Response of Durum Wheat Seedlings to Salinity

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Abstract

Salinity is an important source of abiotic stress, limiting crop performance in most arid and semi-arid areas of the world. This research was conducted to determine the effects of salinity on physiological parameters of durum wheat (Triticum durum Desf.) genotypes. The research was conducted in the tissue culture laboratory at the Agriculture Faculty of Dicle University. The study consisted of one durum wheat commercial cultivar, five local cultivars and four advanced genotypes. There were three replications in a split-plot experimental design. Genotypes were germinated in four NaCl concentrations (0, 50, 100, 150 mM) in plastic boxes. There were statistically assured significant differences among the genotypes for all salt concentrations and all observed parameters (coleoptile length, seedling length, root length, seedling fresh weight, root fresh weight, seedling dry weight, root dry weight, germination rate and seedling vigor). There was significant decrease in all examined parameters depending on the increase of salt concentration. The ‘Sorgul’ genotype was most tolerant to salinity, in terms of root length and root dry weight, whereas ‘Altintoprak 98’ was most tolerant as measured by the impact of salinity on coleoptile length, seedling fresh weight, germination rate and seedling vigor. The ‘Beyaziye’ genotype was the most sensitive to salinity-induced stress. The results from this study demonstrated differences among durum wheat genotypes for seedling parameters measured in the presence of salinity stress.

Keywords: durum wheat, germination, physiological properties, salt tolerance, seedling

Introduction

Salinity is the accumulation of washed soluble salts into land water in arid and semi-arid areas. Evaporation of saline groundwater facilitates the salt to remain on the surface (Ekmecki et al., 2005). Approximately 800 million hectares of global farmland are saline (FAO, 2008). Approximately 1.5 million hectares are saline or alkaline in Turkey (Dinç et al., 1993). Osmotic and ionic stress, induced in saline soils, is detrimental to plant growth and development (Parida and Das, 2005). Salinity can prevent the uptake of soil nutrients and harm plant structure by disturbing metabolic processes. Ionic stress affects plant growth by increasing Na+ and Cl− levels in cells in response to high concentrations of NaCl, and decreased Ca2+, K+ and Mg2+ concentrations.

Wheat (Triticum aestivum L.) is an important source of energy and protein. Wheat acreage in Turkey is 8.1 million ha1, producing an annual average of 20.1 million tons of grain and an average grain yield of 2.480 kg ha1 (FAO, 2013). Approximately 40% of the human daily energy requirement is provided by wheat products in Turkey (FAO, 2008). Production of wheat will need to increase to match the projected global population growth. Wheat has moderate tolerance to salinity stress (Shahzad et al., 2012), but grain yield is significantly reduced in soils containing over 100 mM NaCl or approximately 10 dS/m (Munns et al., 2006). Kanber and Uulu (2010) reported 50% grain yield losses in wheat starting at 6 dS/m. Compared to bread wheat, durum wheat (Triticum durum Desf.) is less tolerant of salinity due to a greater accumulation of Na+ ions in the plant organs (Francois et al., 1986). Salinity tolerance has been shown to vary over wheat growth stages (El-Hendawy et al., 2005; Mass and Poss, 1989). With an increase in salt concentration, seedling fresh weight, root length, seed vigour and germination rate decreased (Ahmad et al., 2006; Akbari et al., 2007; Kizilgeci et al., 2010; Saboora and Kiarostami, 2006). Recognizing the high cost of developing cultivars tolerant to salinity, researchers have recently become more interested in screening plant species for this tolerance. Screening plant species for salinity tolerance or genetic potential to develop tolerance are considered highly promising approaches for developing salt tolerant commercial cultivars. Here, it was examined the response of 10 different durum wheat genotypes to 4 different salt concentrations, including control treatment, under laboratory conditions.

Materials and methods

The experiment was conducted on the tissue culture laboratory of the Agriculture Faculty of Dicle University, Diyarbakir, Turkey. The 10 durum wheat genotypes consisted of 1 commercial variety, 4 advanced lines and 5 local genotypes (Table 1).
Duncan's multiple range test. Means were compared according to randomized split-plot design. The salt doses were main factor recorded on the seventh day. Investigated properties which seeds was recorded on the fourth day, and seedling vigour was temperature for 48 h to measure dry root weight and dry seedling weight. The seedlings were then placed in an oven at 70 °C and fresh seedling weight, were measured on the seventh day. Significant differences were found between the genotypes over the three salt treatments and compared to the control. The genotype × salt treatment interaction was significant for seedling length, root length, seedling fresh weight, germination rate and seedling vigour.

Infection risk was avoided by rinsing the wheat seeds with pure water after soaking them in 5% Bleach solution (NaOHCl) for 5 min at 20 °C. For the germination experiment, 10 cm plastic Petri dishes and filter paper were used. The three NaCl concentrations were 50, 100, and 150 mM. For each genotype, 25 seeds and 10 mL salt solution were placed in each Petri dish. The experiments were conducted in a germination room at 25 °C for 7 days. An additional 5 mL saline solution was added to the Petri dishes during the fourth and fifth days. On the sixth day, 5 mL pure water after soaking them in 5% Bleach solution (NaOHCl) for 5 min at 20 °C. For the germination stage, response to salt stress can be measured by changes in coleoptile length compared to the control. It can be therefore advised a shallow placement of seeds in salty soil when testing for tolerance.

Coleoptile length of the genotypes ranged from 2.64 cm to 3.68 cm. For the three salt treatments, coleoptile length ranged from 2.76 cm to 3.31 cm (Table 3). Coleoptile lengths of all genotypes in the 50 mM concentration were greater than coleoptile lengths of the control. Coleoptile length of the ‘Beyaziye’ genotype was 31% shorter than that of the control. ‘Beyaziye’ x ‘Bagacak’ genotype was 31% shorter than that of the control. ‘Beyaziye’ x ‘Bagacak’ was the genotype most susceptible to salinity. At the seedling growth stage, response to salt stress can be measured by changes in coleoptile length compared to the control. It can be therefore advised a shallow placement of seeds in salty soil when testing for tolerance.

Root length of the genotypes was from 3.85 cm to 7.23 cm and for different salt concentration treatments the averages were

\[ \text{Root length} = 3.85 \text{ cm} - 7.23 \text{ cm} \]

Results and discussions

Analysis of variance results are presented in Table 2. Significant differences were found between the genotypes over the three salt treatments and compared to the control. The genotype × salt treatment interaction was significant for seedling length, root length, seedling fresh weight, germination rate and seedling vigour.

| Genotypes         | Coleoptile Length (cm) | Salt Concentration (mM NaCl) |
|-------------------|------------------------|------------------------------|
|                   | 0          | 50            | 100           | 150           | Average          |
| ‘Line 299’        | 2.87       | 3.00          | 2.96          | 2.43          | 2.81              |
| ‘Line 286’        | 2.94       | 3.42          | 3.34          | 2.96          | 3.17              |
| ‘Altinoprank 98’  | 2.82       | 3.11          | 3.21          | 2.95          | 3.02              |
| ‘6DZT21’          | 2.81       | 3.02          | 2.95          | 2.45          | 2.81              |
| ‘6DZT29’          | 2.73       | 2.84          | 2.68          | 2.33          | 2.64              |
| ‘Menceki’         | 3.01       | 3.14          | 3.61          | 2.88          | 3.16              |
| ‘Menceki’         | 4.09       | 4.09          | 3.17          | 3.39          | 3.68              |
| ‘Beyaziye’        | 3.79       | 3.57          | 3.58          | 2.60          | 3.39              |
| ‘Sorgul’          | 3.27       | 3.51          | 3.82          | 2.69          | 3.32              |
| ‘Bagacak’         | 3.19       | 3.40          | 3.16          | 2.91          | 3.17              |
| Mean              | 3.15       | 3.31          | 3.25          | 2.76          | 3.17              |

\[ \text{Mean} = 3.15 \text{ cm} - 2.76 \text{ cm} \]
Table 4. Average value of root length (cm) and seedling length (cm) of some durum wheat genotypes grown in different salt concentration

| Genotypes  | Root Lenght (cm) | Seedling Lenght (cm) |
|------------|------------------|----------------------|
|            | Salt Concentration (mM NaCl) |            | Salt Concentration (mM NaCl) | |
|            | 0     | 50    | 100   | 150   | Average |
|            | 0     | 50    | 100   | 150   | Average |
| Line 299  | 8.62 ± 0.05  | 7.98 ± 0.02  | 7.39 ± 0.03  | 7.23 ± 0.04  | 7.32 ± 0.04  |
| 'Line 286' | 5.84 ± 0.02  | 6.31 ± 0.01  | 4.78 ± 0.01  | 5.61 ± 0.03  | 6.37 ± 0.03  |
| 'Altintoprak 98' | 7.16 ± 0.03  | 6.53 ± 0.02  | 4.22 ± 0.01  | 6.56 ± 0.05  | 7.43 ± 0.05  |
| '6DZT21'  | 6.58 ± 0.02  | 6.77 ± 0.01  | 3.41 ± 0.01  | 5.77 ± 0.03  | 8.12 ± 0.03  |
| 'Mersiniye' | 5.28 ± 0.01  | 5.83 ± 0.02  | 3.16 ± 0.01  | 5.56 ± 0.03  | 9.59 ± 0.03  |
| Menceki1  | 11.30 ± 0.05  | 4.34 ± 0.02  | 4.03 ± 0.01  | 6.60 ± 0.05  | 11.17 ± 0.05  |
| 'Beyaziye' | 3.60 ± 0.02  | 3.96 ± 0.01  | 3.77 ± 0.01  | 3.85 ± 0.03  | 10.68 ± 0.03  |
| 'Sorgul'  | 6.07 ± 0.02  | 6.22 ± 0.01  | 7.01 ± 0.01  | 6.56 ± 0.03  | 8.96 ± 0.03  |
| 'Bagacak'  | 7.40 ± 0.02  | 5.72 ± 0.01  | 4.82 ± 0.01  | 5.96 ± 0.03  | 6.31 ± 0.03  |
| Mean      | 7.11 ± 0.05  | 6.63 ± 0.02  | 6.11 ± 0.01  | 4.39 ± 0.03  | 8.79 ± 0.03  |

Means followed by the same letter are not significantly different (p<0.05)

Table 5. Average value of root fresh weight (mg) and root dry weight (mg) of some durum wheat genotypes grown in different salt concentration

| Genotypes  | Root Fresh Weight (mg) | Root Dry Weight (mg) |
|------------|------------------------|----------------------|
|            | Salt Concentration (mM NaCl) |            | Salt Concentration (mM NaCl) | |
|            | 0     | 50    | 100   | 150   | Average |
|            | 0     | 50    | 100   | 150   | Average |
| Line 299  | 45.97 ± 0.04  | 39.90 ± 0.03  | 23.86 ± 0.02  | 40.92 ± 0.04  | 5.70 ± 0.04  |
| 'Line 286' | 49.70 ± 0.03  | 46.63 ± 0.02  | 21.86 ± 0.01  | 43.35 ± 0.03  | 5.93 ± 0.03  |
| 'Altintoprak 98' | 24.57 ± 0.02  | 39.50 ± 0.03  | 36.33 ± 0.02  | 35.93 ± 0.04  | 4.57 ± 0.04  |
| '6DZT21'  | 42.37 ± 0.02  | 45.76 ± 0.03  | 31.73 ± 0.02  | 41.60 ± 0.04  | 5.20 ± 0.04  |
| 'Mersiniye' | 54.93 ± 0.03  | 40.73 ± 0.02  | 34.26 ± 0.01  | 45.30 ± 0.04  | 5.37 ± 0.04  |
| Menceki1  | 50.00 ± 0.04  | 54.06 ± 0.03  | 49.46 ± 0.02  | 5.46 ± 0.04  |
| 'Beyaziye' | 53.90 ± 0.05  | 29.73 ± 0.04  | 51.93 ± 0.03  | 46.18 ± 0.05  | 4.66 ± 0.05  |
| 'Sorgul'  | 23.66 ± 0.02  | 26.23 ± 0.03  | 26.33 ± 0.02  | 24.94 ± 0.03  | 3.87 ± 0.03  |
| 'Bagacak'  | 28.90 ± 0.03  | 49.76 ± 0.04  | 46.83 ± 0.03  | 40.95 ± 0.04  | 3.97 ± 0.04  |
| Mean      | 41.45 ± 0.05  | 46.64 ± 0.04  | 42.66 ± 0.04  | 3.51 ± 0.05  | 4.84 ± 0.05  |

Means followed by the same letter are not significantly different (p<0.05)

between 4.39 cm and 7.11 cm (Table 4). Root length for salt treatments was less than for the control, and decreased with increasing salt concentrations. Previous studies also reported a decrease in root length with an increase in salt concentration (Akbarimoghaddam et al., 2011; Atak et al., 2006; Kumar et al., 1981). Root length of the 'Menceki' genotype decreased by 64%, compared to the control, at the highest NaCl concentration. Root length is an important parameter when selecting for tolerance to salinity, as roots have direct contact with the soil and are responsible for accessing nutrients and water.

Seedling length of the genotypes averaged between 5.53 cm and 7.76 cm, and lengths for the salt treatments were between 3.77 cm and 8.79 cm (Table 4). Seedling lengths of the salt treatments were less than the control, and tended to decrease with an increase in salt concentration. Akbarimoghaddam et al. (2011) obtained similar results. Significant decreases in seedling length occurred due to a decreased in the osmotic potential. The 'Beyaziye' genotype was most susceptible to salt stress, with a 72% decrease in seedling length (compared to the control) at the highest concentration. Among all of the genotypes, the 'Bagacak' genotype was less affected by salt stress, with a 32% reduction in seedling length at the highest salt concentration, compared to the control.

Root fresh weight of the genotypes ranged from 24.94 g to 49.46 g, and for salt concentration treatments were between 35.51 g and 46.64 g (Table 5). Compared to the control treatment, root fresh weight at 150 mM NaCl concentration was 62% higher for 'Sorgul' genotype and 47% higher for 'Altintoprak 98'. Alternatively, root fresh weight was significantly reduced for 'Line 286' and 'Line 299' in the presence of salt-induced stress. Shahzad et al. (2012) pointed out that root fresh weight decreases with increases in salt concentration, and can be used in selection for tolerance to salt-induced stress.

Root dry weights of the genotypes were between 3.94 mg and 5.30 mg. The root dry weights for the salt treatments were between 3.64 mg and 4.84 mg. As salt concentration increased, the reduction in root dry weight tended to decrease (Table 5). Reductions in root dry weight were related to root length responses. Varda et al. (2014) reported a reduction in durum wheat root dry weight with the increase in salt concentration. Although root dry weight of 'Beyaziye' genotype was the lowest among the studied genotypes, compared to the control, it had the highest root dry weight at 150 mM NaCl, with a 7% increase compared to the control. Root dry weight for the 'Sorgul' genotype increased in the 50 mM and 100 mM salt concentrations, whereas root dry weight of 'Bagacak' and 'Line 299' decreased substantially.

Seedling fresh weight of the genotypes ranged from 37.93 mg to 59.42 mg, and treatment averages were between 32.38 mg and 60.86 mg (Table 6). Seedling fresh weight of the salt treatments was less than the control, which was also reported by Muhammad and Husain (2012). The seedling fresh weights of 'Altintoprak 98' and '6DZT21' increased in 50 mM and 100 mM salt concentrations compared to the control. Seedling fresh weight of 'Beyaziye' was the highest among the genotypes for the control treatment, but fresh weight decreased by 62% in the 150 mM NaCl concentration.

Seedling dry weight of the genotypes was between 4.61 mg and 7.50 mg (Table 6). The treatment seedling dry weight averages were between 4.24 mg and 7.33 mg. Seedling dry
was also reported by Kizilgeci et al. (2010) and Sharma et al. (2011). The highest seedling vigour was recorded for 'Altintoprak 98' and 'Menceki', whereas 'Altintoprak 98' and 'Menceki' had the highest vigour among the 10 genotypes. Seedling vigour of the salt treatments were less than the control treatment. Similar findings were reported by Kara and Kara (2010), Kizilgeci et al. (2010), and Dinç U, Şenol S, Kapur S, Atalay I, Cangir C (1993). Turkish Soils. Dinç U, Şenol S, Kapur S, Atalay I, Cangir C (1993). Turkish Soils.

Conclusions

Both genotype and salt doses effects were significant for the studied parameters: coleoptile length, seedling length, root length, seedling fresh weight, root fresh weight, seedling dry weight, root dry weight, germination rate and seedling vigour. For these parameters, there were also significant reductions with increasing salt concentration. For coleoptile length, seedling fresh weight, germination rate and seedling vigour, 'Altintoprak 98' was the most salt tolerant genotype. Within the context of root length and root dry weight, 'Sorgul' was most tolerant of salinity stress. Seedling length, germination rate and seed vigour showed the greatest potential as selectable parameters to increase salt tolerance. As confirmation of these laboratory results, follow up field testing is recommended.

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