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The Effects of Salinity on Seed Germination in Perennial Ryegrass (*Lolium perenne* L.) Varieties

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Abstract

In this study, the seeds of 12 perennial ryegrass cultivars (turfgrasses: Barsunny, Essence, Libronco, Pearlgreen, Protege, Roadstar, Stravinsky, Sun, and Top Gun), of which 3 were newly introduced (Ankyra, Cutter-II, and Truva) in 2014, were exposed to NaCl concentrations of 0, 50, 100, 150, and 200 mM to investigate effect of salinity on the germination rate, shoot and root lengths and fresh weights, shoot/root ratio, and salt tolerance index (STI). Statistically significant effects on the germination rate, shoot and root lengths and fresh weights, shoot/root ratio, and salt tolerance index were found as a result of the different salinity treatments. These parameters were reduced with increasing salt concentrations; important decreases occurred with 100 mM NaCl and the lowest values were obtained with 200 mM. The overall findings suggest that the Ankyra, Libronco, Roadster, and Stravinsky varieties were more tolerant to salinity than the other varieties.

Keywords: germination, salt stress, seed, turfgrass, tolerance

Çokyıllık Çim (*Lolium perenne* L.) Çeşitlerinde Tuzluluğun Tohum Çimlenmesi Üzerine Etkileri

Özet

Bu çalışmada, çim bitkisi olarak kullanılan ve 3 tanesi 2014 yılı içinde tescil edilerek piyasaya sunulan (Ankyra, Cutter-II, and Truva) 12 farklı çokyıllık çim çeşidinde (Barsunny, Essence, Libronco, Pearlgreen, Protege, Roadstar, Stravinsky, Sun, ve Top Gun) farklı tuz NaCl konsantrasyonlarının (0, 50, 100, 150 ve 200 mM) çeşitlerin çimlenme oranı, sürgün ve kök uzunluğu, sürgün ve kök yaş ağırlığı, sürgün/kök oranı ve tuza dayanım indeksi üzerindeki etkilerini belirlemek amacıyla yürütülmüştür. Araştırma sonuçları farklı tuz konsantrasyonlarının çimlenme oranı, sürgün ve kök uzunluğu, sürgün ve kök yaş ağırlığı, sürgün/kök oranı ve tuza dayanım indeksi üzerinde istatistiksel olarak önemli derecede etki ettiğini göstermiştir. Bu parametreler artan tuz konsantrasyonu ile birlikte azalmıştır. Tuz konsantrasyonun 100 mM NaCl'ye çıkması incelenen özelliklerde önemli ölçüde azalmaya neden olmuş ve en düşük değerler 200 mM dozunda elde edilmiştir. Araştırmadan elde edilen bulgulara göre Ankyra, Libronco, Roadster ve Stravinsky çeşitlerinin diğer çeşitlere kıyasla tuzluluğa daha tolerant olduğu sonucuna varılmıştır.

Anahtar kelimeler: çimlenme, çim bitkileri, tuz stresi, tohum, tolerant

Introduction

Salinity is one the factor limiting the growth and production of agricultural products. Many higher plant species, including the majority of crops, experience growth inhibition when exposed to high concentrations of NaCl (Khatoon et al., 2010; Zabihi-e-Mahmoodabad et al., 2011). A lack of precipitation, high water table water percolation, poor quality irrigation water, and salt build up from fertilizers and deicer result in high soil salinity, which is a common problem in turfgrass management (Zhang et al., 2012). Plant growth inhibition from salt stress derives from the osmotic effects on water uptake, as well as the variable effects of salt stress on plant cell metabolism. The reduced aesthetic and playable functions in turfgrass were reported by Zhang et al. (2012) as a result of the adverse effects of salinity on the development and growth of plants. Salt can have adverse effects on turfgrass growth, including physiological drought, ion toxicity, and ion imbalances. Most cool-season turfgrass species are particularly susceptible to salinity stress during seed germination, with the possible exception of perennial ryegrass (*Lolium perenne* L.). As salt problems become one of the most complex management challenges, screening and breeding cool-season turfgrass cultivars that are salt-tolerant during both seed germination and vegetative growth becomes important (Dai et al., 2009).

The most important stage in the life cycle of plants is seed germination and fast and uniform germination are the intended characteristics of plant, as in many plant types, and the high sensitivity to salt stress occurs during the germination and seedling growing phases. The highest rate of germination generally occurs under nonsalty conditions and its decrease is contingent on the ascending salt concentrations (Turhan et al., 2011). The stage of plant development at which salinity is imposed greatly affects plant growth. Seed germination is affected by salinity stress through osmotic effects, by the prevention or delay of germination, or ion toxicity, possibly rendering the seeds unviable (Huang and Reddman, 1995). Many studies in the literature aim at determining the effects of salinity during the germination stage of various cultivars. In a study examining the effects of salt concentrations from 2 to 48 dS m^{-1} on turfgrass germination (Qian et al., 2007). Dai et al. (2009) reported that an increase in the salt concentration results in a decrease in the germination rate and rate to a significant degree; thus, increasing the germination time. In another study, the effect of 0.5% and 1.5% NaCl on the germination and growth of wheat cultivars was studied, and found an important relationship between salinity and germination (Zabihi-e-Mahmoodabad et al., 2011).

In this study, the seeds, belonging to 12 different perennial ryegrass cultivars to which different salt concentrations were applied, were examined under salt stress conditions for their germination ability and salt tolerance. To this end, applied to the seeds were the following salt concentrations: 0 (control), 50, 100, 150, and 200 mM, and an evaluation of the germination rate, shoot and root length, shoot and root fresh weight, shoot/root rate, and salt tolerance index (STI) were made at the end of the study.

Materials and Methods

Twelve perennial ryegrass cultivars (Barsunny, Essence, Libronco, Pearlgreen, Protege, Roadstar, Stravinsky, Sun, Top Gun, Ankyra, Cutter-II, and Truva) were used for this study. Prior to seeding, the seed surface was sterilized with 2% sodium hypochlorite for 10 min. After sterilization, the seeds were washed with distilled water three times (Bilgili et al., 2011). As the next step, 25 representative seeds of each cultivar were placed in 10-cm petri dishes containing 2 sheets of Watman No. 1 filter paper, which were initially moistened with either 5 mL of distilled water (control) or the different saline treatment solutions: 50, 100, 150, and 200 mM NaCl. The germination chamber was set at 20 °C under darkness condition, and seed germination was determined when the radicle protruded from the seed coat (Wang et al., 2009).

Germination rate (%): Of each turfgrass species, 25 seeds were placed in petri dishes for germination. The germinated seeds were counted after 15 days in the petri dishes and the germination rate was calculated. Seedlings were discarded from the petri dishes until only 20 remained for further study of their characteristics.

Shoot and root length (cm): The 20 remaining seedlings in each petri dish were used for measuring the shoot and root characteristics. After 15 days in the petri dishes, the roots and shoots of the seedlings were separated. Measurements were taken of the distances from the crown to the leaf and root tips as the shoot and root lengths, respectively.

Shoot and root fresh weight (mg): The root and shoot fresh weights of each seedling were determined. The average fresh weights of the root and shoot of each plant seedling were calculated by dividing the total weight by the total number of seedlings.

Shoot/root ratio: The shoot/root length ratio was calculated by dividing shoot lengths by root lengths. The shoot/root weight ratio was calculated by dividing shoot weight by root weight.

Salt tolerance index (%)*:* The salt tolerance index (STI) is the ratio of total fresh weight of the control treatment and fresh weight of the salt concentration. The STI was calculated from the following formula:

STI = (TFW at Sx / TFW at S) × 100],

where STI is the salt tolerance index, TFW is the mean of the total fresh weight, S refers to the control treatment, and Sx is the x treatment.

Experimental design and statistical analysis: The experiment was designed as a completely randomized plot with 4 replications. Data were analyzed statistically and the means of each treatment were analyzed using Duncan's multiple range test and SAS (9.0) packet program.

Results and Discussion

In general, salt stress significantly was decreased the germination rate of the turfgrass varieties in comparison to the control (Table 1).

Table 1. Effects of different salt concentration on germination rate for twelve perennial ryegrass cultivars.

Germination rate (%)					
Varieties	Control	50 mM NaCl	100 mM NaCl	150 mM NaCl	200 mM NaCl
Ankyra	99.50 [a]	99.50 [a]	94.50 [b]	91.25 [b]	84.75 [c]
Barsunny	98.00 [b]	93.50 [ef]	89.50 [e]	87.25 [ef]	79.75 [f]
Essence	95.50 [c]	95.25 [d]	95.50 [b]	84.25 [g]	74.00 [g]
Libronco	94.75 [c]	91.50 [g]	89.25 [e]	86.50 [f]	84.50 [c]
Cutter-II	99.50 [a]	94.75 [d]	74.75 [g]	70.00 [h]	52.00 [h]
Pearlgreen	97.75 [b]	93.25 [ef]	84.75 [f]	83.75 [g]	84.25 [c]
Protege	99.50 [a]	97.25 [c]	94.25 [b]	91.25 [b]	83.25 [d]
Roadster	93.75 [d]	93.50 [ef]	90.50 [d]	89.75 [d]	88.00 [b]
Stravinsky	99.50 [a]	98.50 [b]	98.00 [a]	94.25 [a]	93.00 [a]
Sun	99.25 [a]	97.25 [c]	89.50 [e]	87.75 [e]	81.50 [e]
Top Gun	99.50 [a]	93.75 [e]	91.50 [c]	88.75 [d]	84.25 [c]
Truva	95.50 [c]	92.75 [f]	89.50 [e]	87.25 [ef]	80.50 [f]
Mean	97.42**	95.07**	90.13**	86.83**	80.81**

Numbers in columns followed by different letters are significantly different according to the Duncan's test at the alpha=0.01 level. *: P<0.05, **: P<0.01

Table 2. Effects of different salt concentration on shoot length for twelve perennial ryegrass cultivars.

Shoot length (cm plant^{-1})					
Varieties	Control	50 mM NaCl	100 mM NaCl	150 mM NaCl	200 mM NaCl
Ankyra	6.66 [c]	6.03 [c]	5.82 [a]	5.00 [a-d]	3.95 [j]
Barsunny	6.32 [e]	5.24 [j]	5.31 [e]	4.89 [b-e]	3.81 [k]
Essence	6.36 [de]	6.08 [b]	5.76 [b]	5.57 [a]	4.92 [a]
Libronco	5.54 [j]	5.36 [h]	4.77 [g]	3.54 [f]	3.42 [l]
Cutter-II	5.80 [i]	5.60 [g]	5.18 [f]	4.84 [c-e]	4.30 [f]
Pearlgreen	7.11 [a]	5.84 [e]	5.49 [c]	4.84 [c-e]	4.75 [c]
Protege	6.39 [d]	5.34 [hi]	5.29 [e]	4.63 [c-e]	4.51 [d]
Roadster	5.37 [k]	5.30 [i]	4.59 [i]	4.43 [de]	4.02 [i]
Stravinsky	6.21 [f]	6.05 [bc]	4.64 [h]	4.38 [e]	4.39 [e]
Sun	5.97 [h]	5.77 [f]	5.28 [e]	5.47 [ab]	4.11 [h]
Top Gun	6.86 [b]	6.46 [a]	5.46 [d]	5.17 [a-c]	4.85 [b]
Truva	6.13 [g]	5.89 [d]	5.49 [c]	4.64 [c-e]	4.19 [g]
Mean	6.23**	5.75**	5.26**	4.78**	4.27**

Numbers in columns followed by different letters are significantly different according to the Duncan's test at the alpha=0.01 level. *: P<0.05, **: P<0.01

With the 150 and 200 mM NaCl concentrations, differences among the varieties were remarkable. The Stravinsky, Ankyra, and Protege varieties had germination rates (GRs) higher than 80%, even with the 150 mM NaCl treatment, while the Pearlgreen variety had a lower germination rate with the same NaCl treatment. Salt stress caused 17% in germination rate reductions in the turfgrass varieties with the 200 mM NaCl treatment. At this salt concentration, the highest GR was observed in the Ankyra (84.75%), Libronco (84.50%), and Top Gun (84.25%) varieties, and the lowest GR was observed in the Cutter-II variety (52.00%). Cokkizgin (2012) suggested that increased salinity elicits a reduction in the seed germination rate and the delayed initiation of germination. Our results are in agreement with those of Kokten et al. (2010), who observed a significant difference in the salt tolerance of lentil genotypes and their responses to increasing salt concentrations. The present study identified and compared the salinity tolerance levels of 12 varieties of turfgrass during germination, where the Ankyra, Libronco, Protege, and Stravinsky varieties exhibited the greatest salt tolerance than the others.

In addition, because of the depressing effect of NaCl, seeds saturated with 150 and 200 mM NaCl had a lower germination rate. Increasing salt concentrations cause a reduction of the soil water potential. The osmotic potential of media solutions are decreased by salts, reducing the availability of water to the plant. When salt-stressed, turfgrasses can suffer from indirect water stress, causing a block in seed germination (Marcum, 1994). Similarly, Katembe et al. (1998) and Cokkizgin (2012) also reported that following NaCl treatments, a decrease in the water potential of the solutions resulted in decreased water imbibitions. An increasing NaCl concentration is likely caused by a decrease in the water potential gradient between seeds and their surrounding media. Seed germination is negatively affected by salinity stress, either osmotically through reduced water absorption or ionically through Na^+ and Cl^- accumulation, resulting in an imbalance in nutrient uptake and toxicity effects (Shokohifard et al., 1989; Cokkizgin, 2012)

Table 3. Effects of different salt concentration on root length for twelve perennial ryegrass cultivars.

	Root length (cm plant^{-1})				
Varieties	Control	50 mM NaCl	100 mM NaCl	150 mM NaCl	200 mM NaCl
Ankyra	3.98 ^{e}	2.77 ^{j}	3.17 ^{h}	2.72 ^{g}	2.24 ^{e}
Barsunny	4.03 ^{e}	4.21 ^{d}	3.32 ^{g}	2.05 ^{i}	1.11 ^{k}
Essence	4.54 ^{d}	3.42 ^{h}	3.32 ^{g}	2.85 ^{e}	1.47 ^{j}
Libronco	4.63 ^{c}	3.93 ^{g}	3.81 ^{i}	2.20 ^{h}	1.53 ^{h}
Cutter-II	3.51 ^{h}	3.36 ^{f}	2.79 ^{i}	1.88 ^{j}	1.50 ^{i}
Pearlgreen	5.21 ^{a}	5.24 ^{a}	4.71 ^{a}	2.77 ^{f}	2.13 ^{f}
Protege	4.64 ^{c}	3.90 ^{g}	3.74 ^{c}	2.84 ^{e}	2.72 ^{a}
Roadster	3.68 ^{g}	3.97 ^{f}	3.43 ^{f}	2.88 ^{d}	2.07 ^{g}
Stravinsky	4.83 ^{b}	4.40 ^{b}	3.89 ^{b}	2.45 ^{a}	2.49 ^{d}
Sun	5.17 ^{a}	4.02 ^{e}	3.52 ^{e}	3.25 ^{c}	1.43 ^{j}
Top Gun	3.80 ^{f}	4.29 ^{c}	3.60 ^{d}	3.39 ^{b}	2.68 ^{b}
Truva	4.65 ^{c}	4.29 ^{c}	3.29 ^{g}	3.24 ^{c}	2.53 ^{c}
Mean	4.39**	3.98**	3.55**	2.71**	1.99**

Numbers in columns followed by different letters are significantly different according to the Duncan's test at the alpha=0.01 level. *: P<0.05, **: P<0.01

Table 4. Effects of different salt concentration on shoot fresh weight for twelve perennial ryegrass cultivars.

	Shoot fresh weight (mg plant^{-1})				
Varieties	Control	50 mM NaCl	100 mM NaCl	150 mM NaCl	200 mM NaCl
Ankyra	11.51 ^{a}	9.60 ^{c}	8.93 ^{b}	7.77 ^{c}	6.93 ^{b}
Barsunny	9.47 ^{f}	8.47 ^{d}	8.38 ^{e}	5.91 ^{i}	3.40 ^{j}
Essence	8.28 ^{k}	8.09 ^{h}	6.86 ^{j}	5.56 ^{j}	3.92 ^{i}
Libronco	9.50 ^{f}	8.24 ^{g}	7.39 ^{i}	7.66 ^{d}	7.43 ^{a}
Cutter-II	10.37 ^{e}	7.13 ^{k}	6.71 ^{k}	5.45 ^{k}	3.88 ^{i}
Pearlgreen	10.58 ^{d}	10.15 ^{b}	8.52 ^{d}	7.90 ^{a}	4.83 ^{g}
Protege	8.92 ^{i}	8.40 ^{e}	7.56 ^{h}	6.50 ^{g}	4.21 ^{h}
Roadster	9.12 ^{g}	8.06 ^{l}	7.91 ^{f}	7.84 ^{b}	5.97 ^{e}
Stravinsky	8.83 ^{j}	7.76 ^{j}	7.39 ^{i}	6.88 ^{f}	5.92 ^{e}
Sun	10.99 ^{c}	9.59 ^{c}	8.58 ^{c}	7.56 ^{e}	6.65 ^{c}
Top Gun	11.19 ^{b}	10.43 ^{a}	9.14 ^{a}	6.19 ^{h}	6.10 ^{a}
Truva	9.01 ^{h}	8.27 ^{f}	7.82 ^{g}	6.21 ^{h}	5.38 ^{f}
Mean	9.81**	8.68**	7.93**	6.79**	5.39**

Numbers in columns followed by different letters are significantly different according to the Duncan's test at the alpha=0.01 level. *: P<0.05, **: P<0.01

Among the varieties, significant differences were observed in the shoot and root lengths (Table 2. and Table 3.). Increasing the NaCl concentration resulted in a significant decrease in shoot elongation. The highest shoot and root lengths were obtained in the Pearlgreen variety (7.11 and

5.21 cm, respectively) in the control treatment and the lowest was determined in the Barsunny variety (3.81 and 1.11 cm, respectively) with 200 mM NaCl. Compared to the control plants, the shoot and root length decrease averaged 32% and 54% with 200 mM NaCl, respectively. The least reductions were observed in the Essence and Roadster varieties, with decreases of 22.64% and 25.51%, respectively. However, the Ankyra, Barsunny, and Libronco varieties showed significant shoot and root reductions, with decreases of 39–72%. The shoot/root weights ratio of the salt tolerant varieties were 2.55-3.79 with 200 mM NaCl. Zabihi-e-Mahmoodabad (2011) reported that salt stress during germination is a reliable test for the tolerance evaluation of many species, due to a reduction the root and shoot growth caused by salinity. Some varieties are affected less and grow equally with the control plants and no inhibition effects are caused under saline growth. This is in accordance with the previous reports in melon, eggplant, bean, and tomato (Yasar et al., 2006; Kaya et al., 2007; Kusvuran et al., 2007; Dasgan and Koc, 2009). The general effects of salinity on plant growth reported a reduction in plant growth with shorter stature and sometimes fewer leaves, and roots are also reduced in length and mass (Shannon and Grieve, 1999).

Table 5. Effects of different salt concentration on root fresh weight for twelve perennial ryegrass cultivars.

Root fresh weight (mg plant^{-1})					
Varieties	Control	50 mM NaCl	100 mM NaCl	150 mM NaCl	200 mM NaCl
Ankyra	5.71 ^{a}	4.96 ^{b}	3.49 ^{b}	2.76 ^{c}	2.71 ^{b}
Barsunny	4.37 ^{g}	3.34 ^{i}	3.20 ^{d}	2.12 ^{g}	1.27 ^{l}
Essence	3.59 ^{i}	3.39 ^{h}	2.96 ^{e}	1.69 ^{j}	1.13 ^{j}
Libronco	3.96 ^{h}	3.45 ^{g}	2.13 ^{i}	2.00 ^{h}	2.10 ^{d}
Cutter-II	4.36 ^{g}	3.31 ^{i}	2.05 ^{j}	2.23 ^{f}	1.54 ^{f}
Pearlgreen	4.53 ^{d}	4.63 ^{c}	4.63 ^{a}	3.99 ^{a}	2.78 ^{a}
Protege	4.52 ^{d}	4.41 ^{d}	3.49 ^{b}	3.12 ^{b}	1.99 ^{e}
Roadster	4.49 ^{e}	3.79 ^{f}	2.51 ^{h}	2.39 ^{d}	1.57 ^{f}
Stravinsky	4.46 ^{e}	3.10 ^{j}	2.66 ^{f}	2.32 ^{e}	2.01 ^{e}
Sun	5.21 ^{b}	4.18 ^{e}	2.06 ^{j}	1.63 ^{k}	1.50 ^{g}
Top Gun	4.98 ^{c}	5.19 ^{a}	3.43 ^{c}	2.30 ^{e}	2.18 ^{c}
Truva	4.42 ^{f}	3.06 ^{k}	2.62 ^{g}	1.93 ^{i}	1.45 ^{h}
Mean	4.55**	3.90**	2.94**	2.37**	1.85**

Numbers in columns followed by different letters are significantly different according to the Duncan's test at the alpha=0.01 level. *: P<0.05, **: P<0.01

Table 6. Effects of different salt concentration on shoot/root weights ratio for twelve perennial ryegrass cultivars.

Shoot/root					
Varieties	Control	50 mM NaCl	100 mM NaCl	150 mM NaCl	200 mM NaCl
Ankyra	2.01 ^{g}	1.93 ^{j}	2.56 ^{i}	2.81 ^{f}	2.55 ^{h}
Barsunny	2.16 ^{e}	2.53 ^{b}	2.61 ^{h}	2.78 ^{f}	2.67 ^{g}
Essence	2.30 ^{c}	2.38 ^{d}	2.31 ^{j}	3.29 ^{c}	3.48 ^{d}
Libronco	2.39 ^{a}	2.38 ^{d}	3.47 ^{b}	3.82 ^{b}	3.53 ^{d}
Cutter-II	2.38 ^{a}	2.15 ^{g}	3.26 ^{c}	2.44 ^{h}	2.52 ^{h}
Pearlgreen	2.33 ^{b}	2.19 ^{f}	1.84 ^{i}	1.98 ^{j}	1.73 ^{j}
Protege	1.97 ^{h}	1.90 ^{k}	2.16 ^{k}	2.08 ^{i}	2.11 ^{i}
Roadster	2.03 ^{g}	2.12 ^{h}	3.14 ^{d}	3.27 ^{cd}	3.79 ^{b}
Stravinsky	1.97 ^{h}	2.50 ^{c}	2.77 ^{f}	2.96 ^{e}	2.94 ^{e}
Sun	2.10 ^{f}	2.29 ^{e}	4.15 ^{a}	4.62 ^{a}	4.43 ^{a}
Top Gun	2.24 ^{d}	2.01 ^{i}	2.66 ^{g}	2.68 ^{g}	2.79 ^{f}
Truva	2.03 ^{g}	2.70 ^{a}	2.98 ^{e}	3.21 ^{d}	3.70 ^{c}
Mean	2.16**	2.26**	2.83**	2.99**	3.02**

Numbers in columns followed by different letters are significantly different according to the Duncan's test at the alpha=0.01 level. *: P<0.05, **: P<0.01

The salinity treatments had a significant effect on the fresh weights of the shoots and roots (Table 4 and Table 5). Increasing the salinity reduced the shoot and root fresh weights by approximately 11% and 59% compared to those of the control group. When the salinity increased from 50 mM to 200 mM, the shoot and root fresh weights were markedly decreased in the varieties by 33.79% and 45.11%, respectively. Salt-tolerant and salt-sensitive varieties showed very different development patterns. While the sensitive varieties, Barsunny, Essence, Pearlgreen, and Sun, had high reductions in the shoot and root fresh weights (62% and 70% decrease, respectively), in the tolerant varieties, Ankyra, Libronco, Roadster, and Stravinsky, the shoot and root fresh weights decreased less in comparison to the control (29% and 46%, respectively).

The average shoot and root fresh weights of the varieties was 9.81 mg plant^{-1} and 4.55 mg plant^{-1} under control conditions, and this value gradually decreased throughout the increasing salt concentrations, reaching 5.39 mg plant^{-1} and 1.85 mg plant^{-1} with 200 mM NaCl, respectively. Salt stress involves osmotic and ionic stresses, and the suppression of growth is directly contingent on the total soluble salt concentration and soil osmotic potential. The detrimental effect can be seen at the whole-plant level as plant death or decreased productivity (Kusvuran, 2012). Plants growth in the turfgrass varieties was significantly reduced by 200 mM NaCl. Zabihi-e-Mahmoodabad et al. (2011) reported a decrease with increasing salinity in the shoot and root fresh and dry weights, and other studies also reported this trait as the main indicator of salinity tolerance. Moreover, Hussein et al. (2007) and Carpici et al. (2009) reported that a negative relationship was detected between the vegetative growth parameters and increasing salinity.

Table 7. Effects of different salt concentration on salt tolerance index for twelve perennial ryegrass cultivars.

	STI (%)			
Varieties	50 mM NaCl	100 mM NaCl	150 mM NaCl	200 mM NaCl
Ankyra	83.42 ^{j}	77.56 ^{h}	67.52 ^{g}	60.17 ^{ed}
Barsunny	89.52 ^{f}	88.57 ^{a}	62.49 ^{h}	35.90 ^{j}
Essence	97.74 ^{a}	82.80 ^{e}	67.14 ^{g}	47.37 ^{g}
Libronco	86.76 ^{i}	77.84 ^{h}	80.61 ^{b}	78.19 ^{a}
Cutter-II	68.78 ^{k}	64.68 ^{i}	52.54 ^{j}	37.38 ^{i}
Pearlgreen	95.89 ^{b}	80.53 ^{g}	74.63 ^{d}	45.67 ^{h}
Protege	94.09 ^{c}	84.68 ^{c}	72.80 ^{e}	47.16 ^{g}
Roadster	88.35 ^{g}	86.74 ^{b}	85.97 ^{a}	65.45 ^{c}
Stravinsky	87.89 ^{gh}	83.67 ^{d}	77.92 ^{c}	67.09 ^{b}
Sun	87.24 ^{hi}	78.04 ^{h}	68.78 ^{f}	60.54 ^{d}
Top Gun	93.19 ^{d}	81.66 ^{f}	55.33 ^{i}	54.53 ^{f}
Truva	91.85 ^{e}	86.80 ^{b}	68.93 ^{f}	59.70 ^{e}
Mean	88.73**	81.13**	69.56**	54.93**

Numbers in columns followed by different letters are significantly different according to the Duncan's test at the alpha=0.01 level. *: P<0.05, **: P<0.01

The STI showed a large variation among the varieties at different salt concentrations (Table 6 and Table 7). The STI varied between 35.90% and 78.19% with 200 mM NaCl. The Libronco (78.19%) and Stravinsky (67.09%) varieties performed best with the 200 mM NaCl. On the other hand, Barsunny (35.90%) and Cutter-II (37.38%) showed the lowest STI. The other varieties were moderately affected by the salt treatment. Carpici et al. (2009) reported that the effects of different salt concentrations on the salt tolerance indices of cultivars were of importance. As the salt concentrations increased, the salt tolerance indices of the cultivars decreased. Kokten et al. (2010) determined that tolerant cultivars showed higher salt tolerance indices than sensitive ones.

Conclusion

In conclusion, the overall findings from the present study showed a marked variation in salt tolerance among the twelve perennial ryegrass varieties studied. The increasing NaCl concentrations caused harmful effects on seed germination percentage, shoot and root lengths, shoot and root fresh weights, shoot/root length and weight ratios, and STI. However, there were slightly more harmful effects in the tolerant varieties than in the sensitive ones.

References

Bilgili, U., Carpici, E.B. Asik, B.B. and Celik, N. 2011. Root and shoot response of common vetch (*Vicia sativa* L.), forage pea (*Pisum sativum* L.) and canola (*Brassica napus* L.) to salt stress during early seedling growth stages. *Turkish Journal of Field Crops* 16 (1): 33-38.

Carpici, E.B., Celik, N., and Bayram, G. 2009. Effects of salt stress on germination of some maize (*Zea mays* L.) cultivars. *African Journal of Biotechlogy*, 8 (19) : 4918-4922.

Cokkizgin, A. 2012. Salinity stress in common bean (*Phaseolus vulgaris* L.) seed germination. *Notulae Botanicae Horti Agrobotanici Cluj-Napoca*, 40 (1): 177-182.

Dai, J., Huff, D.R. and Schlossgerg, M.J. 2009. Salinity effects on seed germination and vegetative growth of greens-type *Poa annua* relative to other cool-season turfgrass species. *Crop Science*, 49 : 696-703.

Dasgan, H.Y., Koc, S. 2009. Evaluation of salt tolerance in common bean genotypes by ion regulation and searching for screening parameters. *Journal of Food, Agriculture and Environment*, 7 (2): 363-372.

Huang, J., and Redman, R. 1995. Physiological responses of canola and wild mustard to salinity and contrasting calcium supply. *Journal of Plant Nutrition*, 18 : 1931–1949.

Hussein, M.M., Balbaa, L.K. and Gaballah, M.S. 2007. Salicylic acid and salinity effects on growth of maize plants. *Research Journal of Agriculture and Biological Sciences*, 3 (4): 321-328.

Katembe, W.J., Ungar, A.I. and Mitchell, J.P. 1998. Effect of salinity on germination and seedling growth of two *Atriplex* species (*Chenopodiaceae*). *Annals of Botany*, 82 : 167-175.

Kaya, C., Tuna, A.L., Asraf, M. and Altunlu, H. 2007. Improved salt tolerance of melon (*Cucumis melo* L.) by the addition of proline and potassium nitrate. *Environmental and Experimental Botany*, 60 : 397-403.

Khatoon, T., Hussain, K., Majeed, A., Nawaz, K. and Nisar, M.F. 2010. Morfological variations in maize (*Zea mays* L.) under different levels of NaCl at germinating stage. *World Applied Science Journal*, 8 (10): 1294-1297.

Kokten, K., Karakoy, T., Bakoglu, A. and Akcura, M. 2010. Determination of salinity tolerance of some lentil (*Lens culinaris* M.) varieties. *Journal of Food, Agriculture and Environment*, 8 (1): 140-143.

Kusvuran, S., Ellialtioglu, S., Abak, K. and Yasar, F. 2007. Responses of some melon (*Cucumis* sp.) genotypes to salt stress. *Journal of Agricultural Sciences, Ankara University Faculty of Agriculture*, 13 (4): 395-404.

Kusvuran, S. 2012. Ion regulation in different organs of melon (*Cucumis melo* L.) genotypes under salt stress. *International Journal of Agriculture and Biology*, 14 (1): 141-144.

Marcum, K. 1994. Salt-tolerance mechanisms of turfgrasses. Colf Course Management / September. 55-59.

Shannon, M.C., and C.M. Grieve, C.M. 1999. Tolerance of vegetable crops to salinity. *Scientia Horticulturae*, 78 : 5-38.

Shokohifard, G., Sakageim, K.H. and Matsumoto, S. 1989. Effect of amending materials on growth of radish plant in salinized soil. *Journal of Plant Nutrition*, 12: 119-124.

Turhan, A., Kuscu, H. and Seniz, V. 2011. Effects of Different Salt Concentrations (NaCl) on Germination of Some Spinach Cultivars. *The Journal of Agricultural Faculty of Uludag University*, 25 (1): 65-77.

Qian, Y.L., Fu, J.M., Wilhelm, S.J., Christensen, D. and Koski, A.J. 2007. Relative salinity tolerance of turf-type saltgrass selections. *HortScience*, 42 (2): 205-209.

Yasar, F., Uzal, O., Tufenkci, S. and Yildiz, K. 2006. Ion accumulation, in different organs of green peas genotypes grown under salt stress. *Plant, Soil and Environment*, 52 (10): 476-480.

Wang, W.B., Kim, Y.H., Lee, H.S., Kim, K.Y., Deng, X.P. and Kwak, S.S. (2009). Analysis of antioxidant enzyme activity during germination of alfalfa under salt and drought stresses. *Plant Physiology and Bioch.* 47 (7): 570–577.

Zabihi-e-Mahmoodabad, R., Jamaati-e-Somarin, S., Khayatnezhad, M. and Gholamin, R. 2011. The study of effect salinity stress on germination and seedling growth in five different genotypes of wheat. *Advances in Environmental Biology*, 5 (1): 177-179.

Zhang, Q., Rue, K. and Wang, S. 2012. Salinity Effect on Seed Germination and Growth of Two Warm-season Native Grass Species. *HortScience*. 47 (4): 527-530.