91
Line-5	110.00	69.00	111.56	61.93	110.78	65.47	8.38	5.84	8.00	5.20	8.19	5.52
Line-6	101.33	87.67	113.33	74.00	107.33	80.83	10.33	7.27	7.67	7.00	9.00	7.13
LSD 0.05	7.68	5.75	6.99	6.96	--		0.85	0.75	0.75	0.78	--	
LSD 0.05	6.68		6.81		4.69		0.79		0.76		0.54	

No. of grains spike^{-1} and No. of spikes m^{-2}

Table 8 show the means of no. of grains spike^{-1} and no. of spikes m^{-2} for the studied barley genotypes under the two conditions. With respect no. of grains spike^{-1}, the best genotypes were Giza 123 and Line-4 in the normal condition and Line-1 and Line-6 under saline condition. In addition, Line-2 and Line-4 showed high values only under normal condition. While Line-1 and Line-6 obtained the maximum values under saline soil condition. Many researchers reported that, salinity stress is a big challenge to crop quality and production as it decreases the grain yield and its quality [20, 25, 26, 27, 28]. Additionally, it was reported that growth characteristics such as plant height, number of tillers were significantly affected by saline stress.

For no. of spikes m^{-2}, the most favorable genotypes were Line-1, Line-3 and Line-6 which obtained the maximum values under normal condition while, Line-1, Line-4 and Line-6 were the best under stress condition. On the other direction, Giza 129 and Giza 135 were the fewest ones under saline conditions.

Table 8: Means of no. of grains spike^{-1} and no. of spikes m^{-2} for the ten evaluated genotypes under both normal (N) and saline soil (S) environments during 2019/2020 and 2020/2021 seasons.

Genotypes	No. of grains spike^{-1}						No. of spikes m^{-2}					
	1st season		2nd season		Comb.		1st season		2nd season		Comb.	
	N	S	N	S	N	S	N	S	N	S	N	S
Giza123	72.27	50.20	64.13	51.10	68.20	50.65	426.83	376.33	404.55	313.10	415.69	344.72
Giza2000	66.14	48.35	55.17	50.12	60.66	49.23	428.89	376.33	434.42	329.79	431.65	353.06
Giza129	70.00	46.74	59.50	45.00	64.75	45.87	406.67	256.67	386.00	282.00	396.33	269.33
Giza135	58.00	42.77	61.20	43.00	59.60	42.88	437.33	256.67	398.00	276.67	417.67	266.67
Line-1	72.35	50.84	58.00	51.42	65.18	51.13	470.36	454.67	488.45	364.67	479.40	409.67
Line-2	76.18	47.45	62.72	46.50	69.45	46.98	441.60	396.33	467.23	333.39	454.41	364.86
Line-3	70.17	49.33	56.46	48.14	63.31	48.74	464.01	393.00	476.75	325.47	470.38	359.24
Line-4	70.33	50.05	72.08	46.06	71.21	48.05	433.81	403.00	439.33	383.48	436.57	393.24
Line-5	64.86	47.16	64.04	46.38	64.45	46.77	452.65	333.00	449.69	294.82	451.17	313.91
Line-6	70.00	54.00	64.13	52.00	67.07	53.00	470.63	404.67	448.00	355.33	459.32	380.00
LSD 0.05	7.23	3.51	6.46	4.99	--		35.74	48.20	40.92	18.45	--	
LSD 0.05	5.60		5.67		3.91		41.79		31.25		25.61	

1000-grain weight, biological and grain yield:

Data in Table 9 showed that the heaviest genotypes for 1000-grain weight were Giza2000 and Line-3 for the two conditions, while Giza129 and Giza135 gave the lowest values under the two conditions.

Table 9: Means of 1000-grain weight and biological yield for the ten evaluated genotypes under both normal (N) and saline soil (S) environments during 2019/20 and 2020/21 seasons.

Genotypes	1000- grain weight (g)						Biological yield (t ha^{-1})					
	1st season		2nd season		Comb.		1st season		2nd season		Comb.	
	N	S	N	S	N	S	N	S	N	S	N	S
Giza123	51.13	47.50	47.70	42.97	49.42	45.23	10.14	9.01	11.12	8.20	10.63	8.61
Giza2000	56.20	51.93	55.33	47.80	55.77	49.86	10.80	9.16	11.14	8.47	10.97	8.81
Giza129	36.49	31.42	43.20	38.50	39.84	34.96	8.94	6.78	9.13	5.66	9.03	6.22
Giza135	36.23	32.89	43.80	37.20	40.01	35.05	9.54	5.53	9.19	5.63	9.37	5.58
Line-1	53.63	52.54	49.20	44.73	51.42	48.64	13.62	9.97	11.56	8.57	12.59	9.27
Line-2	50.69	50.36	50.90	47.23	50.80	48.80	12.18	9.00	10.94	7.88	11.56	8.44
Line-3	55.08	54.67	55.47	50.80	55.28	52.73	10.80	8.64	11.93	7.78	11.36	8.21
Line-4	50.20	44.93	46.60	43.10	48.40	44.02	10.85	8.46	10.10	7.97	10.48	8.22
Line-5	50.83	44.07	47.90	42.87	49.37	43.47	10.94	7.97	11.37	5.91	11.16	6.94
Line-6	50.50	48.32	48.97	48.13	49.73	48.23	12.36	10.03	12.21	8.96	12.28	9.50
LSD 0.05	1.92	3.31	2.31	1.92	--		1.94	0.80	1.35	0.56	--	
LSD 0.05	2.66		2.09		1.66		1.46		1.02		0.87	

For biological yield (Table 9), Line-1 and Line-6 were the superior genotypes, while Giza129 and Giza135 were the inferior ones under the two environments. Among the studied genotypes in Table 10, Line-1 and Line-2 under normal environment and Line-1 and Line-6 under saline environments were the best ones for grain yield. On the other direction, Giza129 and Giza135 had the lowest grain yield values. Such results of the reproductive traits exhibited that salinity affected the grain yield through a reduction in various components such as spike number m^{-2} and grain number spike^{-1} in most of the evaluated genotypes. Similar findings were reported on barley by Mansour and Aboulila [20]. The observed consistent reduction in grain yield in the study could be a result of the shortened grain filling period, and a decrease in the spikelet primordial number per spike [24].

Table 10: Means of grain yield for the ten evaluated genotypes under both normal (N) and saline soil (S) environments during 2019/2020 and 2020/2021 seasons.

Genotypes	Grain yield (ton ha^{-1})					
	1st season		2nd season		Comb.	
	N	S	N	S	N	S
Giza123	3.94	3.34	4.09	2.59	4.02	2.97
Giza2000	3.80	3.38	4.00	2.73	3.90	3.05
Giza129	3.74	2.36	3.71	1.98	3.72	2.17
Giza135	4.23	2.28	3.72	1.91	3.98	2.10
Line-1	5.10	3.84	4.46	3.42	4.78	3.63
Line-2	4.63	3.56	4.61	3.00	4.62	3.28
Line-3	4.61	2.98	4.40	2.62	4.51	2.80
Line-4	4.08	3.59	4.17	3.33	4.13	3.46
Line-5	4.51	2.66	4.08	2.61	4.29	2.63
Line-6	4.26	3.86	4.21	3.71	4.23	3.79
LSD 0.05	0.80	0.28	0.52	0.42	--	
LSD 0.05	0.59		0.44		0.36	

Potassium and Sodium content

The content of sodium and potassium and Na/K ratio are presented in Tables (11&12).

The lowest accumulation values of sodium were recorded for Line-1 and Line-6, while the highest values were given by barley cultivars Giza129 and Giza135 under saline condition. The highest accumulation values of potassium were found by Giza123 under the two environmental conditions, whereas Line-1, Line-4 and Line-6 recorded the highest values under saline soil environment only. On the other direction, barley cultivar Giza135 had the lowest accumulation values of potassium under both normal and saline soil environments. These results may be due to immoderate accumulation of Na^+ with concurrent reduction in the uptake of crucial nutrients like K^+ from roots to photosynthetic leaves under saline stress [29]. Also, the collection of Na+ and a reduction in K+ contents in photosynthetic leaves may due to chlorophyll degradation and upset thylakoid membranes [30]. Similar findings were observed in wheat [31] and barley [32]. A positive correlation between the overall salinity tolerance and the ability of a root tissue to retain K^+ was later expanded to at least a dozen other plant species [33]. Plants tend to maintain high K^+ concentration instead of Na^+ in their roots and stems. Numerous studies have shown that plants tend to decrease the toxic effects of Na^+ in their tissues by obtaining sufficient K^+ contents and excreting more Na^+. Potassium is a key macro-nutrient that activates more than 50 enzymes. It has been shown to contribute to the biosynthesis of chlorophyll pigments [34].

Table 11: Means of Na and K content for the ten evaluated genotypes under both normal (N) and saline soil (S) environments during 2019/2020 and 2020/2021 seasons.

Genotypes	Na (mg g^{-1} dw)						K (mg g^{-1} dw)					
	1st season		2nd season		Comb.		1st season		2nd season		Comb.	
	N	S	N	S	N	S	N	S	N	S	N	S
Giza123	213.22	5436.13	224.43	5726.94	218.83	5581.54	541.74	525.62	536.72	505.67	539.23	515.65
Giza2000	236.46	6614.43	233.30	6193.61	234.88	6404.02	413.49	382.66	404.84	340.04	409.17	361.35
Giza129	260.89	8056.77	299.90	8580.16	280.40	8318.46	531.62	324.17	446.50	327.32	489.06	325.75
Giza135	266.70	10297.90	308.90	8558.04	287.80	9427.97	335.83	272.37	397.70	347.52	366.77	309.95
Line-1	229.49	4754.09	219.60	4721.87	224.55	4737.98	451.05	423.91	478.19	473.54	464.62	448.72
Line-2	259.14	7525.97	281.94	6387.02	270.54	6956.49	523.93	401.91	497.32	385.72	510.62	393.81
Line-3	244.47	6807.48	217.33	8518.78	230.90	7663.13	420.80	369.92	415.21	382.44	418.00	376.18
Line-4	176.87	6412.13	208.81	6169.78	192.84	6290.96	464.72	461.16	470.27	451.42	467.50	456.29
Line-5	204.41	6182.33	202.42	6102.82	203.41	6142.58	499.68	413.71	498.15	449.74	498.92	431.73
Line-6	214.76	4615.20	209.60	5386.29	212.18	5000.74	411.67	470.09	409.70	442.95	410.69	456.52
LSD 0.05	13.75	524.64	50.56	553.45	--		23.06	22.09	52.69	23.45	--	
LSD 0.05	365.50		387.04		261.30		22.24		40.13		22.52	

Concerning Na+/K+ ratio, barley cultivars Giza123, Line-1 and line-6 had the lowest values under saline conditions. The higher cytoplasmic content of Na^+ increase the Na^+/K^+ ratio, which affects plant growth and development. Hence, one of the plant defense strategies to minimize the negative effects of immoderate Na^+ or K^+ loss is to maintain a low Na^+/K^+ ratio in the cytoplasm **[35].** Besides, root and shoot Na^+/K^+ ratios also showed increase trend under salinity conditions.

Chlorophyll content

The highest values of chlorophyll contents were observed by Line-1, Line-3 and Line-4 under both normal and saline environments, while Giza129 and Giza135 had the lowest values under the two environmental conditions as shown in Table 12. Concerning, chlorophyll content decreases under saline conditions, these results due to chlorophyll is a green pigment which is an essential component of the photosynthetic system. Relative chlorophyll levels are likely to decrease under salt treatment compared with normal conditions **[36].** Also, Photosynthetic pigments are an important determinant of plant photosynthetic ability and salt stress has resulted in clear decay of these pigments [37].

Also, Narimani *et al.* [38] reported that, salinity stress cause reduction in dry weight, photosynthesis pigments and K^+/Na^+ ratio. It could be conclude that, genotypes that have a higher SPAD value under salt stress condition often produce a higher grain yield than those have the low values of chlorophyll content. Therefore, selection genotypes based on increased or stable chlorophyll content can prevent yield losses under salt stress conditions. Also, salinity stress significantly decreased germination percentage, root and shoot length and fresh weight as well as chlorophyll and proline content [39, 40, 41].

Table 12: Means of Na/K ratio and chlorophyll content (SPAD) for the ten evaluated genotypes under both normal (N) and saline soil (S) conditions during 2019/2020 and 2020/2021 seasons.

Genotype	Na/K ratio						Chlorophyll content (SPAD)					
	1st season		2nd season		Comb.		1st season		2nd season		Comb.	
	N	S	N	S	N	S	N	S	N	S	N	S
Giza123	0.39	10.35	0.42	11.33	0.41	10.84	48.55	47.45	47.13	46.04	47.84	46.75
Giza2000	0.57	17.33	0.58	18.31	0.58	17.82	48.03	46.85	47.04	45.49	47.54	46.17
Giza129	0.49	24.85	0.72	26.24	0.60	25.55	45.80	40.50	46.01	42.60	45.90	41.55
Giza135	0.79	38.40	0.78	24.73	0.79	31.56	47.03	42.03	45.45	41.33	46.24	41.68
Line-1	0.51	11.24	0.46	9.96	0.48	10.60	49.67	46.40	48.67	48.39	49.17	47.39
Line-2	0.50	18.73	0.57	16.56	0.53	17.64	49.47	46.07	47.67	46.67	48.57	46.37
Line-3	0.58	18.39	0.52	22.38	0.55	20.38	50.40	46.63	49.51	46.80	49.96	46.72
Line-4	0.38	13.90	0.44	13.71	0.41	13.81	49.40	47.83	49.67	46.43	49.54	47.13
Line-5	0.41	14.96	0.42	13.57	0.41	14.27	48.59	46.37	47.87	44.58	48.23	45.48
Line-6	0.52	9.83	0.51	12.18	0.52	11.01	47.75	46.78	47.13	45.68	47.44	46.23
LSD 0.05	0.04	3.59	0.16	1.98	--		2.18	1.85	1.49	1.93	--	
LSD 0.05	2.50		1.38		1.40		1.99		1.69		1.28	

The quantitative salinity tolerance indices

Yield stress (YS), yield potential (YP), tolerance index (TOL), mean Productivity (MP), yield reduction ratio (YR), stress tolerance index (STI), yield stability index (YSI) and yield index (YI) were calculated for the evaluated genotypes (Table 12).

Line-1 has the best tolerance indices, including YP, YS, MP, STI and YI. In addition, Line-6 had the preferred estimates for all tolerance indices. Moreover, Line-5 was distinguished only for YP. On the other direction, Giza 129 and Giza 135 were the most susceptible genotypes and had the worst tolerant indices. El-Shawy *et al.* [42] observed that, Line-1 produced high values for STI, YSI and YI and low values of TOL under water stress condition.

Table 12: Tolerance indices of the evaluated barley genotypes as average of the two season.

Genotypes	YP	YS	TOL	MP	YR	STI	YSI	YI
Giza123	8.504	5.356	3.148	6.930	0.370	0.174	0.630	0.988
Giza2000	8.390	5.583	2.807	6.987	0.335	0.175	0.665	1.030
Giza129	6.981	4.110	2.871	5.546	0.411	0.139	0.589	0.758
Giza135	8.421	3.742	4.679	6.081	0.556	0.152	0.444	0.690
Line-1	10.270	6.567	3.703	8.418	0.361	0.211	0.639	1.212
Line-2	9.929	5.982	3.946	7.955	0.397	0.199	0.603	1.104
Line-3	9.684	5.033	4.651	7.359	0.480	0.184	0.520	0.929
Line-4	8.867	6.230	2.637	7.548	0.297	0.189	0.703	1.149
Line-5	9.221	4.725	4.495	6.973	0.488	0.175	0.512	0.872
Line-6	9.099	6.874	2.225	7.987	0.244	0.200	0.756	1.268

The high values of STI indicates high tolerance and high yield potential for the tested genotype. Generally, similar results were observed by MP as well as STI indices, which revealed that these indices were important for selecting materials. The findings recorded by Zare **[43]** indicated that MP and STI were the best criteria for selecting high yielding genotypes under both stress and non-stressed environments in barley. MP and STI were the most important indices for the identify the resistance genotypes to drought in wheat [44]. The values of YSI were 0.756 for Line-6. Mohammadi *et al.* [45] reported that YSI considered as a more useful index to identify drought tolerance and drought-sensitive genotypes. With regard to YI, the values were 1.268 for Line-6 and 1.212 for Line-1.

Conclusion

Salinity stress environments affect the different growth traits, yield and yield traits in both evaluating growing seasons. Among the evaluated genotypes, Line-1 and Line-6 considered as the highest yield potential genotypes under salt stress condition in both growing seasons, possessed high values for YS, MP, STI and YI. Line-6 showed least TOL and YR values, as well as had the lowest values of sodium under salt stress conditions. So, it could be recommended these genotypes for improvement barley productivity under saline soil conditions.

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