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The Effect of Salinity on Wheat Genotypes during Germination Stage

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Abstract: Salinity is a major abiotic stress that adversely affects wheat production in many regions of the world. Salinity stress limits wheat growth, development, and yield. Identification of salinity tolerant genotypes is critical for yield improvement. Therefore, a series of control environment experiments were carried out to evaluate the response of two spring wheat and two winter wheat cultivars (*Triticum aestivum* L.) to different levels of salinity. The experiments were designed in a randomized complete block design (RCBD) with five replications. Twenty seeds of each genotype were placed on pre-moistened filter paper in Petri dishes and placed in an incubator at 20 °C. The seeds were subjected to 4 levels of salinity 0, 50, 100, and 150 mM NaCl. Seedlings were harvested after 8 days, and data on final germination percentage, rate of germination, mean daily germination, shoot and root length, and seedling fresh and dry weight were recorded. The results indicated that winter and spring wheat genotypes differed significantly for germination percentages, rate of germination, mean daily germination, shoot and root lengths, and seedling fresh and dry weight. The results showed that salinity did not affect final germination percentage until salinity level reached to 100 mM NaCl; whereas seeds subjected to 100 and 150 mM NaCl retarded germination by 1 and 2 days of spring wheat, and 2-3 days of winter wheat respectively, as compared with 0 and 50 mM NaCl treatment. The data also showed that increasing salinity level significantly decreased shoot and root length, however, the study found that salinity affected root growth more severely than shoot growth of seedlings. Significantly, root length and dry weight of root ranked genotypes in the same order as their salt-tolerance. Therefore, the study concluded that the measurements of root growth would be effective criteria for screening wheat genotypes for salt tolerance at seedling stages.

Keywords: *Triticum aestivum* L, germination index, salinity tolerance index, seedling vigor index.

INTRODUCTION

Salinity is a major abiotic factor reducing plant growth and productivity throughout the world. It is estimated that over 800 million ha will be affected by salinity soon (Rengasamy, 2006; FAO, 2008, Shahbaz and Ashraf, 2013). Salinity affects more than 40% of soils in the Mediterranean regions (Nedjimi, 2014). Recent tendency and future demographic predictions propose that it is important to produce more crops which require effective utilization of salt-affected land and saline water resources. (Qadir *et al.* (2008) found that at least 20 percent of the world's irrigated land is salt-affected and/or irrigated with saline water. About two million additional ha of cropping lands are affected by salinity every year (Rengasamy, 2006; Tuteja, 2007, Jamil *et al.,* 2011). Irrigated agriculture is a major human activity, which often leads to secondary salinization of land and water resources in arid and semi-arid conditions (Shrivastava and Kumar, 2015). Because of salinization increase in agricultural lands, it is expected that about 50 % of cropland will be lost by the middle of the 21st century (Wang *et al.,* 2007). Saline soils are

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found where rainfall is low and in coastal regions where saline water has entered the soil (Tanji, 1990). Still, even in regions with sufficient rainfall, salt can be accumulated in poor drainage soils. Another source of soil salinity is the substantial use of fertilizers (Plaut *et al.,* 2013).

Wheat (*Triticum aestivum* L.) is the world's most widely grown cereal crop for food (Carte, 2002). It is an important staple food source for 30% of humans all over the world and its farming is important for global food security (Muthusamy *et al*., 2017). Wheat is a generally grown in irrigated, dry, and high rainfall areas and from temperate, humid to dry and cold conditions (Dubcovsky and Dvorak 2007). Growing of human population and reduction in agriculture land availability are two threats for agricultural sustainability (Shahbaz and Ashraf, 2013). Considering the importance of wheat on an economic basis, the demand for wheat is expected to increase in the future with the increase in global population (Barnes and Shields, 1998). Global wheat production is projected to be about 735 million tons in 2016-17 (FAO, 2013). Currently, about 65 % of the wheat crop is used for food, 17 % for animal feed, and 12 % in industrial applications, including biofuels (Oleson, 1994; FAO, 2013). To meet the demand, 40 % more grain in 2020 is required (Andersen *et al*., 1999). Increases in the cultivated area are expected to contribute only about one-fifth of the global cereal production between 1995 and 2020 (Andersen *et al.,* 999). Therefore, improvements in crop yields will be required to bring about the necessary production increases.

Germination of seed is vital for the seedling establishment for ensuing plant stand. Salinity can affect germination and seedling growth by producing an osmotic pressure that prevents or reduces water uptake. Also, salinity may affect germination due to Na and Cl ions toxicity (Munns, *et al.,* 2006). Wheat has a moderate tolerance to salinity (Acevedo *et al*, 2002). Francois *et al*. (1986) found that salinity level of > 4.5 dSm^{-1} electrical conductivity of the saturation extract decreases the percentage of plants establishment per unit area, and at 8.8 dSm^{-1} the wheat plants emergence decreased to 50 percent (Francois *et al.,* 1986). Salinity stress symptoms include, reduced seed germination, plant growth, and plant yield. However, plant species and genotypes within species show differential responses to salinity stress (Djanaguiraman and Prasad, 2013, Setter *et al.,* 2016). To our knowledge, screening spring and winter wheat germplasms to salinity stress and understanding the genetic variability for the seedling characteristic was not studied in details. Therefore, the objective of this study is to evaluate spring and winter wheat genotypes for salinity tolerance at the germination stages and to determine seedling growth traits associated with salinity tolerance.

MATERIAL AND METHODS

Plant Materials: Four genotypes of wheat *(Triticum aestivum* L.) were used in this study. Two genotypes of spring wheat (H0800310 and SD4279) and two genotypes of winter wheat (OK04111 and TX06A001263) were obtained from crop physiology research laboratory at Kansas State University, Manhattan KS. USA

Experimental and Treatment Conditions: The experiments were conducted during spring 2014 in a controlled environment at the Department of Agronomy, Kansas State University, Manhattan, KS, USA. A split plot experiment based on randomized complete block design (RCBD) with five replications was employed. The main plots were allocated to salinity levels, whereas the sub-plots were assigned for wheat genotypes. Three different concentrations of a saline solution prepared with deionized water (50, 100 and 150 mM NaCl with electric conductivity [EC] value of 5.6, 10.6 and 16.2 dSm-1) were used for salinity treatments and deionized water was

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used as a control solution (0 mM NaCl). Healthy seeds of each genotype were surface sterilized with sodium hypochlorite solution (5 %) for five minutes, and rinsed with sterilized distilled water, air dried and used for the experiment. A set of 20 seeds were placed in a petri dish with Whatman no. 1 filter paper discs; and it was moisturized 5 mL of the different saline solutions (50, 100 and 150 mM NaCl) and a control solution (0 mM NaCl). The filter paper was moisturized on a daily basis till the end of experiment and filter papers were changed once in every two days to prevent salt accumulation due to evaporation. The seeds moisturized with deionized water instead of NaCl solution saved as an absolute control treatment for the experiment. A total of five replications used for control and NaCl treatments. All the Petri dishes were placed in the dark throughout the germination period (total of 8 days) at 20±2°C in an incubator (Low temperature Illuminated incubator, Thermo Scientific Model 818, USA). Seeds were considered germinated (Feekes 0.9) when both shoot and root extended more than 2 mm from the seed (Islam *et al*., 2012). The following traits were recorded during the germination period, and 8 days after sowing:

Germination traits: Germination percent (*G %*) was expressed according to Nasri *et al*., 2011. The following formula was used to calculate *G%*:

$$G\ \% = (NSG \div TNSS) \times 100$$

Where *NSG* is the number of seeds germinated at the end of the experiment (8 days after sowing). *TNSS* is the total number of seeds sown.

Germination index (*GI %*) in each NaCl treatment was calculated according to the equation given by Karim *et al*. (1992). The following formula was used to calculate GI %:

$$GI\ \% = (\%\ GNaCl \div \%\ GC) \times 100$$

Where *% GNaCl* is germination percent at different NaCl treatments. *% GC* is germination percent in control treatment.

The germination rate (GR) was calculated according to the equation given by Rubio-Casal,*et al* (2003). The count of germinated seeds was recorded at 24 hours interval from sowing till the end of experiment (8 days after sowing) and used to calculate GR. The following formula was used to calculate GR:

GR=(n1t1)+ (n2t2)+⋯+ (nxtx)÷TNGS

Where n_1 is the number of seeds germinated on the first day of germination, t_1 is the number of days taken for the first germination, and *TNGS* is the total number of seeds germinated.

Mean daily germination (MDG) was calculated as per Gairola *et al*. (2011). The following formula was used to calculate MDG:

$$MDG = TNGS \div TNDG$$

Where *TNGS* is the total number of germinated seeds and *TNDG* is the total number of days taken for final germination.

Early seedling traits: Thereafter, morphological traits *viz*., shoot and root length, and fresh and dry weight were subsequently measured from 5 uniform seedlings from each replication at an early seedling stage (Feekes 1). Selected seedlings were dissected and shoot, and root length were recorded. The length from the seed to the tip of the root and leaf blade was calculated and expressed in cm to measure the root length and shoot length, respectively, using a digital vernier caliper. The fresh weight of shoot and root was recorded using a weighing balance (Salter Brecknell, ESA-600, China) and then dried in an oven maintained at 70 °C till it attains stable weight. After that, shoot and root dry weights were recorded. Using the morphological traits, the salinity tolerance index (STI) and Seedling vigor index (SVI) were calculated.

The following formula was used to calculate STI (Tsegay *et al*., 2014):

$$STI = (SdwNaCl \div SdwC) \times 100$$

Where *SdwNaCl* is the dry weight of seedling

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from NaCl treatment. *SdwC* is the dry weight of seedling from control treatment.
The following formula was used to calculate SVI (Abdoli *et al.* 2013):

$$SVI = (SL \times G\%)100$$

Where *SL* is seedling length and *G%* is germination percent.

Experiment Design and Data Analysis: The experiment design was a randomized complete block design (RCBD) with five replications. The analysis of variance of the data and the comparison of the means were done using least significant difference (LSD) using SAS 9.4 (SAS Institute Inc., Cary, NC, USA).

RESULTS

Analysis of variance results showed that salinity, genotype, and salinity x genotypes interaction had a significant effect ($P<0.0001$ or $P < 0.05$) on germination %, germination index, mean daily germination, germination rate, and seedling vigor index. However, salinity x genotypes interaction had no significant effect on mean daily germination (Tables 1 and 2). Also, the results showed that salinity, genotype, and their interaction had a significant effect ($P<0.0001$ or $P < 0.05$) on all seedling characteristics studied (Tables 1 and 2). These four genotypes were ranked based on the seedling salinity tolerance and vigor index (Fig 3 a and b), such that those with the smallest and largest reduction percent over the control were ranked respectively as the most and least tolerant genotype at 150 mM NaCl. These genotypes were (1) tolerant to salinity at germination stage (SD4279 and H0800310) (2) moderately tolerant to salinity at germination stage (TX06A001263) and (3) susceptible to salinity at germination stage (OK04111).

Table (1). Probability values of effects of salinity (S), genotype (G) and salinity x genotype interaction on germination and early seedling traits in experiment 1 at germination stage (Feekes 0.9).

Traits	Salinity(S)	Genotype(G)	SxG
Germination %	<.0001	<.0001	0.0013
Germination index (%)	<.0001	<.0001	0.0013
Mean daily germination	<0.0001	0.0478	0.1691
Germination rate (d^{-1})	<0.0001	< 0.0001	<.0001
Shoot length (cm)	<0.0001	< 0.0001	0.0340
Root length (cm)	<0.0001	< 0.0001	0.0123
Seedling length (cm)	<0.0001	< 0.0001	0.0022
Seedling fresh weight (g)	<0.0001	< 0.0001	<.0001
Seedling dry weight (g)	<0.0001	< 0.0001	0.0233
Salt tolerance index	<0.0001	< 0.0001	0.0160
Seedling vigor index	<0.0001	< 0.0001	0.0358

Table 2 Effect of salinity stress on germination and seedling traits of two spring wheat and two winter wheat genotypes. Individual datum is the mean of four replications. Means that have the same letter in each trait are not significantly different ($p \leq 0.05$) from each other.

Traits	NaCl levels (mM)			
	0	50	100	150
Germination %	100 ^{a}	96.8 ^{b}	84.0^{c}	73.0^{d}
Germination index (%)	100^{a}	96.8^{b}	84.0^{c}	73.0^{d}
Mean daily germination	8.3 ^{a}	7.6^{a}	4.4^{b}	3.1^{c}
Germination rate (d^{-1})	2.0^{c}	2.1^{c}	2.6^{b}	3.5^{a}
Speed of germination	9.9^{a}	9.5^{b}	7.0^{c}	4.6^{d}
Shoot length (cm)	8.3^{a}	8.1^{a}	6.8^{b}	5^{c}
Root length (cm)	6.5^{a}	6.3^{b}	5.3^{c}	2.9^{d}
Seedling fresh weight (g)	0.18^{a}	0.17^{b}	0.15^{c}	0.13^{d}
Seedling dry weight (g)	0.08^{a}	0.07^{b}	0.06^{c}	0.04^{d}
Salt tolerance index	100^{a}	93.0^{b}	73.7^{c}	53.6^{d}
Seedling vigor index	14.8^{a}	14.0^{b}	10.1^{c}	5.9^{d}

Germination Parameters: Germination percentage (G %) of wheat genotypes was significantly ($P < 0.0001$) reduced by increasing salinity level. Genotypes SD4279 and H0800310 were tolerant to salt stress, whereas genotypes OK04111 and TX06A001263 were sensitive to

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salt stress at 150 mM NaCl. Mostly, an increasing level of salinity stress resulted in a decrease in germination percentage over control. However in these two genotypes, the germination percentage was not affected at 50 mM NaCl but decreased by20% at 100 mM NaCl, and by 30 and 33% at 150 mM NaCl over the control (0 mM NaCl; Fig. 1a).

The results showed that salinity significantly reduced germination index (GI) at moderate and high NaCl concentrations with the largest decrease at 150 mM NaCl. The results showed a decline by 33 % in the germination index in OK04111 genotype under a high level of salinity 150 mM NaCl. However, under the same level of salinity, genotype SD4279 had about 20 % decline in term of germination index (Fig. 1b--). In addition, the analysis of variance showed that salinity significantly increased (P < 0.0001) germination rate (GR) (Tables 1 and 2). Figure 1d showed that increasing salinity concentration resulted in a dramatic increase in germination rate. Genotypes OK04111 and TX06A001263 showed an increase in germination rate over the control by 77 % and 95 %, respectively at 150 mM NaCl, whereas genotype SD4279 had a percent of increase of 36 % at the same level of salinity 150 mM NaCl over the control. Mean daily germination (MDG) was strongly decreased with salt stress in all genotypes. The results showed that, in some genotypes, moderate salinity decreased mean daily germination by a lesser extent and severe stress decreased. Genotypes OK04111 and TX06A001263 showed a decline over the control by 67 and 69 % respectively, whereas genotype SD4279 showed a decline over the control by 44 %, (Fig 1c).

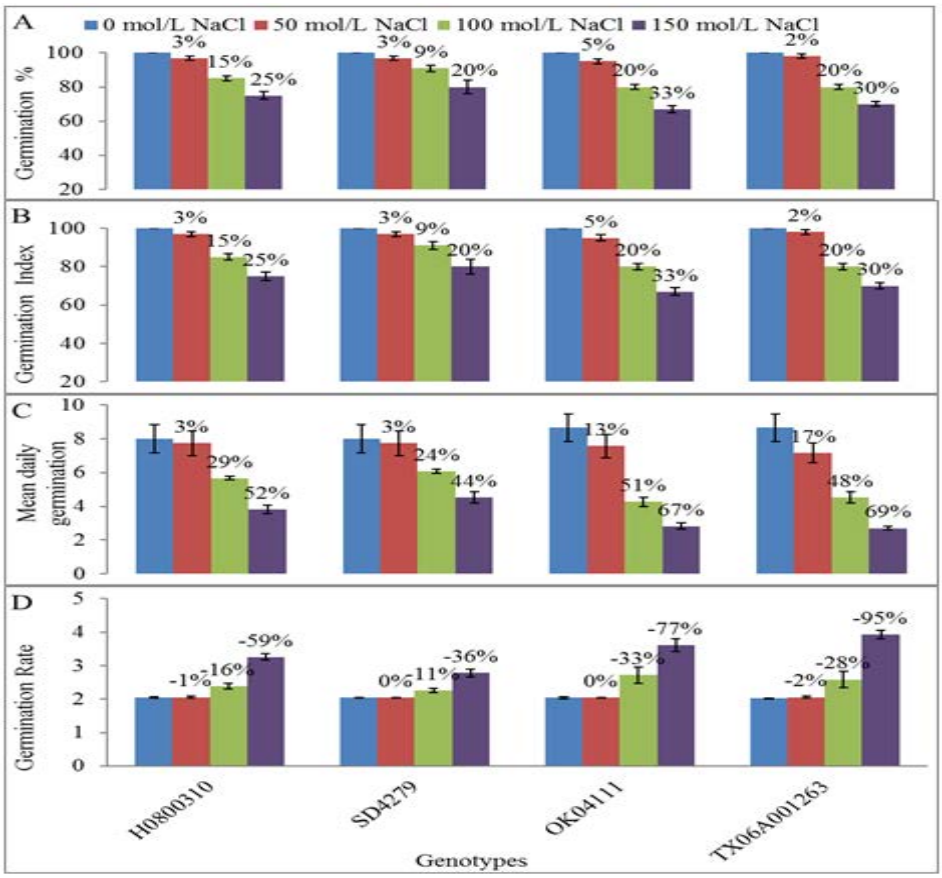

Figure (1). The effects of different salinity levels (0, 50, 100, and 150 mM NaCl) on (A) germination percentage (B) germination index (%) (C) mean daily germination and (D) germination rate (d) of two spring wheat and two winter wheat genotypes. Percent reduction in all traits due to level of salinity (50, 100, and 150 mM NaCl) as compared to control is indicated. Vertical lines on top of bars indicate standard error of means (n = 5).

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Seedling Parameters: All seedling parameters decreased with increasing salinity level (Tables 1 and 2). Under non-saline conditions (0 mM NaCl), genotypes showed no significant differences in terms of shoot length. However, under moderate and high levels of NaCl condition, there were significant differences in the response of genotypes to salinity levels (Fig. 2a). Under high level of salinity, 150 mM NaCl, the genotypes OK04111 and TX06A001263 had the greatest decrease in shoot length, and genotypes SD4279 and H0800310 had the lowest decrease in shoot length. Similarly, there were significant differences among genotypes in terms of root length in response to salinity stress. Increasing NaCl level resulted in a significant decrease in root elongation as compared to the control. Increasing salinity levels inhibited the root length of wheat genotypes. In fact, root length was more affected by salt stress than shoot length. Genotypes OK04111 and TX06A001263 showed a percent decline of above 60 % (Fig. 2 b). In addition, increasing salinity level consistently reduced the growth and biomass production of almost all wheat genotypes used in this study. In comparison with control, the maximum reduction in seedling fresh weight was observed in OK04111 and TX06A001263 with a reduction percentage of 30 and 30 %, respectively. Seedling dry weight was also decreased with increasing salt concentrations (50 to 150 mM NaCl; Fig. 2c). The seedling dry weight was decreased to a higher level than fresh weight under a high level of salinity 150 mM NaCl. The highest decline of fresh weight was by 33 % in OK04111, while the dry weight declined by 57 % in the same line (Fig.2 c and d). Results regarding salt tolerance (ST) of different wheat genotypes showed that genotype SD4279 was tolerant to salinity stress at the germination stage. However, genotypes H0800310 and TX06A001263 were moderate to salinity stress, and genotype OK04111 was sensitive to salinity stress. Based on tolerance at the germination stage, genotypes were grouped as tolerant, moderate, and sensitive genotypes based on salinity tolerance index. The results showed that genotype SD4279 had a reduction percentage of 33 % over control. Therefore, this genotype was more tolerant to salinity stress, and genotypes H0800310 and TX06A001263 had reduction percentages of 47, 49% respectively, and therefore these genotypes were moderate to salt stress at germination stages, though the genotype OK04111 had a reduction percentage of 56% and therefore this genotype was sensitive to salt stress at germination stages (Fig. 3a). Increasing salinity concentrations from 50 to 150 mM NaCl gradually decreased seedling vigor index. The highest seedling vigor index was observed in control, while salinity at 50, 100, and 150 mM NaCl significantly decreased seedling vigor index. A significant decrease was observed at 150 mM NaCl salinity in genotype OK04111. Data showed that the genotype OK04111 had 69 % decline over control, while the SD4279 had 50 % decline over control (Fig. 3b).

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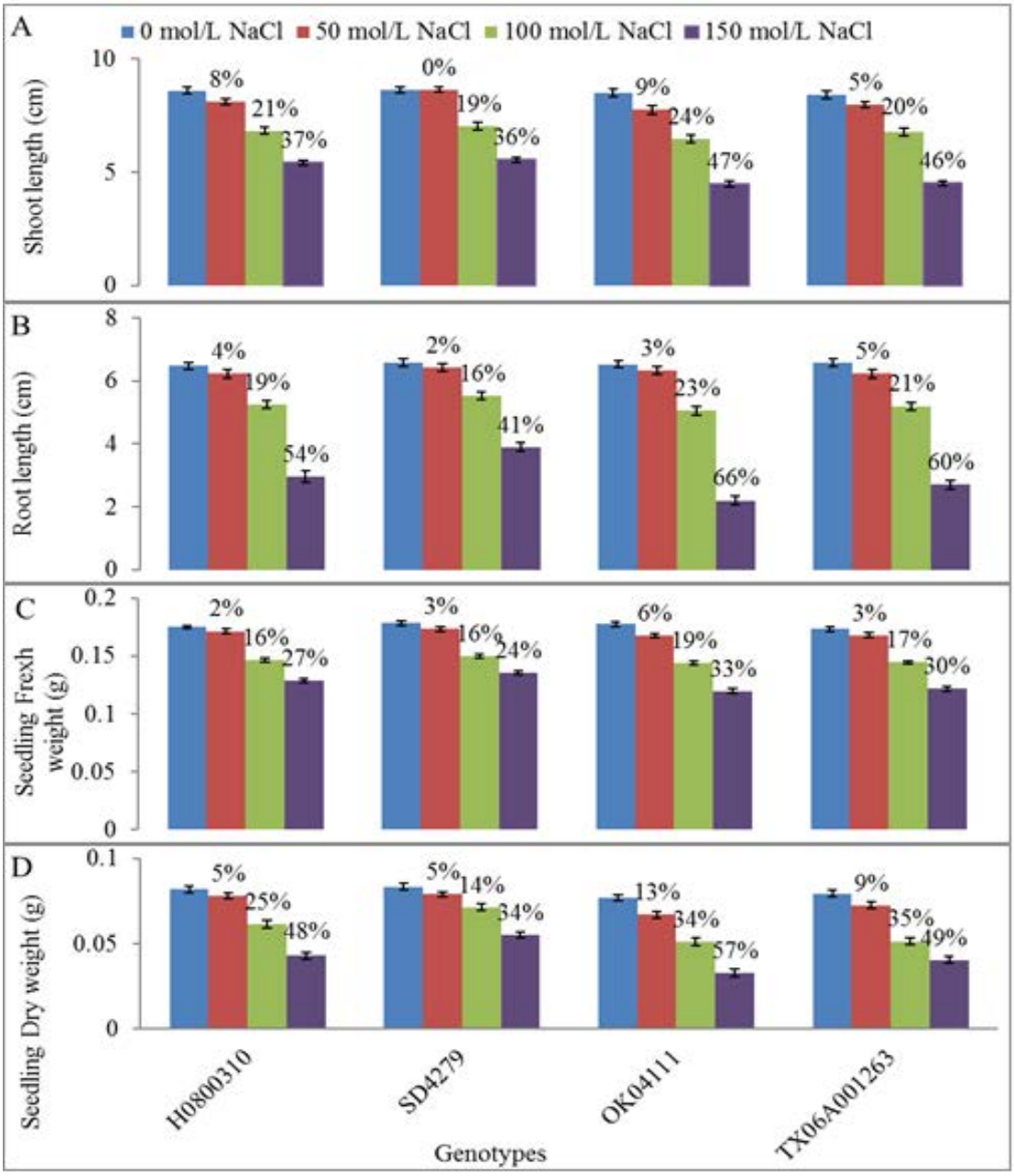

Figure (خطأ! لا يوجد نص من النمط المعين في المستند.**).** Effect of different salinity levels (0, 50, 100, and 150 mM NaCl) on (A) shoot length (cm), (B) root length (cm), (C) Seedling Fresh Weight, (D) seedling dry weight (g), (D) salt tolerance index, and (E) seedling vigor index of two spring wheat and two winter wheat genotypes. Percent reduction in all traits due to the level of salinity (50, 100, and 150 mM NaCl) as compared to control is indicated. Vertical lines on top of bars indicate standard error of means (n = 20).

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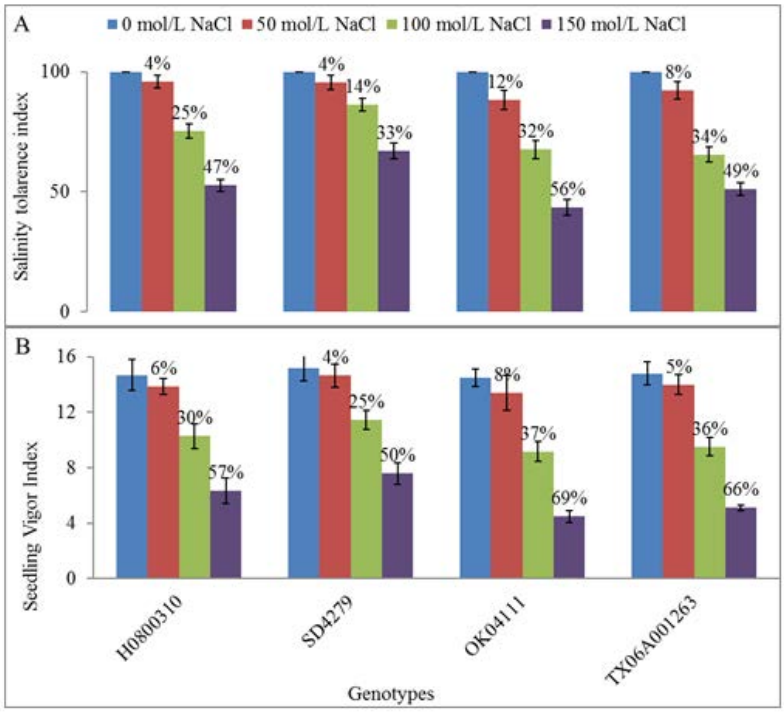

Figure (3). Effect of different salinity levels (0, 50, 100, and 150 mM NaCl) on (A) salt tolerance index, and (B) seedling vigor index of two spring wheat and two winter wheat genotypes. Percent reduction in all traits due to the level of salinity (50, 100, and 150 mM NaCl) as compared to control is indicated. Vertical lines on top of bars indicate standard error of means (n = 20).

DISCUSSION

The results showed that by increasing NaCl concentrations the germination in wheat genotypes was delayed and decreased, also the germination percentage, germination index, germination rate, and mean daily germination were significantly ($P < .0001$) decreased by salinity stress. Similar results were reported by Rahman *et al.* (2008); Khayatnezhad, and Gholamin, (2010); Nasr *et al*. (2012); Kumar *et al*. (2012); and Hussain *et al*. (2013). These studies reported that there exists genetic variability among wheat genotypes for salinity tolerance based on seed germination percentage and seedling growth. Salinity affects germination in two ways: (1) a high concentration of salt in the growth medium decreased the osmotic potential to a level that prevented water uptake and reduced utilization of nutrients essential for germination, and (2) Na^+ and Cl^- ions are toxic to the embryo (Kayani *et al*., 1990; Munns,*et al*. 2006). Winter wheat genotypes responded differently to the salinity level. It appears that at concentrations up to 150 mM NaCl in the growth solution, the water potential of the seeds is still sufficiently low to bring an adequate amount of water for the several metabolic processes that lead to germination. Other studies reported that the difficulty of growth under salinity stress may result from decreased water potential of the seeds (Rahman *et al*., 2008; Muhammad and Hussain, 2012). The results of this study are analogous to those described by other researchers (Catalan *et al*., 1994; Kazemi and Eskandari, 2011; Muhammad and Hussain, 2012). Physiologically, salinity stress has a negative impact on many processes however the most significant effect is reducing cell division and expansion, which result in decreasing shoot and root length. With increasing NaCl concentration, it affected seedling fresh and dry weight. Reduction of seedling dry weight relatively depended on shoot and root lengths and branches. The results obtained in this study were consistent with previ-

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ous findings that have indicated significant differences in the salt tolerance of wheat genotypes and their differential responses to increased salt concentrations (Catalan *et al*., 1994; Rahman *et al*., 2008; Adjel *et al*., 2013). In addition, the results showed that the most sensitive growth characters to salinity were root length, which agreed with a previous study by (Akbarimoghaddam *et al.* 2011), and dry matter production while germination percentage was the least sensitive under salinity. Nevertheless; the genotypes which had higher germination percentages also had higher root length, shoot length, and dry matter production. For this reason, seedling length and dry weight are considered as selection criteria for salinity tolerance. It is estimated that in addition to higher dry weight, longer shoots and roots development will allow more successful selection for high salt tolerance. Yet, root length and dry weight can be considered as selection criteria only when there is a high germination percentage. For these reasons, the seedling vigor index, which is a function of both germination percentage and seedling length, was determined to be a more consistent selection criterion. Genotypes such SD4279 and H0800310 were considered as salinity tolerant genotypes.

CONCLUSIONS

In conclusion, this investigation was carried out to inspect winter and spring wheat genotypes for salinity tolerance and to evaluate the effects of salinity on germination and seedling growth of 2 spring and 2 winter wheat genotypes. Genotypic variability for salt tolerance was found among different wheat genotypes. Seedling vigor index is a good parameter for evaluating salinity tolerance at germination stages. According to that, the genotypes were ranked based on the seedling vigor index, such those with the smallest and largest reduction percentages over the control were ranked respectively as the most and least tolerant genotypes at 150 mM NaCl. According to that genotypes were divided into three categories (1) tolerant to salinity at germination stage (SD4279 and H0800310), (2) moderately tolerant to salinity at germination stage (TX06A001263), and (3) susceptible to salinity at germination stage (OK04111). Overall, it can be determined that under control (0 mM NaCl) conditions, all wheat genotypes had good germination and growth attributes. However, wheat genotypes showed a differential response at higher levels of salinity. Yet, salinity reduced all germination traits of wheat genotypes. These results indicate that genetic variation exists among those wheat genotypes in terms of germination under salinity stress condition. Further studies are needed to see the effect of salt stress on the germination and seedling growth of these germplasms under field conditions.

Salinity tolerance and seedling vigor indexes were the best germination traits that can be used as a selection criterion for salinity tolerance in wheat. Based on those genotypes, SD4279 and H0800310 were identified as tolerant genotypes to salinity stress at germination stages. These investigations showed the existence of significant genetic variability in spring and winter wheat lines for salinity stress at germination stages. Therefore, additional research might be directed to develop a new screening technique to identify a large germplasm collection for salinity tolerance during germination and seedling stages of development. This study focused on the effect of salinity stress at germination stages, therefore, further research on the effects of salinity stress during the booting, flowering and post-flowering stages, grain filling, and seed development are needed to evaluate the effect of salinity stress at later stages of wheat growth and development.

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تأثير الملوحة على أصناف مختلفة من القمح أثناء مرحلة الإنبات

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المستخلص : تعتبر الملوحة من أهم العوامل البيئية التي تؤثر سلبًا على إنتاج محصول القمح في العديد من مناطق العالم. حيث إن الاجهاد الملحي يحد من نمو محصول القمح وتطوره، وبالتالي يؤثر على الناتج النهائي للمحصول. لهذا أصبح تحديد وإيجاد الأصناف النباتية الوراثية المتحملة للملوحة أمراً بالغ الأهمية لتحسين الناتج النهائي للمحصول. لذلك تم إجراء سلسلة من التجارب المعملية لتقييم استجابة اثنين من أصناف القمح الربيعي واثنين من أصناف القمح الشتوي (*Triticum aestivum* L) لمستويات مختلفة من الملوحة. نفذت التجارب وفق تصميم القطاعات العشوائية الكاملة بخمسة مكررات. تم زراعة 20 بذرة من كلٍّ من التراكيب الوراثية في أطباق بتري تحتوي عل ورقة ترشيح. وتم معاملة البذور بتراكيز مختلفة من المحلول الملحي (0، 50، 100، و150 مل مول من كلوريد الصوديوم). حفظت الأطباق في الحاضنة عند 20 م درجة مئوية لمدة 8 أيام. تم خلال هذه الفترة التأكيد من إضافة الماء أو المحلول الملحي لكل الأطباق وحسب التركيز المطلوب. كما تم خلال هذه الفترة تجميع البيانات الخاصة بالأنبات. بعد ثمانية أيام من الزرع تم إنهاء التجربة وتم تجميع البيانات الخاصة بنسبة الإنبات، معدل الإنبات، متوسط الإنبات اليومي، طول السويقة وطول الجذور، وزن البادرات الطازج والجاف. أشارت النتائج إلى أن الطرز الوراثية للشتاء والربيع اختلفت بشكل كبير لنسب الإنبات، ومعدل الإنبات، ومتوسط الإنبات اليومي، وطول الجذور، وأوزان الجذور الطازجة والجافة. أظهرت النتائج أن الملوحة لم تؤثر على نسبة الإنبات النهائية حتى وصل مستوى الملوحة إلى 100 مل مول من كلوريد الصوديوم. في حين إن البذور المعاملة بملوحة بتركيز 100 و150 مل مول تأخرت بها عملية الإنبات ليوم أو يومين على التوالي بالنسبة لبادرات القمح الربيعي ومن يومين إلى ثلاثة أيام على التوالي بالنسبة لبادرات القمح الشتوي، بالمقارنة مع 0 و50 مل مول من كلوريد الصوديوم. وأظهرت البيانات أيضا أن ارتفاع مستوى الملوحة، صاحبه انخفاض كبير في طول النبات وطول الجذر، ومع ذلك وجدت الدراسة أن تأثير الملوحة على نمو الجذر كان أكثر حدة من تأثير الملوحة على نمو الساق بشكل ملحوظ، وتؤكد الدراسة على أن طول الجذر والوزن الجاف للجذور صنفت النباتات بنفس الترتيب من حيث تحملها للملوحة. ولذلك، خلصت الدراسة إلى أن قياسات نمو الجذور ستكون معايير فعالة لفحص التراكيب الوراثية للقمح من أجل تحمل الملوحة في مراحل الإنبات.

الكلمات المفتاحية: الإنبات، مؤشر الإنبات، الملوحة، مؤشر تحمل الملوحة، مؤشر قوة البادرة.

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