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DETERMINATION OF THE MOST EFFECTIVE CHARACTERISTICS IN GRAIN YIELD OF BREAD WHEAT UNDER SALINITY STRESS

Kh. E. Ragab(1)* and A.M. S. Kheir(2)

(1) Wheat Research Department, Field Crops Research Institute, Agriculture Research Centre, Egypt.

(2) Soil, Water and Environment Research Institute, Agriculture Research Centre, Egypt.

*Corresponding author: kragab1972@yahoo.com

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ABSTRACT: A pots experiment was conducted in cage-house at Wheat Research Department and the laboratory of Soil Improvement and Conservation Department, Sakha Agricultural Research Station, Agricultural Research Center, Egypt in 2015/2016 and 2016/2017 seasons. The stepwise regression analysis method used to determine the most effective characteristics related to wheat grain yield under three salinity levels. The data collected on five characteristics groups i.e., seedling, phenological, spike, physiological, yield and its contributes. The results showed that, the salinity levels less than 3.5 dSm^{-1} did not negatively affect wheat seedling growth, while, increasing salinity levels more than 3.5 dSm^{-1} significantly decreased all studied seedling characteristics. The salinity level of 3.5 dSm^{-1} led to earliness percentage of 4.2, 4.9, 3.8 and 2.2% in booting, heading, anthesis and maturity developmental stages, respectively. Meanwhile, increasing salinity levels up to 10.5 dSm^{-1} caused decrease for emergence speed by 21.7% and delay booting, heading and anthesis developmental stages by 3.9, 10.8 and 8.5%, respectively. Salinity stress decreased flag leaf area and increased chlorophyll pigments concentration, where the increase percent was higher for chlorophyll a compared with chlorophyll b and the total chlorophyll. Salinity stress decreased all studied spike characteristics with strong effect on number of kernels $spike^{-1}$ and spike kernels weight. Salinity stress decreased yield and its contributes where its effect was strong on plant height, root dry weight, biological and grain yield. The stepwise regression showed that biological yield, spike kernels weight, emergence index, number of spikes pot^{-1} and hundred kernels weight under salinity stress are the important selection criteria of high grain yield.

Key words: Wheat, salinity, stepwise regression, grain yield.

INTRODUCTION

Wheat is one of the oldest and most cultivated cereal species worldwide. It is globally plays an important role in food security (De Santis et al., 2018). In arid and semi-arid regions such as Egypt, salinity is one of the major factors that affect plant growth and metabolism and causing severe damage and a loss of plant productivity (Vaidyanathan et al., 2003). Improving salt tolerance of wheat genotypes considered as the most efficient way to increase wheat yield because salinity management through improved irrigation techniques or reclamation is often expensive and provides only short-term solutions for salinity problem (Amer et al., 1989). The effects of salinity stress on several growth stages of bread wheat were discussed. Seed germination is one of the most critical stages in the plant life cycle, as it directly determines the failure or success of the subsequent growth

stages (El-Hendawy et al. 2011; Liu et al. 2018). Salinity stress may have little effect on the final germination percentage of most crops, but it might cause a significant delaying of the germination time because of a delay of water uptake as well as a decrease in the α-amylase activities (Murtaza and Asghar 2012). Both bread and durum wheat are more sensitive to salt stress during germination than after the three-leaf stage of growth and they reported that, the tolerant genotypes can be identified at the early growth stage (Francois et al. 1986; Aflaki et al. 2017). Salinity stress caused decrease in emergence index, shoot dry weight and shoot length (Ragab and Taha 2016). Al-Ashkar (2019) evaluated wheat double haploid lines using three salinity levels; 0, 100, and 200 mM NaCl for 25 days and reported that shoot length and shoot dry weight were indicative of salt-tolerance, indicating their importance in improving and evaluating salt tolerant genotypes for breeding programs. The effect of 200 mM NaCl salinity level on yield components and chlorophyll components in pots experiment and found that salinity stress deceased chlorophyll a, chlorophyll b and shoot dry weigh by 21, 33 and 20%, respectively (Tareq et al. 2011). Increasing salinity levels from 4000 to 8000 ppm NaCl decreased number of days to heading, plant height, number of spikes plot^{-1}, number of kernels spike^{-1}, 1000 kernels weight and grain yield Maha et al. 2017). Salinity treatments significantly increase chlorophyll and carotenoid content per leaf area (Shah et al. 2017). Many researchers used stepwise regression analyses in order to identify the most important characteristics affecting grain yield in both normal and stress conditions. Fouad, (2018) and Abd El-Mohsen and Abd El-Shafi (2014) used stepwise regression analysis to justify the superior characteristics to use in selection for high grain yield under normal and stress conditions. The estimation of correlation and regression analysis among yield and yield components may provide effective selection criteria to improve wheat grain yield and their results observed positive phenotypic correlation for the grain yield with number of tillers plant^{-1} and 1000-grain weight (Rasheed et al. 2015; Khames et al. 2016; Jan et al 2017). The objective of this study is to determine the most effective characteristics related to wheat grain yield under salinity stress.

MATERIALS AND METHODS

A pots experiment was conducted in cage-house at Wheat Research Department and the laboratory of Soil Improvement and Conservation Department, Sakha Agricultural Research Station, Kafrelsheikh, Agricultural Research Center, Egypt during 2015/2016 and 2016/2017 growing seasons. Eighteen bread wheat genotypes previously characterized for salinity stress (Ragab, and Kheir 2019) namely; Giza 168, Giza 171, Misr 1, Misr 2, Sakha 93, Sakha 94, Sakha 95, Gemmeiza 7, Gemmeiza 9, Gemmeiza10, Gemmeiza11, Gemmeiza12, Sids 1, Sids 12, Sids 13, Shandweel 1, Line 1 and Line 2 were used as a representative sample of bread wheat population. The experiment was conducted in 30 × 40 cm black plastic bags filled with about 17 kg of tap water washed sand. On 25th November (the optimum sowing date) for both 2015/2016 and 2016/2017 growing seasons, twelve uniform seeds of the studied genotypes were sown into the depth of 4cm. Three salt stress treatments (3.5, 7.0, and 10.5 dSm^{-1}) were induced using diluted Mediterranean seawater, in addition to the control treatment (tap water, 0.5 dSm^{-1}) (Table 1). Control treatment used a concentration of 0.5 dSm^{-1}; close to the salinity of Nile river in Egypt (0.7 dSm^{-1}) as the main source of irrigation water.

Table 1: Tap water / sea water mix percent, electrical conductivity (EC), cations and anions analysis of the three studied salt treatments.

Salt treatments	Tap water ml	Sea water ml	Sea water mix percent	EC (dsm^{-1})	Cation (mgL^{-1})				Anions (mgL^{-1})			
					K+	Na+	Mg++	Ca++	SO4-	CL-	HCO3-	CO3-
control	1000	0	0	0.5	0.22	1.72	1.38	1.48	0.32	0.94	3.54	-
1	948	52	5.2	3.5	0.78	21.3	9.88	3.11	0.4	31.1	3.5	-
3	881	119	11.9	7	1.52	42.5	19.75	6.21	0.92	65.6	3.47	-
3	823	177	17.7	10.5	2.28	63.8	29.63	9.32	0.98	101	3.42	-
Sea water				50.7	11.2	308	142.9	45	2.22	502	3	-

The pots irrigated every week with amounts of 2 liters pot^{-1} of irrigation solution corresponding to each salinity level, taking into consideration the leaching requirements to avoid salt accumulation (Letey et al. 2011). The salt stress was applied from the sowing irrigation. The NPK multi-nutrients fertilizer 20:10:20 were used by 0.5 g pot^{-1} $week^{-1}$ dissolved in irrigation solution. Chelating microelements FULV-E (0.6%Zn.0.2% Cu,5,0%Mg, 2.0%B, 5%N,4.0%K_2o,4%Fe, 1.2 Mn, 8% fulvic acid and 6% citric acid) was sprayed every week with the rate of 3cm L^{-1}. The plants were protected against fungi diseases using the fungicide CABRIO™ TOP 60% wg with the rate of 1g/L and against insect damage using the insecticide NASR LATHION / CHEMINOVA 57% with the rate of 5cm L^{-1}. The eighteen bread wheat genotypes were arranged in randomize complete block design with three replications. After four days from sowing, the emerged seedlings were counted daily and the speed of seedling emergence was estimated by the formula described by the association of official seed analysis (AOSA, 1983) with some modifications. Emergence index (EI) = (No. of emerged seed / days of first count + …..+ (No. of emerged seed / days of final count). The grate value of EI is the high speed of emergence. After twenty days from sowing, the plants were thinned and only five seedlings were carefully left in each pot to grow until maturity. From the thinned seedlings, five seedlings were used to measure shoot length (ShL, cm), shoot fresh weigh (ShFW, g) and Shoot dry weigh (ShDW, g). The studied characteristics at adult plant stage were number of days to booting (DB), number of days to heading (DH), number of days to anthesis (DA), number of days to maturity (DM), plant height (PH, cm), number of tillers pot^{-1} (TP^{-1}), number of spikes pot^{-1} (SP^{-1}), spike length (SL, cm), number of spikelets $spike^{-1}$ (SS^{-1}), spike kernels weight (SKW), number of kernels $spike^{-1}$ (KS^{-1}), hundred kernels weight (100KW), biological yield pot^{-1} (BY, g) and grain yield pot^{-1} (GY, g). After heading, flag leaf area was determined following the formula of Carleton and Foote (1965) based on mean of three main stem flag leaves. Leaf area (cm^2) = leaf length × maximum leaf width × 0.75 (0.75 = Correction factor for family Graminae). In the first season only, after heading, three dicks (0.6 mm diameter) of the flag leaf, were taken and add to 5ml of extraction solution (N,N-dimethyl formamide) and kept in dark box at 4^oC (in the refrigerator) overnight. The absorption values at the specific wavelength were estimated using MILTON ROY-spectronic 1201. Porra et al. (1989) equations were used to estimate the concentration in nano moles per milliliter of chlorophyll a (Chl a), chlorophyll b (Chl b), and total chlorophyll total (Chl).

$$\text{Chl a}_{\text{concentration}} = (13.71 \times A663.6) - (2.85 \times A\ 646.6)$$

$$\text{Chl b}_{\text{concentration}} = (22.39 \times A646.6) - (5.42 \times A\ 663.6)$$

$$\text{Total Chl}_{\text{concentration}} = (8.29 \times A663.6) + (19.54 \times A\ 646.6)$$

Where $A_{xxx.x}$ refers to the absorbance value at the specific wavelength (xxx.x in nm).

After harvesting, the root system was extracted from each pot using fine tap water on 2.5 mm plastic mesh and dried at 65^{o}C to estimate root dry weight (RDW, g). The collected data were statistically analyzed by GenStat 14th edition microcomputer program (VSN International, 2011); multi environments trials in two factor factorial in RCBD. The means of salt treatments were obtained and mean differences were compared with least significant differences (LSD). Stepwise regression was used to automatically identify the characteristics influencing grain yield under normal and salinity stress. Multi regression analysis stepwise method among grain yield as dependent variable and the remaining studied characteristics as independent variables done using IMB®SPSS statistics version 25 (2017).

RESULTS AND DISCUSSION

The analysis of variance for seedling characteristics (Table 2) showed highly significant differences between years, genotypes, salt concentrations and their interactions for all studied characteristics. The variance of years and salinity had the main portion of total variation compared to the other source of variations. The coefficient of variation ranged from 6.1% for shoot length to 14.0% for shoot fresh weight. Regarding phenological characteristics, highly significant differences were recorded for all sources of variation and the main portion of total variation were due to years, salinity concentration and years × salt concentration interaction variances. Similar results were obtained by Ragab and Taha (2016) and Maha et al. (2017) whoreported that the variance due to salinity had the major portion from the total variance. The coefficient of variation ranged from 1.3% to 6.0% for days to maturity and emergence index, respectively. For physiological characteristics, highly significant differences were found for all source of variations and the main portion of total variation was due to salinity concentration variance. The coefficient of variation ranged from 6.4% for flag leaf area to 13.0% for chlorophyll b. For spike characteristics, highly significant differences were found for all source of variations and the main portion of total variations were due to years and salinity concentration variance. The coefficient of variation ranged from 6.5% for spiklets spike^{-1} to 19.0% for spike kernel weight. For yield and its contributes, highly significant differences were recorded for all sources of variation except for years in grain yield and hundred kernels weight and salt concentration genotypes interaction for hundred kernels weight . The main portion of total variation was due to salinity concentration variance in most cases. The coefficient of variation ranged from 3.9% for plant height to 22.0% for grain yield.

Table 2: Mean squares of years (Y), genotypes (G), salt concentrations (S) and their interactions and coefficient of variation (CV %) for seedling, phenological, physiological, spike characteristics, yield, and its contributes of the studied bread wheat genotypes.

Characteristic	Source of variance										CV%
	Y	Residual	S	G	Y×S	Y×G	S×G	Y×S×G	Residual	Total	
	df										
	1	4	3	17	3	17	51	51	284	431	
Seedling characteristics											
Shoot length	519.5**	519.500	237.9**	65.95**	36.9**	11.3**	4.96**	6.5**	1.980		6.1
Shoot fresh weigh	17.13**	0.046	12.1**	1.31**	0.995**	0.21**	0.12**	0.09**	0.051		15.0
Shoot dry weigh	0.183**	0.0004	0.113**	0.021**	0.027**	0.003**	0.001**	0.001**	0.001		14.0
Phenological characteristics											
Emergence index	4994**	0.302	323.4**	8.03**	135.6**	4.8**	3.0**	2.8**	0.743		6.0
Days to booting	18362**	7.321	3577.2**	692.4**	3560.1**	101.2**	35.2**	21.0**	3.665		2.5
Days to heading	21710**	16.930	3434.9**	510.1**	2758.7**	78.4**	38.0**	25.0**	2.942		2.0
Days to anthesis	38344**	19.218	2616.6**	382.81**	2749.2**	52.7**	21.1**	16.0**	3.105		1.8
Days to maturity	30763**	17.709	304.9**	200.39**	758.0**	35.3**	14.4**	11.1**	3.418		3.9
Physiological characteristics											
Flag leaf area	-	-	22251.9**	1020.4**	-	-	191.7**	-	10.280		6.4
Chlorophyll a	-	-	1440.1**	38.7**	-	-	11.8**	-	1.175		7.2
Chlorophyll b	-	-	29.8**	4.3**	-	-	2.4**	-	0.314		13.0
Total chlorophyll	-	-	1850.5**	60.5**	-	-	17.6**	-	1.932		7.2
Spike characteristics											
Spike kernels weight	10.6**	0.454	22.4**	4.2**	6.3**	0.9**	0.5**	0.4**	0.225		19.0
Spike length	36.8*	2.817	82.1**	24.9**	9.8**	4.1**	1.5**	1.2**	0.747		7.9
Spikelet spike^{-1}	0.003ns	15.358	215.1**	19.5**	20.9**	6.3**	3.1**	2.5**	1.413		6.5
Kernels spike^{-1}	9445.0**	19.840	4136.6**	588.6**	439.5**	277.8**	245.2**	135.1**	24.880		8.5
Yield and its contributing characteristics											
Tiller pot^{-1}	157.7**	0.939	162.1**	324.8**	2515.9**	115.9**	52.0**	40.8**	7.083		12.2
Spike pot^{-1}	158.3**	2.630	345.4**	179.4**	170.3**	57.7**	23.1**	17.1**	6.996		16.0
Plant height	7664.2**	12.953	26149.5**	1030.6**	2676.7**	216.1**	110.6**	89.1**	8.125		3.9
Root dry weight	-	-	481.5**	71.3**	-	-	10.9**	-	1.344		19.0
100 Kernels weight	8.2 ns	1.371	13.3**	7.7**	10.2**	1.0**	0.4 ns	0.43**	0.264		12.0
Biological yield	4452.3**	79.640	45288.2**	4646.9**	746.1**	704.6**	759.7**	479.9**	46.630		10.8
Grain yield	41.7ns	134.180	10604.4**	788.7**	188.9**	229.4**	104.3**	103.2**	36.840		22.0

ns, * and **, insignificant, significant at 0.05 and 0.01 probability levels, respectively.

Seedling characteristics

The effects of salt concentrations on seedling, phenological, physiological, spike characteristics and yield and its contributes are listed in Table (3). Under 3.5 dSm^{-1} salinity level, shoot length, shoot fresh weight and shoot dry weight were increased by 7.1, 3.4, and 4.8 %, respectively. These results indicated that the low level of salinity ≤ 3.5 dSm^{-1} diluted seawater did not causes significant changes in wheat seedling characteristics particularly the shoot length and dry weight. The 7.0 dSm^{-1} salinity level caused an insignificant increase in the shoot length. Significant decrease in regarding shoot fresh and dray weight with reduction percent 20.2 and 9.5, respectively (Table 3). With increase salinity level up to 10.5 dSm^{-1}, the salinity effects were more aggressive and that reflected on reduction percent values, which reached to 8.6, 37.1 and 28.6 for shoot length, shoot fresh weight and shoot dry weight respectively. Generally, the salinity level ≤ 3.5 dSm^{-1} diluted seawater did not negatively affect wheat seedling growth. While, increasing salinity levels more than 3.5 dSm^{-1} lead to significant decrease for all studied seedling characteristics. Similar results were reported that salinity stress decreased shoot dry weight and shoot length (Ragab and Taha 2016; Tareq et al. 2011)) indicating their importance in improving and evaluating salt tolerant genotypes for breeding programs (Al-Ashkar et al. 2019). Bread and durum wheat are more sensitive to salt stress during germination than after the three-leaf stage of growth and the tolerant genotypes can be identified at the early growth stage (Francois et al. 1986; Aflaki et al. 2017). Significant delaying of the germination time and decrease shot weight maybe happened by a delay of water uptake as well as a decrease in the α-amylase activities (Murtaza and Asghar 2012).

Phenological characteristics

The emergence index was increased by 0.4% under 3.5 dSm^{-1} salinity level. On other hand, comparing to control treatment it was significantly decreased by 14.7 and 21.7% reduction under 7.0 dSm^{-1} and 10.5dSm^{-1} salinity levels, respectively, (Table 3). Under control and 10.5dm^{-1}salinity levels, the number of days was increased by 10.2 days (from 73.2 to 83.4) for booting stage; by 9.2 days (from 83.3 to 94.5) for heading stage and by 8.0 days (from 94.4 to 102.4) for anthesis stage, but, the days to maturity did not change. On the other side, the 3.5 dSm^{-1} salinity level led to approximately 3 days decrease for the number of days to booting, heading, anthesis and maturity. Generally, the studied salinity levels had varying effects on the bread wheat emergence, booting, heading, anthesis and maturity development stages. The salinity level 3.5 dSm^{-1} led to earliness by 4.2, 4.9, 3.8 and 2.2% in the booting, heading, anthesis and maturity developmental stages, respectively, while, increasing salinity levels caused decrease emergence speed by 21.7% and lateness in all studied developmental stages that reached to 13.9, 10.8 and 8.5 for booting, heading and anthesis under salinity level 10.5dSm^{-1}. Similar results were obtained by Al-Naggar et al. (2015) who confirmed that salt stress at 9000 ppm significantly increased (delaying) days to heading by 15.9% and days to maturity by 14.7% in wheat. On the other hand, Asfaw and Danno 2011 found that increased salinity levels delaying heading and Maturity of tef crop [*Eragrostis te*f (Zucc.) Trotter] accessions and varieties in Ethiopia. Allel et al (2019) evaluated North African barley accessions at reproductive stage against salinity and they found that the severe salinity levels of 200 mM NaCl delayed heading and maturity date for the majority of moderately salt tolerant barley genotypes. In addition, they suggested that a longer heading and maturity periods may contribute to salt tolerance and delayed heading and maturity processes gives the opportunity of late differentiation and ripening, enabling the plant to maintain higher number of kernels spike^{-1} and consequently high grain yield. The salinity levels decreased emergence speed (Ragab and Taha 2016), delayed germination and has a little effect on the final germination percentage (Murtaza and Asghar 2012) which maybe explain the delaying of heading and maturity in wheat. On the contrary, Maha et al. (2017) reported decreasing number of days to heading as increasing salinity levels from 4000 to 8000 ppm NaCl.

Table 3: Salinity effects on seedling, phenological, physiological, spike and yield and contributed characteristics.

Characteristic	Salt concentrations (dSm^{-1})				$LSD_{0.05}$	Change %		
	0.5	3.5	7	10.5		3.5	7	10.5
Seedling characteristics								
Shoot length (cm)	23.06	24.69	23.17	21.07	0.38	7.1	0.5	-8.6
Shoot fresh weigh (g)	1.78	1.84	1.42	1.12	0.06	3.4	-20.2	-37.1
Shoot dry weigh (g)	0.21	0.22	0.19	0.15	0.01	4.8	-9.5	-28.6
Phenological characteristics								
Emergence index	15.68	15.75	13.37	12.27	0.20	0.4	-14.7	-21.7
Days to booting (day)	73.20	70.10	74.20	83.40	0.50	-4.2	1.4	13.9
Days to heading (day)	85.30	81.10	85.70	94.50	0.44	-4.9	0.5	10.8
Days to anthesis (day)	94.40	90.80	94.30	102.40	0.47	-3.8	-0.1	8.5
Days to maturity (day)	138.10	135.10	135.30	138.10	0.48	-2.2	-2.0	0.0
Physiological characteristics								
Flag leaf area (cm^2)	66.06	57.25	42.90	33.95	0.29	-13.3	-35.1	-48.6
Chlorophyll a (nmol ml^{-1})	9.58	16.93	17.01	16.69	0.29	76.7	77.6	74.2
Chlorophyll b (nmol ml^{-1})	3.57	4.31	4.53	4.78	0.15	20.7	26.9	33.9
Total chlorophyll (nmol ml^{-1})	13.14	21.24	21.54	21.48	0.37	61.6	63.9	63.5
Spike characteristics								
Spike length (cm)	11.61	11.37	11.06	9.66	0.22	-2.1	-4.7	-16.8
Spikelets spike^{-1}	19.62	18.95	17.97	16.37	0.30	-3.4	-8.4	-16.6
Kernels spike^{-1}	64.07	61.67	58.67	49.91	1.30	-3.7	-8.4	-22.1
Spike kernels weight (g)	2.79	2.73	2.53	1.80	0.12	-2.2	-9.3	-35.5
Yield and contributed characteristics								
Tiller pot^{-1}	20.30	20.70	21.90	23.00	0.70	2.0	7.9	13.3
Spike pot^{-1}	17.30	17.80	16.30	13.80	0.70	2.9	-5.8	-20.2
Plant height (cm)	88.27	82.98	68.79	53.59	0.76	-6.0	-22.1	-39.3
Root dry weight (g)	8.79	6.98	4.96	4.07	0.72	-20.6	-43.6	-53.7
100 kernels weight (g)	4.44	4.36	4.23	3.66	0.13	-1.8	-4.7	-17.6
Biological yield (g)	85.47	79.61	61.90	39.94	1.82	-6.9	-27.6	-53.3
Grain yield (g)	37.30	34.03	26.35	15.00	1.60	-8.8	-29.4	-59.8

Physiological characteristics

Gradual increasing salinity levels for 3.5, 7.0 and 10.5 dSm^{-1} led to significantly decreased flag leaf area with 13.3, 35.1, and 48.6% respectively. Meanwhile, salinity levels of 3.5, 7.0 and 10.5 dSm^{-1} led to increase chlorophyll a by 76.7, 77.6 and 74.2%, respectively; chlorophyll b by 20.7, 26.9 and 33.9%, respectively; total chlorophyll by 61.6, 63.9 and 63.5%, respectively. From these results, it can be concluded that, salinity stress caused decreasing flag leaf area and increasing chlorophyll pigments concentration, with high increase percent for chlorophyll a compared with chlorophyll b and the total chlorophyll.

Shah et al. (2017) confirmed that wheat plants under increasing saline treatments exhibited more green leaves compared to non-saline conditions and significant increase the chlorophyll and carotenoid content per leaf area at all levels of applied fertilizer. On the contrary, Tareq et al. (2011) found that 200 mM salinity level decreased chlorophyll a and chlorophyll b by 21 and 33% respectively. salinity has inhibitory effects on physiological aspects of wheat, which impair the growth and yield of the crop (Rani 2019).

Spike characteristics

Increasing salinity levels from control to 10.5 dSm^{-1} caused decrease spike length from 11.61 cm to 9.66 cm with reduction percent reached 16.8%; number of spikelet $spike^{-1}$ from 19.62 to 16.37 cm with reduction percent reached 16.6%; number of kernels $spike^{-1}$ from 64.07 to 49.91 with reduction percent reached 22.1%; spike kernels weight from 2.79 to 1.80 g with reduction percent reached 35.5% (Table 3). Generally, salinity stress led to decrease all studied spike characteristics with strong effect on number of kernels $spike^{-1}$ and spike kernels weight. Maha et al. (2017) reported decreasing number of kernels $spike^{-1}$ as increasing salinity levels from 4000 to 8000 ppm NaCl.

Yield and its contributing characteristics

The number of tillers pot^{-1} was increased from 20.3 for control to 23.0 for 10.5dSm^{-1} (13.3%). Meanwhile the number of spikes pot^{-1} was decreased from 17.3 for control to 13.8 for 10.5dSm^{-1} (20.2%). As salinity levels were elevated infertile tillers increased but, fertile ones were reduced. Increasing salinity levels from control to 10.5dSm-1 caused decrease plant height from 88.27 to 53.59 cm with reduction percent reached 39.3%; root dry weight from 8.79 to 4.07 g with reduction percent reached 53.7%; 100 kernels weight from 4.44 to 3.66 g with reduction percent reached 17.6%; biological yield from 85.47 to 39.93g with reduction present reached 53.3%; grain yield from 37.3 to 15.0 g with reduction reached 59.8%. These results showed that salinity stress decreased yield and its contributing characteristics with strong effect on plant height, root dry weight, biological and grain yield. Tareq et al. (2011) studied salinity (0 and 200 mM NaCl) effects on yield components and chlorophyll components in pots experiment and reported that salinity stress caused significant decrease for number of tillers $plant^{-1}$, number of spikes $plant^{-1}$ and 100 kernels weight. Ragab and Taha (2016) reported that salinity (seawater dilution) caused significant decrease of plant height, biological yield, grain yield and 100 kernels weight. Maha et al (2017) reported decreasing with increasing salinity levels (4000 and 8000 ppm NaCl) for plant height, number of spike pot^{-1}, and 1000 kernels weight.

Stepwise regression analysis

Stepwise regression analyses were done in order to catch the most important characteristics contributing to bread wheat grain yield under control and the three salt concentrations (Table 4).

The analysis under 0.5 dSm^{-1} salt concentration (control) was over in six steps. Biological yield, spike kernels weight, spike length, plant height, shoot fresh weight and number of spikes pot^{-1} were remained in the final model, respectively, (R^2 = 0.72). The formula of the final model was $\hat{Y}$ = 14.21+ 0.34 X1 + 8.91X2 - 2.20 X3 - 0.26 X4 + 5.93 X5 + 0.41 X6. With respect to the positive and significant regression coefficient of biological yield, spike kernels weight, shoot fresh weight and number of spikes pot^{-1}, it could be indicated that increasing the values of this characteristics would increase the grain yield. Considering the negative and significant regression coefficient of spike length and plant height, it could be indicated that increasing the values of this traits might decrease the grain yield.

Table 4: Result of stepwise regression analysis for grain yield in bread wheat genotypes under control and three salt concentrations.

Model	Unstandardized Coefficients		Standardized Coefficients	t	P. value	R^2 model	Adjusted R^2 Model
	B	Std. Error	Beta				
0.5 dSm^{-1} Salt concentration (control)							
(Constant)	14.21	8.37		1.70	0.09	0.72	0.71
Biological Yield (x1)	0.34	0.04	0.67	7.93	0.00		
Spike kernels weight (x2)	8.91	1.26	0.56	7.06	0.00		
Spike Length(x3)	-2.20	0.68	-0.24	-3.24	0.00		
Plant Height (x4)	-0.26	0.08	-0.25	-3.31	0.00		
shoot fresh weight(x5)	5.93	1.87	0.21	3.18	0.00		
Spikes pot^{-1} (x6)	0.41	0.20	0.16	2.02	0.05		
Model formula	***$\hat{Y}$= 14.21+0.34X1+8.91X2-2.20X3-0.26X4+5.93X5+0.41X6***						
3.5 dSm^{-1} Salt concentration							
(Constant)	-18.51	6.43		-2.88	0.01	0.61	0.59
Biological Yield (x1)	0.19	0.04	0.41	5.32	0.00		
Spike kernels weight (x2)	4.77	1.20	0.33	3.98	0.00		
Spikes pot^{-1} (x3)	0.52	0.17	0.24	3.05	0.00		
Plant Height (x4)	0.18	0.08	0.20	2.28	0.03		
Model formula	***$\hat{Y}$= -18.51 + 0.19X1+ 4.77 X2 + 0.52 X3 + 0.18 X4***						
7 dSm^{-1} Salt concentration							
(Constant)	0.04	1.97		0.02	0.98	0.76	0.66
Biological Yield (x1)	0.28	0.03	0.63	9.27	0.00		
Spike kernels weight (x2)	3.49	0.84	0.28	4.19	0.00		
Model formula	***$\hat{Y}$= 0.04 + 0.28X1 + 3.49 X2***						
10.5 dSm^{-1} Salt concentration							
(Constant)	-1.22	2.92		-0.42	0.68	0.79	0.74
Biological Yield (x1)	0.18	0.03	0.38	5.54	0.00		
Spike kernels weight (x2)	2.22	0.75	0.24	2.96	0.00		
Emergence Index(x3)	-0.39	0.16	-0.13	-2.42	0.02		
Spikes pot^{-1} (x4)	0.35	0.09	0.24	3.74	0.00		
100kernels weight (x5)	1.37	0.58	0.21	2.38	0.02		
Model formula	$\hat{Y}$= -1.22 +0.18X1 + 2.22 X2 - 0.39 x3 + 0.35 X4 + 1.37 X5						

The regression analysis under 3.5 was over in four steps. Biological yield, spike kernels weight, number of spikes pot^{-1} and plant height were remained in the final model, respectively, (R^2 = 0.76). The formula of the final model was $\hat{Y}$ = -18.51 + 0.19 X1 + 4.77 X2 + 0.52 X3 + 0.18 X4. Positive and significant of the regression coefficient of the import characteristics indicated that increasing the values of these characteristics would increase the grain yield.

Regarding the 7.0 dSm^{-1} salt concentration, the regression analysis was over in only two steps. Biological yield and spike kernels weight were remained in the final model, respectively, (R^2 = 0.61). The formula of the final model was $\hat{Y}$= 0.04 + 0.28 X1 + 3.49 X2. Positive and significant of the regression coefficient of the two characteristics indicated that increasing the values of these characteristics would increase the grain yield.

The regression analysis under 10.5 dSm^{-1} was over in five steps. Biological yield, spike kernels weight, emergence index, number of spikes pot^{-1} and 100 kernels weight were remained in the final model, respectively, (R2 = 0.79). The formula of the final model was $\hat{Y}$ = 1.22 +0.18X1 + 2.22 X2 - 0.39 x3 + 0.35 X4 + 1.37 X5. Positive and significant of the regression coefficient of biological yield, spike kernels weight, number of spikes pot^{-1} and 100 kernels weight indicated that increasing the values of these characteristics would increase the grain yield. In general, biological yield, spike kernels weight and number of spike pot^{-1} characteristics were import by the stepwise regression under both control and salinity treatments, so these characteristics had an important role as selection criteria of the high grain yield under both normal and salinity stress. These results were in agreement with those found by Fouad (2018) who used stepwise multiple linear regression analysis and they revealed that number of kernels spike^{-1}, number of spike plant^{-1} and 100 kernels weight were the most affected characteristics on grain yield under both normal and stress conditions (water regime). Abd El-Mohsen and Abd El-Shafi (2014) reported stepwise multiple linear regression analysis revealed that four traits, i.e., the number of tillers plant^{-1}, the number of grains spike^{-1} and the 1000 grain weight with R^2 = 97.29%, had justified the best grain yield prediction model under normal condition. Gholizadeh (2014) reported that the biological yield, harvest index and chlorophyll content were the most important traits influencing seed yield under saline soil. In addition, Rasheed et al (2015), Khames et al. (2016) and Jan et al. (2017) observed positive phenotypic correlation for the grain yield with tillers plant^{-1} and 1000-grain weight. Hannachi et al. (2013) reported that under rainfed environment the biomass and harvest index are good measurement for predicting grain yield.

CONCLUSION

The salinity level of 3.5 dSm^{-1} led to earliness by 4.2, 4.9, 3.8 and 2.2% in the booting, heading, anthesis and maturity developmental stages, respectively. While, increasing salinity levels > 3.5 dSm^{-1} caused decrease emergence speed by 21.7% and delaying in all studied developmental stages that reached to 13.9, 10.8 and 8.5 for booting, heading and anthesis under 10.5dSm^{-1} salinity level. Salinity stress decreased flag leaf area and increased chlorophyll pigments concentration, with high increase percent for chlorophyll a compared with chlorophyll b and the total chlorophyll. Salinity stress decreased all studied spike characteristics with strong effect on number of kernels spike^{-1} and spike kernels weight. Salinity stress decreased

yield and its contributing characteristics with strong effect on plant height, root dry weight, biological and grain yield. The stepwise regression confirmed that biological yield, spike kernels weight and number of spikes pot^{-1} characteristics had an important role for selection criteria of high grain yield under both control and salinity stress.

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تحديد الصفات الاكثر تأثيرا في محصول الحبوب لقمح الخبز تحت الاجهاد الملحي

خالد الدمرداش رجب[1]، أحمد محمد سعد خير[2]

[1] قسم بحوث القمح –معهد بحوث المحاصيل الحقلية –مركز البحوث الز راعية –مصر

[2] معهد بحوث الأراضي والمياه والبيئة –مركز البحوث الز راعية –مصر

الملخص العربى

تم إجراء هذا البحث في الصوبة السلكية (تجربة أصص) في قسم بحوث القمح – معهد بحوث المحاصيل الحقلية ومعمل قسم بحوث تحسين وصيانة الأراضي – معهد بحوث الأراضي والمياه بمحطة البحوث الزراعية بسخا –كفر الشيخ –مركز البحوث الزراعية – مصر، خلال الموسمين المتعاقبين 2016/2015 و2017/2016، تم استخدام 18 تركيب وراثي من قمح الخبز للقمح. يهدف هذا البحث إلى تحديد الصفات الأكثر تأثيرا في محصول الحبوب تحت الاجهاد الملحي. تم ترتيب جميع المعاملات قطاعات كاملة العشوائية بثلاث مكررات. وسجلت البيانات على خمس مجموعات من الصفات وهي صفات البادرة والصفات الفينولوجية والفسيولوجية وصفات السنبلة وصفات المحصول ومكوناته. تم إجراء التحليل الاحصائي وكذلك تحليل الانحدار المتعدد التدريجي، وأظهرت النتائج أن مستوى الملوحة 3.5 ديسيمنز / متر لم يؤدي الي تاثير سلبى على نمو بادرة القمح كما أدى إلى التبكير بنسبة 4.2 ، 4.9 ، 3.8 و 2.2 ٪ في مراحل الحبلان والطرد والتزهير والنضج الفسيولوجي على الترتيب، بينما تسببت زيادة مستويات الملوحة حتي 10.5 ديسيمنز / متر في تقليل سرعة الانبات بنسبة 21.7٪ وتأخر في جميع مراحل التطور التي تمت دراستها والتي بلغت 3.9 و 10.8 و 8.5 % في مراحل الحبلان والطرد والتزهير على الترتيب ، كما تسبب الإجهاد الملحي في تناقص مساحة ورقة العلم وزيادة تركيز أصباغ الكلوروفيل ، مع زيادة كبيرة في الكلوروفيل (أ) مقارنة بالكلوروفيل (ب) والكلوروفيل الكلي. كما أدى إجهاد الملوحة إلى تقليل جميع صفات السنبلة المدروسة مع تأثير قوي على عدد ووزن حبوب السنبلة. قلل الإجهاد الملحي من المحصول ومكوناته مع وجود تأثير قوي على ارتفاع النبات والوزن الجاف للجذور والمحصول البيولوجي ومحصول الحبوب. كما اظهر تحليل الانحدار المتعدد التدريجي انه كان للخمسة صفات التالية ؛ المحصول البيولوجي و وزن حبوب السنبلة و سرعة الانبثاق و عدد السنابل لكل اصيص و وزن 100 حبة تأثيرا كبيرا في محصول الحبوب و بالتالي يمكن استخدامها لانتخاب المحصول العالي تحت ظروف الاجهاد الملحي.

أسماء السادة المحكمين

أ.د/ محمد سعد مغـــــازى كلية الزراعة – جامعة كفر الشيخ

أ.د/ إبراهيم حسينى درويش كلية الزراعة – جامعة المنوفية