Determination of the most important characteristics in bread wheat grain yields under salinity stress

Khaled Ragab
Crops Research Institute
Ahmed Kheir (drahmedkheir2015@gmail.com)
Soils, Water and Environment Research Institute https://orcid.org/0000-0001-9569-5420

Research article

Keywords: wheat, salinity, stepwise regression, grain yield, phenology, photosynthesis

Posted Date: November 17th, 2020

DOI: https://doi.org/10.21203/rs.3.rs-104824/v1

Abstract

Background

Salinity has adverse effects on crop production in arid and semi-arid regions but so far, less attention has been paid to this impact on wheat characteristics. A pot experiment was carried out in cage-house to determine the most important characteristics in wheat under wide range of salinity using the stepwise regression analysis. The data collected on five groups of characteristics (i.e. seedling, phonology, spike, physiology, yield and its contributions).

Results

The findings showed that the salinity levels below 3.5 dSm^{-1} triggered stimulation in the growth of wheat seedling, while the salinity rates increased by more than 3.5 dSm^{-1} significantly reduced all the seedling characteristics studied. The salinity level of 3.5 dS m^{-1} resulted in an earliness percentage of 4.2, 4.9, 3.8 and 2.2% respectively in the developmental stages of booting, heading, anthesis and maturity. Meanwhile, rising salinity levels up to 10.5 dSm^{-1} resulted in a 21.7% decrease in emergence speed and a delay of 3.9, 10.8 and 8.5% in booting, heading and anthesis developmental stages respectively. Salinity stress decreased the flag leaf area and increased concentration of chlorophyll pigments, where the percentage increase for chlorophyll a was higher compared with chlorophyll b and total chlorophyll. The stress of salinity decreased all the studied spike characteristics with significant effect on the number of $spike^{-1}$ and spike kernel weights.

Conclusions

Salinity stress decreased yield and other 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 and number of spikes pot^{-1} characteristics under both normal and salinity stress are the important selection criteria of high grain yield.

Background

Wheat is one of the oldest and most cultivated cereal species worldwide. Egypt is the largest imported country of wheat in the world (Asseng et al. 2018; Kheir et al. 2019). Furthermore, wheat plays an important role in food security globally (Godfray et al. 2010; De Santis et al. 2018). Salinity is one of the major factors influencing plant growth and metabolism in arid and semi-arid regions, causing significant damage and a loss of plant productivity (Seleiman and Kheir 2018; Ding et al. 2020). Improving the salt tolerance of wheat genotypes considered to be the most effective way to increase wheat yield since salinity control is often costly through enhanced irrigation techniques or recycling and only offers short-term solutions to the salinity issue (Nongpiur et al. 2016). However, improving the tolerance of wheat genotypes to salinity stress in arid and semi- arid regions still unknown. Therefore, it is important to explore the effects of salinity stress on several stages of bread wheat development. Seed germination is one of the most important phases of the plant life cycle, as it directly influences the failure or success of the subsequent growth phases (Liu et al. 2018). Both bread and durum wheat are more prone to salt stress during germination than after the three-leaf growth stage and the resistant genotypes can be identified at an early stage of development (Francois et al. 1986; Aflaki et al. 2017). Furthermore, salinity stress could cause a decrease in emergence index, shoot dry weight and shoot length (Sharif et al. 2019). The shoot length and shoot dry weight could be considered indicative of salt tolerance, indicating their significance in improving and evaluating salt tolerant genotypes for breeding programs (Al-Ashkar et al. 2019). Nevertheless, the effect of wide range of salinity on yield components, chlorophyll and other physiological traits on wheat grown in arid regions still unknow. Furthermore, stepwise regression analysis could be used justify the superior characteristics to use in selection for high grain yield under normal and stress conditions but has less attention so far. 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. Therefore, the purpose of this study is to determine the most effective grain yield-related characteristics under salinity stress using the stepwise regression analysis.

Results

Study of variance for all characteristics

For all characteristics studied, the study of variance for seedling characteristics (Table 2) showed highly significant variations between years, genotypes, salt concentrations and their interactions. The range of years and salinity relative to the other source of variability had the main portion of overall variation. The variation coefficient ranged from 6.1 % for shooting duration to 14.4 % for shooting fresh weight. Highly significant differences were reported for all sources of variation with respect to phonological characteristics, and the main portion of total variation was due to variations in years, salinity concentration and years with salt concentration. The coefficient of variation ranged from 1.3% to 5.8% for days to maturity and emergence index, respectively. Highly significant differences for all source of variations were observed for physiological characteristics, and the main portion of total variation was due to variance in salinity concentration. The coefficient of variation ranged from 6.3% for flag leaf area to 12.6% for chlorophyll b. Highly significant discrepancies were observed for spike characteristics across all sources of variations, and the main portion of total variations is due to years and variance in salinity concentration. The coefficient of variation ranged from 6.3% for spiklets spike^{-1} to 18.7% for spike kernel weight. Highly significant differences were reported for yield and its contributions for all sources of variation, except for years in grain yield. In most cases, the principal portion of overall variation was due to variations in salinity concentration. The coefficient of variation ranged from 3.9% for plant height to 21.4% for grain yield.

Table 2

Seedling characteristics

The impacts of salt concentrations on seedling, phonological, physiological, spike and yield characteristics and its contributions were described in Table 3. Under 3.5 dS m^{-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 dS m^{-1} diluted seawater causes stimulation in wheat seedling characteristics especially the shoot length and dry weight. The salinity level of 7.0 dS m^{-1} caused the duration of the shoot to increase insignificantly. Significant decrease in regarding shoot fresh and dry weight with reduction percent 20.2 and 9.5, respectively (Table 3). With increasing the salinity level up to 10.5 dS m^{-1}, the salinity effects were more severe 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. The salinity level of 3.5 dS m^{-1} diluted seawater usually triggered stimulation in the growth of wheat seedlings.

Phonological characteristics

The index of emergence increased by 0.4 % below the amount of salinity of 3.5 dS m^{-1}. On the other hand, it was substantially reduced below 7.0 dS m^{-1} and 10.5dS m^{-1} salinity levels by 14.7 and 21.7 % relative to the control treatment (Table 3). Under control and 10.5 dS m^{-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 improve. On the other hand, the degree of salinity of 3.5 dS m^{-1} has contributed to a decrease of around 3 days for the number of days to boot, heading, anthesis and maturity. In general, the amounts of salinity studied had differing effects on the stages of growth of bread wheat, booting, heading, anthesis and maturity.

Physiological characteristics

Gradually rising levels of salinity for 3.5, 7.0 and 10.5 dS m^{-1} resulted in a substantially reduced flag leaf region with 13.3, 35.1 and 48.6 % respectively. Meanwhile, chlorophyll levels of 3.5, 7.0 and 10.5 d Sm^{-1} increased by 76.7, 77.6 and 74.2% respectively; chlorophyll b increased by 20.7, 26.9 and 33.9% respectively; total chlorophyll increased by 61.6, 63.9 and 63.5% respectively.

Table3

Spike characteristics

Increasing salinity levels from control to 10.5dS m^{-1} caused a decrease in 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). In general, salinity stress led to a reduction of all studied spike characteristics with a strong impact on the number of $spike^{-1}$ kernels and spike kernel weight.

Yield and its contributing characteristics

The number of tillers pot^{-1} was increased from 20.3 for control to 23.0 for 10.5 dS m^{-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%). Since salinity levels were elevated infertile tillers but, fertile ones were reduced. Increasing salinity levels from control to 10.5d Sm^{-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%.

Stepwise regression analysis

Stepwise regression analyzes were performed to capture the most critical characteristics contributing to regulated yield of bread wheat grain and three concentrations of salt (Table 4). The analysis under 0.5 dS m^{-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 = $14.21+ 0.34 X1 + 8.91X2 - 2.20 X3 - 0.26 X4 + 5.93 X5 + 0.41 X6$. 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 important regression coefficient of spike length and plant height, it could be inferred that the grain yield will be decreased by growing the sum of this trait.

The regression analysis under 3.5 dS $m^{-1}$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 = $-18.51 + 0.19 X1 + 4.77 X2 + 0.52 X3 + 0.18 X4$

Table 4

Regarding the 7.0 dS m^{-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 = 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 = 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.

Discussion

Salinity problem is a major constraint to the global cereal production but breeding for tolerance and exploring the most characteristics of wheat under salinity stress has been slow (Genc et al. 2019). Although rising salinity levels more than 3.5 dS m^{-1} for all seedling characteristics studied result in a substantial decrease. Similar findings indicate that salinity stress decreased shooting dry weight and shooting duration (Tareq et al. 2011) and suggested their significance in developing 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 (Aflaki et al. 2017). A substantial delay in germination time and a decrease in shot weight may have occurred due to a delay in water uptake and a decrease in the production of α-amylase (Elsadek and Yousef 2019).

The salinity level of 3.5 dS m^{-1} resulted in earliness of 4.2, 4.9, 3.8 and 2.2% in the developmental stages of booting, heading, anthesis and maturity, respectively, while rising salinity levels caused a decrease of 21.7% and lateness in all the developmental stages studied which reached 13.9, 10.8 and 8.5 for booting, heading and anthesis under salinity level 10.5dSm^{-1}. Similar findings were obtained by (Al-Naggar et al. 2015). 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. At the reproductive stage, (Allel et al. 2019) evaluated North African barley accessions against salinity and found that the extreme salinity levels of 200 mM NaCl delayed heading and maturity date for most moderately salt tolerant barley genotypes. Additionally, they indicated that longer heading and maturity periods can lead to salt tolerance, and delayed heading and maturity processes provide the opportunity for late differentiation and maturation, allowing the plant to maintain a higher number of $spike^{-1}$ kernels and consequently a high grain yield. The salinity levels decreased emergence pace delayed germination and had a minor impact on the percentage of final germination which could explain the delay of heading and maturity in wheat.

It was also found that, salinity stress induced reduced area of the flag leaf and increased concentration of chlorophyll pigments, with a large percentage increase for chlorophyll a compared to chlorophyll b and total chlorophyll. (Shah et al. 2017) reported that wheat plants display more green leaves relative to non-saline conditions under can saline treatments, and significantly increased the chlorophyll and carotenoid content per leaf area at all levels of fertilizer used. On the contrary, (Tareq et al. 2011) found that the salinity level of 200 mM decreased by 21 and 33% respectively chlorophyll a and chlorophyll b. Salinity has inhibitory effects on wheat physiological aspects which impair crop growth and yield (Rani et al. 2019).

Salinity stress decreased yield and its contributing characteristics with significant effect on plant height, root dry weight, biological and grain yield. This may be attributed to decreasing the biomass and total dry matter with higher salinity levels (STAVRIDOU et al. 2017). Positive and significant of the regression coefficient of the import characteristics 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 for 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.

Conclusions

The salinity level of 3.5 dS m^{-1} resulted in earliness of 4.2, 4.9, 3.8 and 2.2% in the booting, heading, anthesis and maturity developmental stages, respectively. Although rising salinity levels > 3.5 dSm-1 resulted in a 21.7% decrease in the rate of emergence and a delay in all the developmental stages studied which reached 13.9, 10.8 and 8.5 for booting, heading and anthesis below the salinity level of 10.5dSm^{-1}.. 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. The stress of salinity decreased all of the studied spike characteristics with significant impact on the number of spike^{-1} and spike kernel weights. Salinity stress reduced yield and its contributing characteristics with a strong impact on plant height, dry root weight, biological yield, and yield of grains. The stepwise regression verified that under both normal and salinity stress, biological yield, spike kernel weight and number of spikes pot^{-1} characteristics had a significant role in selection criteria for high grain yield.

Methods

A pot 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 genotypes of bread wheat: 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. The experiment was conducted in 30 × 40 cm black plastic bags filled with about 17.0 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 dS m^{-1}) were induced using diluted Mediterranean seawater, in addition to the control treatment (tap water, 0.5 dSm^{-1}) (Table 1).

Table 1

The pots irrigated every five days 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. The salt stress treatments were 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^{TM} TOP 60% wg with rate 1g/L and against insect damage using the insecticide NASR LATHION / CHEMINOVA 57% with the rat of 5cm L^{-1}. The eighteen bread wheat genotypes were arranged in randomize complete block design with three replications. Each salt treatment was considered as an independent experiment. 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 (A.O.S.A. 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 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. 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 $4^{o}C$ (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).

Using fine tap water on 2.5 mm plastic mesh, the root system was extracted from each pot after harvesting and dried at 65 ° C to estimate root dry weight (RDW, g).MSTATC microcomputer software statistically analyzed the collected data, integrating one factor model over the years, and salt treatments. MSTATC microcomputer software statistically analyzed the collected data, integrating one factor model over the years, and salt treatments. Stepwise regression was used to automatically classify the grain yield affecting characteristics under normal and salinity stresses. Multi-regression analysis approach between grain yield as dependent variable and the remaining studied features as independent variables made using IMB® SPSS version 25 (2017).

Abbreviations

Not applicable

Declarations

Ethics approval and consent to participate

Not applicable

Consent for publication

Not applicable

Availability of data and materials

All data generated or analyzed during this study are included in this submitted article

Competing interests

The authors declare that they have no competing interests

Funding

This research was funded by Agricultural Research Center, Egypt, in the part of performing the experiments, and statistical analysis.

Authors' Contributions

KER made the conception of the work and designed the experiments. KER and AMSK performed the experiments. KER and AMSK conducted data analysis and contributed towards writing the manuscript, helped in interpreting results. KER supervised the findings of the work.

Acknowledgments

The authors are thankful to Soils, Water and Environment Research Institute (SWERI), and Field Crops Research Institute, Agricultural Research Centre for providing the financial support and research facilities.

References

A.O.S.A. (1983) Seed vigor testing handbook . Contribution No.32 to the.handbook on seed testing. Association of official seed analysis Springfield, IL

Abd El-Mohsen AA, Abd El-Shafi MA (2014) Regression and path analysis in Egyptian bread wheat. J Agri-Food & Appl Sci, 2 (5):139-148

Aflaki FM, Sedghi AP, Pessarakli M (2017) Investigation of seed germination indices for early selection of salinity olerant genotypes. Emir J Food Agric 29 (3):222–226. DOI: 210.9755/ejfa.2016-9712-1940

Al-Ashkar I, Alderfasi A, El-Hendawy S, Al-Suhaibani N, El-Kafafi S, Seleiman MF (2019) Detecting salt tolerance in doubled haploid wheat lines. Agronomy 9 (211):doi:10.3390 / agronomy 9040211

Al-Naggar AMM, Sabry SRS, Atta MMM, Ola MAE-A (2015) Effects of salinity on performance, heritability, selection gain and correlations in wheat (Triticum aestivum L.) doubled haploids. Sci Agri 10 (2):70-83. DOI: 10.15192/PSCP.SA.12015.15110.15192.17083

Allel D, Amar AB, Badri M, Abdelly C (2019) Evaluation of salinity tolerance indices in North African barley accessions at reproductive stage. Czech Journal of Genetics and Plant Breeding 55 (2):61–69. https://doi.org/10.17221/17250/12017-CJGPB

Asfaw KG, Danno FI (2011) Effects of salinity on days to heading (DTH), days from heading to maturity (DHTM) and days to maturity (DTM) of tef [Eragrostis tef (Zucc.) Trotter] accessions and varieties in Ethiopia. Asian J Agric Sci 3 (4):250-256

Asseng S, Kheir AMS, Kassie BT, Hoogenboom G, Anbdelaal AIN, Haman DZ, Ruane AC (2018) CanEgyptbecomeself-sufficientinwheat? Environmental Research Letters 13:094012

De Santis MAO, Kosik D, Passmore Z, Flagella PR, Lovegrove A (2018) Comparison of the dietary fibre composition of old and modern durum wheat (Triticum turgidum spp. durum) genotypes. Food Chem 244:304–310. https://doi.org/310.1016/j.foodchem.2017.1009.1143

Ding Z, Kheir AMS, Marwa GMA, Ali OMA, Abdelaal AIN, Lin X, Zhou Z, Wang B, Liu B, He Z (2020) The integrated effect of salinity, organic amendments, phosphorus fertilizers, and deficit irrigation on soil properties, phosphorus fractionation and wheat productivity. Scientific Reports 10:2736

Elsadek MA, Yousef EAA (2019) Smoke-Water Enhances Germination and Seedling Growth of Four Horticultural Crops. Plants 8 (4):104

Fouad HM (2018) Correlation, Path and Regression Analysis in Some Bread Wheat (Triticum aestivum L) Genotypes under Normal Irrigation and Drought Conditions Egypt J Agron 40 (2):133-144

Francois LE, Maas EV, Donovan TJ, Youngs VL (1986) Effect of salinity on grain yield and quality, vegetative growth and germination of semi-dwarf and durum wheat. Agronomy J 87:1053–1058.

Genc Y, Taylor J, Lyons G, Li Y, Cheong J, Appelbee M, Oldach K, Sutton T (2019) Bread Wheat With High Salinity and Sodicity Tolerance. Frontiers in Plant Science 10 (1280). doi:10.3389/fpls.2019.01280

Godfray HCJ, Beddington JR, Crute IR, Haddad L, Lawrence D, Muir JF, Pretty J, Robinson S, Thomas SM, Toulmin C (2010) Food security: The challenges of feeding 9 Billion people. Science 327:812-818

Kheir AMS, El Baroudy A, Aiad MA, Zoghdan MG, Abd El-Aziz MA, Ali MGM, Fullen MA (2019) Impacts of rising temperature, carbon dioxide concentration and sea level on wheat production in North Nile delta. Science of the Total Environment 651:3161–3173

Liu L, Xia W, Li H, Zeng H, Wei B, Han S, Yin C, Villasuso AL (2018) Salinity inhibits rice seed germination by reducing α-amylase activity via decreased bioactive gibberellin content. Front Plant Sci 9:275– 284. doi:210.3389/fpls.2018.00275.

Nongpiur RC, Singla-Pareek SL, Pareek A (2016) Genomics Approaches For Improving Salinity Stress Tolerance in Crop Plants. Curr Genomics 17 (4):343–357.

Porra RJ, Thompson WA, Kriedemann PE (1989) Determination of accurate extinction coefficients and simultaneous equations for assaying chlorophylls a and b extracted with four different solvents: verification of the concentration of chlorophyll standards by atomic absorption spectroscopy. Biochimica et Biophysica Acta 975:384-394.

Rani S, Sharma MK, Kumar N, Neelam. (2019) Impact of salinity and zinc application on growth, physiological and yield traits in wheat. Current Science 116 (8)

Seleiman MF, Kheir AMS (2018) Saline soil properties, quality and productivity of wheat grown with bagasse ash and thiourea in different climatic zones. Chemosphere 193:doi.org/10.1016/j.chemosphere.2017.1011.1053

Shah SH, Houborg R, McCabe MF (2017) Response of Chlorophyll, Carotenoid and SPAD-502 Measurement to Salinity and Nutrient Stress in Wheat (Triticum aestivum L.) Agronomy 7 (61):doi: 10.3390/agronomy7030061

Sharif I, Aleem S, Farooq J, Rizwan M, Younas A, Sarwar G, Chohan SM (2019) Salinity stress in cotton: effects, mechanism of tolerance and its management strategies. Physiol Mol Biol Plants 25 (4):807–820

STAVRIDOU E, HASTINGS A, WEBSTER RJ, ROBSON PRH (2017) The impact of soil salinity on the yield, composition and physiology of the bioenergy grass Miscanthus 3 giganteus. GCB Bioenergy 9:92–104, doi: 110.1111/gcbb.12351

Tareq MZ, Hossain MA, Mojakkir AM, Ahmedr R, Fakir MSA (2011) Effect of salinity on reproductive growth of wheat. Bangladesh J Seed Sci & Tech 15 (1):1 1 l-1 l6.

Tables

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^{++}	SO_4^-	CL^-	HCO_3^-	CO_3^-
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	0.40	31.1	3.50	-
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	45.0	2.22	502	3.00	-

EC: soil salinity expressed as electrical conductivity

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

Characteristic	Source of variance							CV%
	Y	S	Y×S	G	Y×G	S×G	Y×S×G	
	df							
	1	3	3	17	17	51	51	
Seedling characteristics								
Shoot length	521.3**	237.6**	36.8**	66.0**	11.3**	5.0**	6.5**	6.1
Shoot fresh weigh	17.1**	12.1**	1.0**	1.3**	0.2**	0.1**	0.1**	14.4
Shoot dry weigh	0.176**	0.115**	0.026**	0.021**	0.003**	0.001**	0.001**	13.9
Phonological characteristics								
Emergence index	5014**	324.9**	136.5**	8.0**	4.8**	3.0**	2.8**	5.8
Days to booting	18330.1**	3567.9**	3575.4**	692.7**	102.6**	35.1**	20.9**	2.5
Days to heading	38307.0**	2613.9**	2752.7**	383.1**	52.7**	21.2**	15.7**	3.9
Days to anthesis	38307**	2614.0**	2753.0**	7.873 **	383.1**	52.7**	21.2**	1.8
Days to maturity	30754.7**	304.5**	759.9**	200.4**	35.4**	14.4**	11.1**	1.3
Physiological characteristics								
Flag leaf area	-	11128.0**	-	510.3**	-	95.9**	-	6.3
Chlorophyll a	-	720.2**	-	19.3**	-	5.9**	-	7.1
Chlorophyll b	-	14.9*	-	2.2**	-	1.2**	-	12.6
Total chlorophyll	-	925.5**		30.3**		8.8**	-	7.1
Spike characteristics								
Spike kernels weight	10.6**	22.4**	6.3**	4.2**	0.9**	0.5**	0.4**	18.7
Spike length	36.9**	82.2**	9.7**	24.7**	4.1**	1.5**	1.2**	7.6
Spikelet spike^{-1}	0.003**	215.1**	21.0**	19.5**	6.3**	3.1**	2.5**	6.3
Kernels spike^{-1}	9451.0**	4135.5**	440.1**	588.8**	277.8**	245.1**	134.9**	8.4
Yield and its contributing characteristics								
Tiller pot^{-1}	154.1**	161.8**	2532.8**	324.9**	114.8**	52.3**	40.6**	12.3
Spike pot^{-1}	160.1**	345.8**	171.6**	178.9**	57.3**	23.1**	16.9**	16.1
Plant height	7664.2**	26148.2**	2676.0**	1031.1**	216.0**	110.6**	89.2**	3.9
Root dry weight	-	240.9**	-	35.7**	-	5.4**	-	17.9
100 Kernels weight	8.2**	13.3**	10.2**	7.7**	1.0**	0.4**	0.4**	12
Biological yield	4449.3**	45299.7**	746.0**	4647.0**	704.4**	759.7**	479.9**	10.3
Grain yield	41.7 ns	10604.1**	188.9*	788.6**	229.4**	104.3**	103.2**	21.4

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

Table3: salinity effects on seedling, Phonological, physiological, and yield and contributed characteristics.

Characteristic	Salt concentrations (dSm $^{-1}$)				LSD	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	0.37	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
Phonological 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	1.66	-13.3	-35.1	-48.6
Chlorophyll a (nmol ml $^{-1}$)	9.58	16.93	17.01	16.69	0.58	76.7	77.6	74.2
Chlorophyll b (nmol ml $^{-1}$)	3.57	4.31	4.53	4.78	0.74	20.7	26.9	33.9
Total chlorophyll (nmol ml $^{-1}$)	13.14	21.24	21.54	21.48	1.30	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

(LSD 0.01): least significant differences

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	*= 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	*= -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	*= 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	= -1.22 +0.18X1 + 2.22 X2 - 0.39 x3 + 0.35 X4 + 1.37 X5					