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Salinity Effects on Seed Germination in Different Tall Fescue (*Festuca arundinaceae* Schreb.) Varieties

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Abstract

Seeds of 9 tall fescue (*Festuca arundinaceae* Schreb.) cultivars (Apache, Arid-III, Barvado, Da Vinci, Eldorado, Prospect, and Tomahawk), 2 of which were newly introduced (Brigantine and Jaguar 4G) in 2014, were used to investigate the effects of different NaCl concentrations (0, 50, 100, 150 and 200 mM) on their germination rate, shoot and root length, shoot and root fresh weight, shoot/root ratio and salt tolerance index (STI). The experiment was designed as a completely randomized with four replicates at the laboratory of Kizilirmak Vocational High School, Cankiri Karatekin University, in 2014. The results showed that different salinity treatments had statistically considerable effects on the germination rate, shoot and root length, shoot and root fresh weight, shoot/root ratio, and salt tolerance index (STI). The values of these parameters were reduced with increasing salt concentration. In all parameters, considerable decreases occurred with 100 mM concentration and the lowest values were obtained from 200 mM. The overall findings suggest that the Apache, Da Vinci, Prospect, and Tomahawk varieties were more tolerant than the other ones.

Key Words: Salt stress, salinity, turfgrass, tolerance, seedling

Tuzluluğun Farklı Kamışsı Yumak (*Festuca arundinaceae* Schreb.) Çeşitlerinde Tohum Çimlenmesi Üzerine Etkileri

Abstract

Çeşitlerden 2 tanesi (Brigantine and Jaguar 4G) 2014 yılında tescil edilen, 9 farklı kamışsı yumak (*Festuca arundinaceae* Schreb.) çeşidinde (Apache, Arid-III, Barvado, Da Vinci, Eldorado, Prospect, ve Tomahawk) farklı tuz 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 tolerans indeksleri üzerine etkileri araştırılmıştır. Araştırma, Çankırı Karatekin Üniversitesi, Kızılırmak Meslek Yüksekokulu Laboratuvarı'nda, 4 tekrarlamalı olarak, 2014 yılında tesadüf parselleri deneme desenine göre yürütülmüştür. Araştırma sonuçları, farklı tuz uygulamalarının çimlenme oranı, sürgün ve kök uzunluğu, sürgün ve kök yaş ağırlığı, sürgün/kök oranı ve tuza tolerans indeksi üzerinde istatistiksel olarak önemli düzeyde etkili olduğunu göstermiştir. İncelenen parametrelerin değerleri artan tuz konsantrasyonu ile azalmıştır. Değerlerde 100 mM tuz konsantrasyonu ile önemli azalmalar meydana gelmiş ve en düşük değerler 200 mM'da elde edilmiştir. Araştırma bulguları göz önüne alındığında Apache, Da Vinci, Prospect ve Tomahawk çeşitlerinin diğerlerine kıyasla daha tolerant oldukları sonucuna varılmıştır.

Anahtar Kelimeler: Çim bitkileri, çimlenme, tuzluluk, tuz stresi, tolerans

INTRODUCTION

Under salinity stress, reduction in plant growth usually interlinked with a variety of biochemical, physiological, and molecular characteristics [1]. Salinity is one of the problems that must be deal with in turf-grass management, due to both restrictions in freshwater use for landscape irrigation and exposure to salt stress in coastal areas [2]. Its high levels reduce the ability of plants to absorb water from the soil and have toxic effects on cell metabolism [3]. Zhang et al. [4] indicated that salinity adversely affects plant growth and development, resulting in reduced aesthetical and playable functions of turfgrass. Salt can have unfavorable effects on turfgrass growth, including physiological drought, ion toxicity, and ion imbalances. with the possible exception of perennial ryegras (*Loliuperenne* L.).

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 of salt-tolerant cool-season turfgrass cultivars during both seed germination and vegetative growth becomes important [5]. The effect of salinity on plant growth is related to the stage of plant development at which salinity is imposed [6]. This stress affects seed germination either through osmotic effects, by preventing or delaying germination, or through ion toxicity, which can render the seeds unviable [7].

The tall fescue seeds, belonging to 9 different cultivars which were subjected to different salt concentrations, were examined for germination ability under salt stress conditions and their salt tolerance during germination. For this purpose, salt concentrations of 0 (control), 50, 100, 150, 200 mM were applied to the seeds and germination rate, shoot and root length, shoot and root fresh weight, shoot/root rate, and salt tolerance index (STI) were evaluated at the end of the study.

MATERIALS and METHODS

In this study, 9 tall fescue cultivars (Apache, Arid-III, Barvado, Da Vinci, Eldorado, Prospect, and Tomahawk), 2 of which were newly introduced (Brigantine and Jaguar 4G) in 2014, were used as materials. Seeds of each turfgrass varieties used in the experiment were surface-sterilized. Twenty five representative seeds per cultivar were placed on a filter paper in 10 cm petri dishes containing two sheets of Watman No. 1 filter paper moistened initially with 5 ml of distilled water (control), or with different concentrates solutions 50, 100, 150, and 200 mM NaCl (saline conditions). Germination chamber was at 20 °C and with dark conditions. The seeds were considered germinated when there was radicle protrusion through the seed coat.

Germination rate (%)

Of each turfgrass cultivars, 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 seedlings were separated into roots and shoots. The distances from the crown to leaf tip and root tip were measured as the shoot length and root length, respectively.

Shoot and root fresh weight (mg)

The shoot and root fresh weights of each seedling were measured. The average fresh weights of shoot and root of each plant seedling were measured by dividing the total weight by the total number of seedlings.

Shoot/root ratio

This was calculated for weight by dividing shoot values by root values.

Salt tolerance index

The salt tolerance index (STI) is the ratio of shoot fresh weight of the control treatment and fresh weight of the salt concentration. The STI was calculated by 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 replicates. 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 DISCUSSIONS

Statistically significant ($P<0.01$) were observed differences among NaCl concentrates for germination rate. Germination rate of the tall fescue varieties significantly decreased in salt stress compared to the control. The 150 and 200 mM NaCl concentrations led to significant differences among the varieties. Arid-III, Barvado and Tomahawk varieties had germination rates higher than 70%, even with the 150 mM NaCl concentration, while the Eldorado variety had a lower germination rate with the same NaCl treatment. Salt stress caused 22% reductions of germination rate in the tall fescue varieties in the 200 mM NaCl concentrate. The highest germination rate was observed in the Tomahawk (87.3%), Barvado (85.8%), and Arid-III (81.3%) varieties. However, the Eldorado varieties showed the lowest germination rate (66.8%) with the 200 mM NaCl treatment (Table 1).

Bakth et al. [8] indicated that the relative germination rate, relative germination potential and the ratio of root to seedling of four oats varieties declined with raising salt concentration. This study identified and compared salinity tolerance levels of 9 varieties during germination to turfgrass and Arid-II, Barvado, and Tomahawk showed better performance than the other varieties. In addition, because of the depressing effect of NaCl seeds saturated with 150 and 200 mM NaCl (15.39% and 22.30% decreasing) had lower germination rate. Similarly, Katembe et al. [9] and Cokkizgin [10] also reported that the imbibitions of water reduced with the decrease in water potential of the solutions resulting from following NaCl treatments. Since the high salt level limited the water absorption, it has adverse impact on the germination. Our results were relevant to the findings of Dai et al. [5] and Nizam [11] studied on different plants.

In the present study, shoot and root lengths were reduced gradually with increasing NaCl concentrations from 0 to 200 mM (Table 2 and Table 3). When compared the control plants, shoot and root lengths decreased average 42% and 46% with 200 mM NaCl treatment, respectively. The highest shoot and root lengths were observed in the Brigantine variety (7.03 and 4.62 cm, respectively) in control treatment, whereas the lowest was determined in the Arid-III varieties (2.16 and 0.91 cm, respectively) with 200 mM NaCl. The lowest reductions were determined in the Barvado and Tomahawk varieties, with decreases of 35.32% and 42.66%, respectively. However, the Apache, Arid-III, Brigantine and Prospect cultivars showed remarkable shoot and root reductions, with decreases of 63-71%. Anbumalarmathi and Mehta [12] assessed that plumule length of all the rice varieties decreased with an increase in salinity. Reduction of seedling height is a common phenomenon of many crop plants grown under saline conditions. Similarly, radicle length was also decreased with increased salinity. 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 [13].

The average shoot and root fresh weights of the varieties was 9.62 mg $plant^{-1}$and 5.21 mg $plant^{-1}$ under control conditions, and this value gradually decreased throughout the increasing salt concentrations, reaching 6.82 mg $plant^{-1}$ and 2.61 mg $plant^{-1}$ with 200 mM NaCl, respectively (Table 4 and Table 5).

Table 1. Effects of different salt concentration on germination rate

Germination rate (%)					
Cultivars	Control	50 mM NaCl	100 mM NaCl	150 mM NaCl	200 mM NaCl
Apache	97.8 d	81.8 g	74.8 f	73.0 g	69.3 f
Arid-III	98.8 b	98.0 a	91.8 c	90.0 b	81.3 c
Barvado	99.8 a	96.5 c	94.3 a	93.3 a	85.8 b
Da Vinci	99.8 a	97.3 b	90.0 a	86.8 d	80.3 d
Eldorado	98.5 c	92.3 f	81.3 e	78.8 e	66.8 h
Brigantine	97.8 d	95.0 e	90.3 d	77.3 f	73.3 e
Jaguar 4G	99.8 a	95.0 e	92.8 b	79.3 e	68.0 g
Prospect	98.0 cd	95.3 de	90.3 d	87.3 cd	80.0 d
Tomahawk	100 a	95.8 d	93.3 b	87.8 c	87.3 a
Mean	98.9**	94.1**	88.7**	83.7**	76.9**

Means in a column followed by the same letter are not significantly differ according to the Duncan's test at the 0.01 level of significance. *: P<0.05, **: P<0.01

Table 2. Effects of different salt concentration on shoot length

Shoot length (cm plant^{-1})					
Cultivars	Control	50 mM NaCl	100 mM NaCl	150 mM NaCl	200 mM NaCl
Apache	6.48 e	4.38 f	5.05 ab	3.21 g	2.36 h
Arid-III	7.03 a	6.18 a	5.08 ab	4.14 b	2.90 f
Barvado	4.58 ı	3.87 g	3.75 de	3.44 e	2.85 g
Da Vinci	4.70 h	4.55 e	3.52 e	3.34 f	3.04 e
Eldorado	6.61 c	5.31 b	3.89 de	3.47 e	3.39 c
Brigantine	5.16 g	5.30 b	4.41 b-d	3.85 c	2.16 ı
Jaguar 4G	6.95 b	4.87 d	5.59 a	4.42 a	3.92 a
Prospect	5.34 f	4.86 d	4.14 c-e	3.55 d	3.25 d
Tomahawk	6.54 d	5.05 c	4.75 bc	4.42 a	3.75 b
Mean	5.93**	4.93**	4.46**	3.76**	3.07**

Means in a column followed by the same letter are not significantly differ according to the Duncan's test at the 0.01 level of significance. *: P<0.05, **: P<0.01

Table 3. Effects of different salt concentration on root length

Root length (cm plant^{-1})					
Cultivars	Control	50 mM NaCl	100 mM NaCl	150 mM NaCl	200 mM NaCl
Apache	3.17 h	2.73 g	2.49 e	2.12 f	0.91 ı
Arid-III	3.08 ı	3.39 d	2.68 b	2.44 b	1.17 f
Barvado	3.73 d	3.93 c	2.63 c	1.89 g	1.08 g
Da Vinci	3.81 c	2.69 h	2.30 g	1.51 h	1.34 e
Eldorado	3.57 e	2.88 e	2.38 f	2.35 c	1.55 d
Brigantine	3.47 f	2.84 f	2.52 d	2.50 a	2.09 a
Jaguar 4G	4.62 a	4.14 b	2.92 a	2.49 a	1.81 b
Prospect	3.90 b	2.87 ef	2.54 d	2.24 d	1.03 h
Tomahawk	3.30 g	4.50 a	2.69 b	2.21 e	1.77 c
Mean	3.63**	3.33**	2.57**	2.19**	1.42**

Means in a column followed by the same letter are not significantly differ according to the Duncan's test at the 0.01 level of significance. *: P<0.05, **: P<0.01

Table 4. Effects of different salt concentration on shoot fresh weight

Shoot fresh weight (mg plant^{-1})					
Cultivars	Control	50 mM NaCl	100 mM NaCl	150 mM NaCl	200 mM NaCl
Apache	8.34 g	7.93 ı	7.63 f	6.50 h	5.53 g
Arid-III	9.18 e	9.11 e	9.36 b	8.91 b	7.52 c
Barvado	8.59 f	8.45 f	8.06 e	7.54 e	7.40 d
Da Vinci	8.33 g	8.41 g	8.24 d	6.91 f	6.44 f
Eldorado	11.15 b	10.23 c	8.68 c	8.59 d	7.90 b
Brigantine	12.32 a	10.93 b	6.75 g	3.95 ı	4.12 h
Jaguar 4G	11.10 c	11.26 a	10.91 a	9.27 a	9.09 a
Prospect	9.40 d	9.56 d	9.33 b	8.73 c	6.94 e
Tomahawk	8.20 h	8.12 h	7.63 f	6.80 g	6.47 f
Mean	9.62**	9.33**	8.51**	7.47**	6.82**

Means in a column followed by the same letter are not significantly differ according to the Duncan's test at the 0.01 level of significance. *: P<0.05, **: P<0.01

Table 5. Effects of different salt concentration on root fresh weight

	Root fresh weight (mg plant^{-1})				
Cultivars	Control	50 mM NaCl	100 mM NaCl	150 mM NaCl	200 mM NaCl
Apache	4.46 ı	3.06 h	3.14 f	3.22 f	2.16 g
Arid-III	5.80 a	5.71 b	5.27 a	5.62 a	2.49 e
Barvado	5.70 b	5.83 a	5.16 b	4.34 c	3.43 c
Da Vinci	5.39 d	4.90 d	4.63 c	3.13 g	2.74 d
Eldorado	4.90 g	4.10 f	2.77 g	2.45 h	1.36 h
Brigantine	5.11 f	2.23 ı	1.91 h	1.49 ı	1.43 h
Jaguar 4G	5.60 c	4.69 e	4.23 d	4.92 b	3.99 a
Prospect	4.73 h	3.41 g	3.42 e	3.39 e	2.35 f
Tomahawk	5.21 e	5.09 c	4.64 c	3.88 d	3.54 b
Mean	5.21**	4.34**	3.91**	3.60**	2.61**

Means in a column followed by the same letter are not significantly differ according to the Duncan's test at the 0.01 level of significance. *: P<0.05, **: P<0.01

As the salt concentrations increased, the shoot and root fresh weights of the cultivars decreased. In our study, while the Barvado and Tomahawk cultivars (21-39% decreasing) were significantly higher in all salinity concentrations when compared to the control varieties, growth was inhibited in the Eldorado and Brigantine cultivars with 200 mM NaCl. When the salinity increased from 50 mM to 200 mM, the shoot and root fresh weights were markedly decreased in the Eldorado and Brigantine varieties by 66% and 72%, respectively. The shoot/root ratio of the salt tolerance varieties were 2.28-5.86 with 200 mM NaCl (Table 6). Zabihi-e-Mahmoodabad et al. [14] reported that the shoot and root fresh and dry weights decreased with increasing salinity and many other studies also reported this trait as the main indicator of salinity tolerance. Moreover, Hussein et al. [15], Carpici et al. [16], Anbumalarmathi and Mehta [12] and reported that a negative relationship was detected between the vegetative growth parameters and increasing salinity.

The STI showed a large variation among the varieties at different salt concentrations (Table 7). Its values were obtained between 33.41% and 86.14% with 200 mM NaCl. The Barvado (86.14%) and Arid-III (81.86%) varieties were the best performing with the 200 mM NaCl treatment. Nevertheless, while the Apache (66.25%) and Brigantine (33.41%) cultivars showed the lowest values, the other ones were moderately affected by the salt treatment. Carpici et al. [16] informed 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. [17] determined that tolerant genotypes showed higher salt tolerance indices than sensitive ones.

Table 6. Effects of different salt concentration on shoot/root

	Shoot/root				
Cultivars	Control	50 mM NaCl	100 mM NaCl	150 mM NaCl	200 mM NaCl
Apache	1.87 d	2.59 c	2.43 e	2.02 e	2.56 c
Arid-III	1.58 e	1.60 g	1.78 f	1.58 h	3.02 b
Barvado	1.51 g	1.45 h	1.56 h	1.74 g	2.15 de
Da Vinci	1.55 f	1.72 f	1.78 f	2.21 d	2.35 cd
Eldorado	2.28 b	2.50 d	3.14 b	3.51 a	5.86 a
Brigantine	2.41 a	4.91 a	3.53 a	2.65 b	2.89 b
Jaguar 4G	1.98 c	2.40 e	2.58 d	1.89 f	2.28 cd
Prospect	1.99 c	2.81 b	2.73 c	2.58 c	2.96 b
Tomahawk	1.58 e	1.60 g	1.64 g	1.75 g	1.83 f
Mean	1.86**	2.40**	2.35**	2.21**	2.88**

Means in a column followed by the same letter are not significantly differ according to the Duncan's test at the 0.01 level of significance. *: P<0.05, **: P<0.01

Table 7. Effects of different salt concentration on salt tolerance index

Cultivars	50 mM NaCl	100 mM NaCl	150 mM NaCl	200 mM NaCl
Apache	95.05 e	91.49 f	77.93 f	66.25 g
Arid-III	99.21 c	101.9 a	97.00 a	81.86 a
Barvado	98.34 d	93.80 d	87.74 c	86.14 a
Da Vinci	100.9 b	99.98 b	82.94 e	77.39 d
Eldorado	91.81 f	77.84 g	77.09 g	70.84 f
Brigantine	88.71 g	54.77 h	32.03 h	33.41 h
Jaguar 4G	101.4 ab	98.24 c	83.53 d	81.84 b
Prospect	101.7 a	99.33 b	92.89 b	73.87 e
Tomahawk	99.02 c	93.01 e	82.86 e	78.84 c
Mean				

*Means in a column followed by the same letter are not significantly differ according to the Duncan's test at the 0.01 level of significance. *: P<0.05, **: P<0.01

CONCLUSIONS

The present study on the salt tolerance of turfgrass varieties showed a marked variation in their sensitivity to salt tolerance. The increasing NaCl concentration caused harmful effects on seed germination in the evaluated properties such as, shoot and root lengths and fresh weight. However, there were slightly more harmful effects in the tolerant varieties than in the sensitive ones.

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