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SCREENING FOR SALT TOLERANCE OF 12 TURKISH TRITICALE CULTIVARS DURING GERMINATION AND EARLY SEEDLING STAGE

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Abstract: This investigation was carried out to determine the response of 12 Turkish cultivars to different salt stress levels during the germination and early seedling stages at Hatay Mustafa Kemal University in 2022. In present research, four different sodium chloride treatments (60, 120, 180 and 240 mM) and a control (0 mM) treatment were used. Germination ratio, germination index, mean germination time, root and shoot length, root and shoot fresh weight, root and shoot dry weight and biomass weight parameters were investigated to determine the salt tolerance of triticale cultivars. Cultivars, salt doses and their interactions had significant effects on all examined characteristics. In general, germination parameters and early seedling stage characteristics of the cultivars were adversely affected by increasing salt doses. Yet, it was determined that the responses to increasing salt doses were different among the cultivars. Although Mehmetbey cultivar was undesirably affected by increased salt doses, it was found to be more resistant than the other cultivars. On the other hand, Umranhanim was determined as the most sensitive cultivar to salt stress. After investigating the resistance of Mehmetbey cultivar to salt stress under field conditions, this cultivar can be included into breeding programs or cultivated in fields with salinity problems.

Keywords: Abiotic stress, Germination, Salt stress, Seedling stage, Triticale

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1. Introduction

From germination to emergence stage, seeds are exposed to various abiotic stress factors such as drought, flooding, extreme heat or cold, salinity, mineral deficiency and toxicity (Khan et al., 2013). It is estimated that on-going global warming and climate change will even further aggravate the effects of abiotic stressors on plants. Climate change, naturally or caused by anthropogenic activities, is posing incredible challenges to agricultural activities around the world. Some estimates suggest that over 90 % of rural farmland was affected by abiotic stressors at some point during the growing season (Cramer et al., 2011). Therefore, it is essential to understand the stress responses of plants to identify resistant varieties that can tolerate abiotic stressors.

Salinity is a soil-based abiotic stress factor and generates important problems in agricultural production of arid and semi-arid regions. Data show that 933 million hectares, equivalent to 7% of arable land worldwide, are affected by salinity (Gangwar et al., 2020; Mora et al., 2020; Ahmadi et al., 2022). Salinity in agricultural lands significantly affects the germination, emergence, growth and crop formation of plants (Pakniyat et al., 2003; Gorji et al., 2017). Thus, it is very important to select species and/or cultivars suitable for such agricultural lands for production.

Triticale is primarily grown for feed grain and biomass production. In addition, the stems are used as straw, while the grains are used in human nutrition. Whatever the advantages of this plant, history of triticale has been shaped by humans. Nearly 100 years of research has been conducted on botanical and genetic properties of triticale species to turn them into a product (Haesaert and de Baets, 1996; Mergoum and Gomez-Macpherson, 2004). It has been found that triticale could tolerate some abiotic stress conditions better than the other cereal species (Roake et al., 2009). For instance, Motzo et al. (2013) reported that triticale was more drought tolerant than durum wheat. The USDA salinity laboratory has reported that the salinity tolerance of triticale was better than wheat and even similar to barley (Blum, 2014).

Triticale is usually seen as an alternative of other small grain cereals, primarily wheat and barley, for growing under adverse conditions or in low-input farming systems. The presence of appropriate genetic variation is a pre-requisite for the development of any character through selection and reproduction. It has been determined that there was an intraspecific variation in salt tolerance of triticale plants (Norlyn and Epstein, 1984). On the other hand, triticale has the potential to be an important genetic resource for the transfer of resistance genes against biotic and abiotic stress conditions (Vaillancourt et al., 2008). Successful seed germination plays a critical role in ensuring the desired plant density and economic production. Saline soil conditions significantly limit seed germination (Almansouri et al., 2001; Atis, 2011). The first step in determining the genetic potential of this plant for salt tolerance is testing it at germination and early seedling stages.

Various techniques have been suggested to protect plants from environmental stresses. One of these techniques is the identification of salt-resistant species and/or cultivars. In this study, tolerance of some Turkish triticale cultivars to different salinity levels during germination and early seedling stages were investigated.

2. Materials and Methods

The research was conducted under laboratory conditions in Field Crops Department of Mustafa Kemal University, Faculty of Agriculture in 2022. Twelve triticale (X Triticosecale Wittmak) cultivars were used as plant material of the present study. Information about triticale cultivars are provided in Table 1.

Table 1. Turkish triticale cultivars used in the study and their registration institutions

Name of cultivars	Registration institutions
Alperbey	Bahri Dagdas International Agricultural Research Institute Directorate
Aysehanim	Eastern Mediterranean Transitional Zone Research Institute Directorate
Bera	Yonca Agriculture Products
Egeyildizi	Ege Agricultural Research Institute Directorate
Esin	Gap International Agricultural Research and Centre of Education Directorate
Karma 2000	Transitional Zone Agricultural Research Institute Directorate
Mehmetbey	Eastern Mediterranean Transitional Zone Research Institute Directorate
Mikham-2002	Bahri Dagdas International Agricultural Research Institute Directorate
Ozer	Bahri Dagdas International Agricultural Research Institute Directorate
Tatlicak 97	Bahri Dagdas International Agricultural Research Institute Directorate
Truva	Limagrain Turkiye
Umranhanim	East Anatolian Agricultural Research Institute Directorate

The experimental design was two-factorial arranged in a completely randomized design with four replications. Four salt doses (60, 120, 180 and 240 mM) and control (distilled water) were used for salt stress in germination media. All salt solutions were prepared with sterile distilled water. Triticale seeds were sterilized using sodium hypochlorite (rate of 1%). To sterilize the seeds, 60 g seeds were weighed and then were washed with 100 ml of 1% sodium hypochlorite by shaking for 10 minutes. Sterilized seeds were washed 3 times with sterilized distilled water to remove chemical residues over the seeds. Sterile disposable Petri dishes with 9 cm diameter were used to germinate the seeds under salt stress. Two-layer filter paper was placed in Petri dishes and 10 mL salt solution for salt stress and 10 mL sterilized distilled water for control was used in germination media. To sow the seeds into Petri dishes, a sterile cabin was used to ensure sterile media during the germination and early seedling stage. Seeds treated with control and salt doses were incubated in an incubator at 24±1 °C for 10 days. Germinated seeds were counted in every 24 hours during 7 days. With the use of number of germinated seeds, germination ratio (GR), germination index (GI) and mean germination time (MGT) were calculated. At the end of 10 days, all Petri dishes were opened and root and shoot length (RL and SL), root fresh weight (RFW), shoot fresh weight (SFW), root dry weight (RDW) and shoot dry weight (SDW) characteristics were measured on seedlings. The RFW and SFW were weighed and the samples were dried in an oven at 65 °C for 24 hours. Weighing was made to determine the RDW and SDW characteristics of the dried samples (Equations 1-3).

$$GR\% = \frac{Total\ Germinated\ Seeds}{Total\ Seeds\ Used\ for\ Germination\ Test} \times 100 \quad (1)$$

$$GI = \sum G/T \quad (2)$$

where; G is the number of germinated seeds per day and T is the germination period.

$$MGT\ (day) = \sum (n \times d)/N \quad (3)$$

where; n is the number of seeds germinated on each day, d is the number of days from the beginning of the test and N is the total number of seeds germinated at the termination of the experiment (Ellis and Roberts, 1981).

All data obtained from the present experiments were subjected to two-way ANOVA and biplot analysis with the use of SAS JMP 13 statistical software. The Tukey pair-wise test was applied to compare significant means (P<0.05) (Genç and Soysal, 2018).

3. Results and Discussion

3.1. Effects of Cultivars on Germination Parameters and Seedling Properties

Effects of cultivars on germination and seedling parameters are provided in Table 2. All characteristics were significantly (P<0.0001) affected by cultivars. The data for GR, GI, MGT, RL and SL are given Table 3. GR values of the cultivars ranged from 36.50% to 87.25% with the highest value from Mehmetbey cultivar and the lowest value from Esin cultivar. Egeyildizi and Aysehanim cultivars gave similar results with Mehmetbey cultivar. Esin cultivar with lowest GR was placed into the same group with Bera and Karma 2000 cultivars. The GI values of the cultivars varied between 3.05 and 8.16 with the highest value from Mehmetbey cultivar and the lowest value from Bera cultivar. However, Bera, Esin and Karma 2000 cultivars were placed into the same group. MGT values ranged from 2.55 days to 6.47 days with the highest value from Umranhanim cultivar and the lowest value from Ozer cultivar. In other words, Ozer cultivar achieved the fastest germination under different salt doses. RL values of the cultivars varied between 1.99 - 9.67 cm with the highest value from Aysehanim cultivar and the lowest value from Umranhanim cultivar. SL values of the cultivars changed between 4.56 and 9.97 cm.

The mean values for the parameters of RFW, SFW, RDW, SDW and BW are given in Table 4. RFW values of the cultivars varied between 21.07 - 82.50 mg plant^{-1} with the highest value from Mehmetbey cultivar and the lowest value from Umranhanim cultivar. SFW values of the cultivars ranged between 38.81 and 85.95 mg plant^{-1} with the highest value from Karma 2000 cultivar and the lowest value from Umranhanim cultivar. RDW values of the cultivars varied between 4.00 and 10.85 mg plant^{-1} with the highest value from Mikham-2002 cultivar and the lowest value from Umranhanim cultivar. SDW values of the cultivars changed between 5.44 and 10.45 mg plant^{-1} with the highest value from Mikham-2002 cultivar and the lowest value from Umranhanim cultivar. BW values of the cultivars varied between 994.4 and 3019.2 mg Petri^{-1} with the highest value from Mehmetbey cultivar and the lowest value from Umranhanim cultivar.

3.2. Effects of Salt Doses on Germination Parameters and Seedling Properties

Salt doses had significant effects on germination parameters and seedling properties of triticale cultivars (Table 2). Mean values for GR, GI, MGT, RL and SL at different salt doses are given Table 5. Decreasing GR values were seen with increasing salt doses. As compared to control treatment, 240 mM salt dose yielded 38.29% reduction in GR. The GI values also decreased with increasing salt doses.

Table 2. Effects of cultivars, salt doses and their interactions on investigated parameters

Items	Cultivars (C)	Salt doses (SD)	C×SD
Germination ratio, GR, (%)	<.0001	<.0001	<.0001
Germination index, GI	<.0001	<.0001	<.0001
Mean germination time, MGT, (day)	<.0001	<.0001	<.0001
Root length, RL, (cm)	<.0001	<.0001	0.0002
Shoot length, SL, (cm)	<.0001	<.0001	0.0050
Root fresh weight, RFW, (mg/plant)	<.0001	<.0001	0.0002
Shoot fresh weight, SFW, (mg/plant)	<.0001	<.0001	0.0037
Root dry weight, RDW, (mg/plant)	<.0001	<.0001	0.0016
Shoot dry weight, SDW, (mg/plant)	<.0001	<.0001	0.0055
Biomass weight, BW, (mg/Petri)	<.0001	<.0001	<.0001

Table 3. Mean values and Tukey pair-wise test results for GR, GI, MGT, RL and SL of the cultivars

Cultivars	Investigated parameters				
	GR (%)	GI	MGT (day)	RL (cm)	SL (cm)
Alperbey	71.00±5.21 bcd	6.01±0.45 cd	4.19±0.20 bc	2.38±0.68 f	5.37±0.90 de
Aysehanim	81.25±4.59 ab	7.07±0.49 b	3.38±0.19 cde	9.67±1.46 a	7.78±1.18 bc
Bera	38.75±5.39 g	3.05±0.42 f	4.14±0.23 bc	3.32±0.40 ef	6.42±0.79 cd
Egeyildizi	78.75±4.78 ab	5.80±0.39 cd	4.84±0.21 b	5.30±0.77 cde	7.27±1.03 bc
Esin	36.50±5.80 g	3.21±0.48 f	4.58±0.37 b	6.81±1.38 bc	7.83±1.07 bc
Karma 2000	38.00±3.86 g	3.45±0.28 f	3.10±0.26 de	5.78±0.82 b-e	8.33±1.06 ab
Mehmetbey	87.25±3.49 a	8.16±0.27 a	3.21±0.12 de	8.42±1.13 ab	7.35±1.19 bc
Mikham-2002	60.75±4.52 def	4.79±0.39 e	4.88±0.21 b	4.50±0.48 c-f	7.66±1.03 bc
Ozer	60.50±5.06 ef	5.71±0.50 d	2.55±0.11 e	6.59±0.97 bcd	8.51±1.10 ab
Tatlicak 97	67.50±6.00 cde	5.61±0.51 de	4.61±0.24 b	4.12±0.63 def	5.21±0.92 de
Truva	74.75±5.97 bc	6.61±0.51 bc	3.71± 0.17cd	5.45±0.75 cde	9.97±1.20 a
Umranhanim	54.75±5.97 f	4.83±0.47 e	6.47±0.45 a	1.99±0.19 f	4.56±0.88 e

GR= germination ratio, GI= germination index, MGT= mean germination time, RL= root length, SL= shoot length.

Increasing MGT values were seen with increasing salt doses. The salt doses of 120, 180 and 240 mM yielded similar MGT values with 4.47, 4.51 and 4.37 days, respectively. RL values varied between 1.99 - 8.76 cm. Increasing salt doses significantly reduced RL values. As compared to control treatment, 240 mM salt dose reduced RL values by 22.72%. Similar findings were also observed for SL values. As compared to RL values, SL results were more affected by increasing salt doses.

The mean values for RFW, SFW, RDW, SDW and BW at different salt doses are given Table 6. RFW values ranged from 32.88 to 74.49 mg plant^{-1} with the highest value from the control treatment and the lowest value from 240 mM salt dose. Decreasing RFW values were seen with increasing salt doses. The salt doses of 180 mM and 240 mM yielded similar results. SFW values varied between 21.11 - 120.70 mg plant^{-1}. Significant decreases were seen in SFW values with increasing salt doses. RDW values varied between 6.51 - 8.90 mg plant^{-1} with the highest value from 60 mM salt dose and the lowest value from 240 mM salt dose. The 180 mM and 240 mM salt doses yielded similar results. In addition, control, 60 mM and 120 mM treatments yielded similar results. SDW values of control, 60 mM, 120 mM, 180 mM and 240 mM treatments were respectively recorded as 11.86, 10.95, 9.62, 7.20 and 4.18 mg plant^{-1}. BW values changed between 434.2 and 3599.9 mg Petri^{-1}. Decreasing BW values were seen with increasing salt doses.

Table 4. Mean values and Tukey pair-wise test results for RFW, SFW, RDW, SDW and BW of the cultivars

Cultivars	Investigated parameters				
	RFW (mg plant^{-1})	SFW (mg plant^{-1})	RDW (mg plant^{-1})	SDW (mg plant^{-1}	BW (mg Petri^{-1})
Alperbey	38.61±4.61 ^{def}	63.63±7.59 ^{bc}	5.78±0.53 ^{de}	8.14±0.78 ^{ab}	1057.9±231.7 ^{d}
Aysehanim	70.12±8.50 ^{ab}	75.80±10.04 ^{ab}	8.87±0.53 ^{ab}	8.75±0.83 ^{ab}	2635.9±394.5 ^{ab}
Bera	35.86±5.70 ^{ef}	68.59±6.69 ^{abc}	6.25±0.74 ^{cd}	9.16±0.79 ^{ab}	965.8±180.1 ^{d}
Egeyildizi	55.75±8.06 $^{b-e}$	68.56±9.11 ^{abc}	6.54±0.47 ^{cd}	9.30±0.76 ^{ab}	2180.9±350.1 ^{bc}
Esin	62.63±7.59 ^{abc}	73.37±10.60 ^{ab}	7.88±0.43 ^{bc}	9.81±0.83 ^{a}	2352.6±387.3 ^{b}
Karma 2000	57.46±4.84 ^{bcd}	85.95±11.64 ^{a}	6.59±0.60 ^{cd}	8.60±0.63 ^{ab}	1325.9±219.0 ^{d}
Mehmetbey	82.50±6.42 ^{a}	72.43±12.57 ^{ab}	10.49±0.34 ^{a}	8.54±1.04 ^{ab}	3019.2±379.7 ^{a}
Mikham-2002	70.17±5.86 ^{ab}	74.22±9.63 ^{ab}	10.85±0.57 ^{a}	10.45±0.96 ^{a}	2112.0±321.0 ^{bc}
Ozer	74.57±5.93 ^{ab}	80.04±10.58 ^{ab}	10.35±0.45 ^{a}	9.74±0.86 ^{a}	2111.5±345.8 ^{bc}
Tatlicak 97	43.21±4.64 ^{cde}	49.84±9.04 ^{cd}	6.76±0.41 ^{cd}	7.35±0.85 ^{bc}	1571.9±281.2 ^{cd}
Truva	57.16±7.10 ^{bcd}	81.40±9.85 ^{ab}	6.87±0.59 ^{bcd}	9.86±0.83 ^{a}	2452.4±364.2 ^{ab}
Umranhanim	21.07±1.98 ^{f}	38.81±6.10 ^{d}	4.00±0.36 ^{e}	5.44±0.65 ^{c}	994.4±153.4 ^{d}

RFW= root fresh weight, SFW= shoot fresh weight, RDW= root dry weight, SDW= shoot dry weight, BW= biomass weight.

Table 5. Mean values and Tukey pair-wise test results for GR, GI, MGT, RL and SL values at different salt doses

Salt doses (mM)	Investigated parameters				
	GR (%)	GI	MGT (day)	RL (cm)	SL (cm)
Control	88.96±1.74 ^{a}	7.77±0.22 ^{a}	3.48±0.13 ^{b}	8.76±0.75 ^{a}	12.35±0.33 ^{a}
60	76.15±3.35 ^{b}	6.53±0.28 ^{b}	3.87±0.15 ^{b}	8.05±0.74 ^{a}	11.04±0.39 ^{b}
120	62.50±3.59 ^{c}	5.21±0.31 ^{c}	4.47±0.23 ^{a}	5.11±0.40 ^{b}	7.57±0.42 ^{c}
180	50.73±3.25 ^{d}	4.19±0.25 ^{d}	4.51±0.23 ^{a}	2.90±0.20 ^{c}	3.63±0.27 ^{d}
240	34.06±2.49 ^{e}	3.09±0.22 ^{e}	4.37±0.26 ^{a}	1.99±0.12 ^{c}	1.34±0.13 ^{e}

GR= germination ratio, GI= germination index, MGT= mean germination time, RL= root length, SL= shoot length.

Table 6. Mean values and Tukey pair-wise test results for RFW, SFW, RDW, SDW and BW at different salt doses

Salt doses (mM)	Investigated parameters				
	RFW (mg plant^{-1})	SFW (mg plant^{-1})	RDW (mg plant^{-1})	SDW (mg plant^{-1})	BW (mg Petri^{-1})
Control	74.49±4.50 ^{a}	120.70±4.02 ^{a}	8.20±0.33 ^{a}	11.86±0.31 ^{a}	3599.9±176.5 ^{a}
60	73.52±4.92 ^{a}	96.78±3.83 ^{b}	8.90±0.43 ^{a}	10.95±0.48 ^{a}	2801.4±188.6 ^{b}
120	58.50±4.08 ^{b}	66.96±3.28 ^{c}	7.86±0.45 ^{a}	9.62±0.38 ^{b}	1772.5±152.4 ^{c}
180	39.40±2.98 ^{c}	41.39±4.60 ^{d}	6.52±0.39 ^{b}	7.20±0.38 ^{c}	883.8±68.4 ^{d}
240	32.88±2.82 ^{c}	21.11±1.97 ^{e}	6.51±0.47 ^{b}	4.18±0.35 ^{d}	434.2±41.8 ^{e}

RFW= root fresh weight, SFW= shoot fresh weight, RDW= root dry weight, SDW= shoot dry weight, BW= biomass weight.

3.3. Effects of Interactions (Cultivar × Salt Dose) on Germination Parameters and Seedling Properties

Cultivar × salt dose interactions had significant effects germination parameters and early seedling characteristics. Interaction bar-charts of all investigated properties are provided in Figure 1 - 10. The GR values of all cultivars decreased with increasing salt doses (Figure 1). In terms of GR, Mehmetbey cultivar was identified as the most resistant at 240 mM salt dose. The GI values of all Triticale cultivars also decreased with increasing salt dose (Figure 2). The highest GI at 240 mM salt dose was obtained from Mehmetbey cultivar. MGT values did change significantly with changing salt doses (Figure 3). However, as compared to other cultivars, MGT values of Umranhanim cultivar increased with increasing salt doses. RL values of Triticale cultivars substantially decreased with increasing salt doses (Figure 4). Similar results were also found for SL (Figure 5). These results indicated that seedling growth was adversely affected by increasing salt doses. The RFW values of the cultivars decreased with increasing salt doses (Figure 6). The lowest decrease in RFW was seen in Ozer cultivar. SFW values of all cultivars significantly decreased with increasing salt doses (Figure 7). In terms of SFW, Mehmetbey cultivar was identified as the most adversely affected from salt stress. The RDW and SDW values significantly decreased with increasing salt doses (Figure 8 and 9). All cultivars practically yielded identical results for RDW under 240 mM salt stress as compared to the control. The lowest SDW value was seen in 240 mM salt dose of Mehmetbey cultivar. The BW values of triticale cultivars decreased as the salt dose increased (Figure 10).

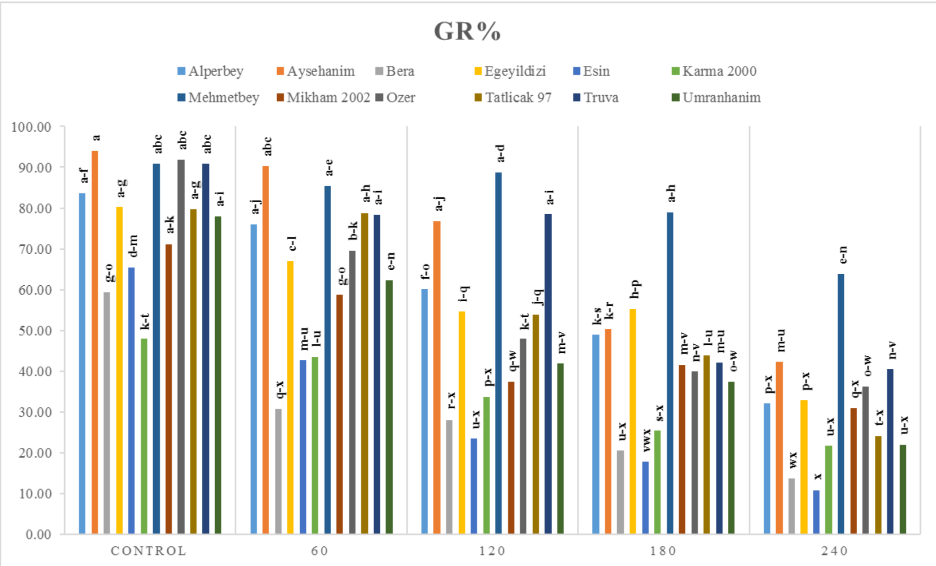

Figure 1. Effects of interactions on germination ratio (GR) of some Turkish triticale cultivars.

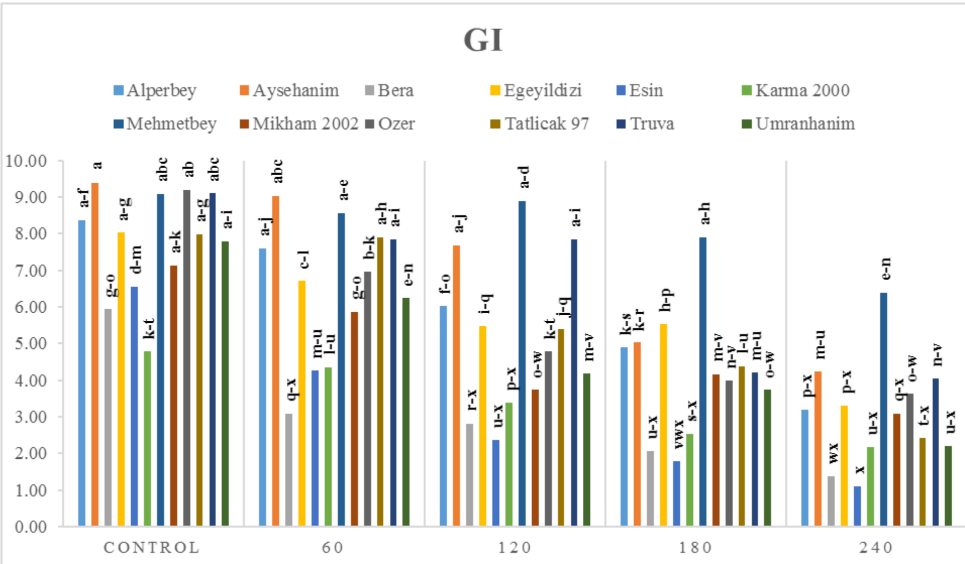

Figure 2. Effects of interactions on germination index (GI) of some Turkish triticale cultivars.

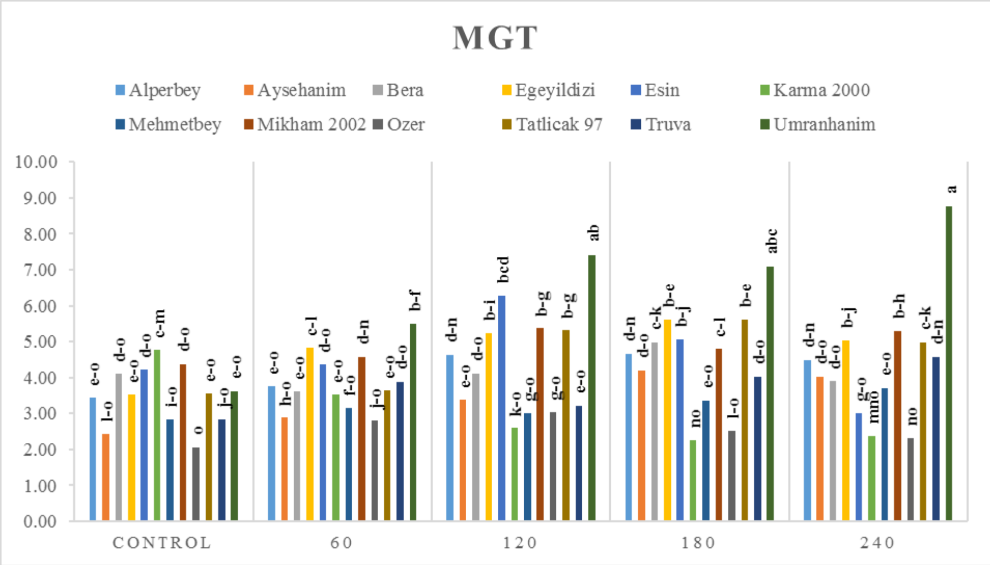

Figure 3. Effects of interactions on mean germination time (MGT) of some Turkish triticale cultivars.

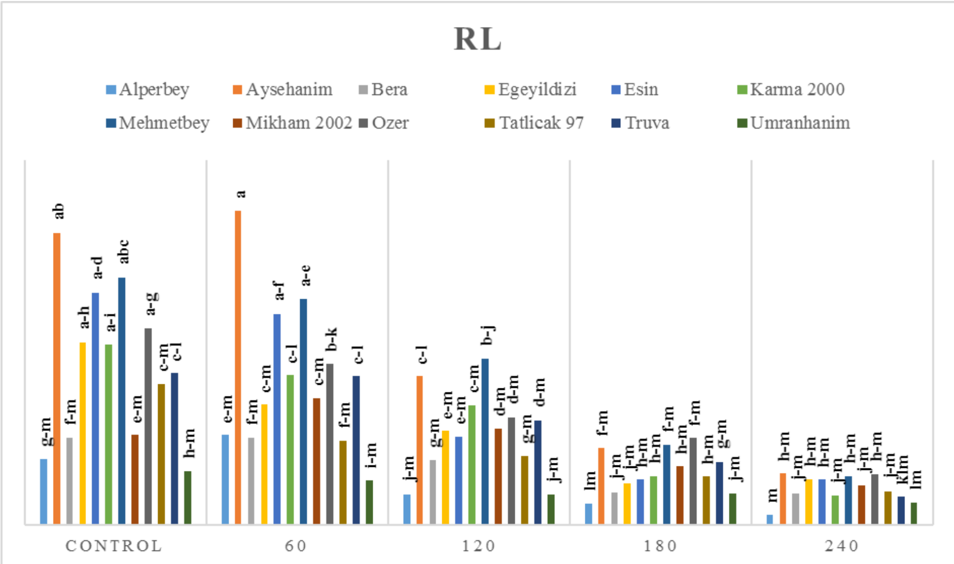

Figure 4. Effects of interactions on root length (RL) of some Turkish triticale cultivars.

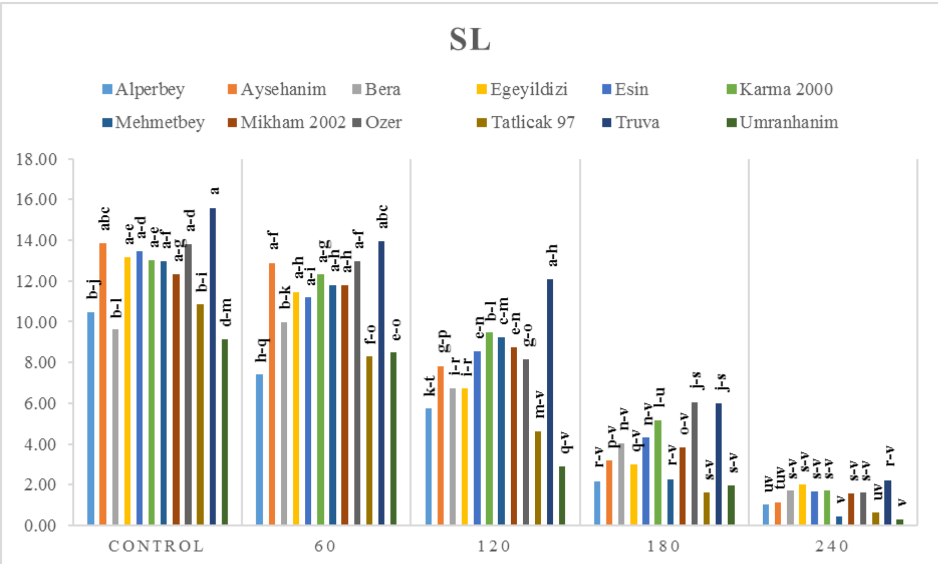

Figure 5. Effects of interactions on shoot length (SL) of some Turkish triticale cultivars.

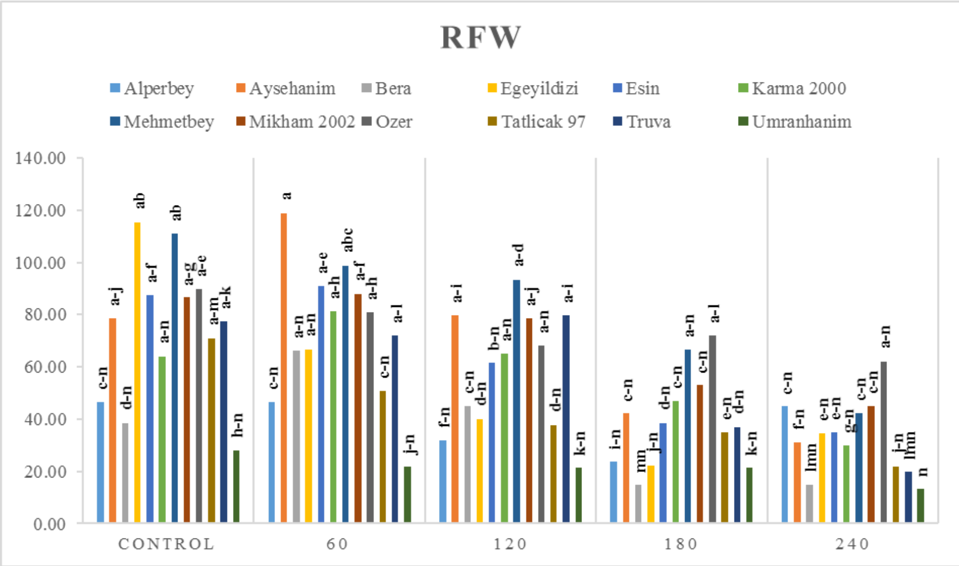

Figure 6. Effects of interactions on root fresh weight (RFW) of some Turkish triticale cultivars.

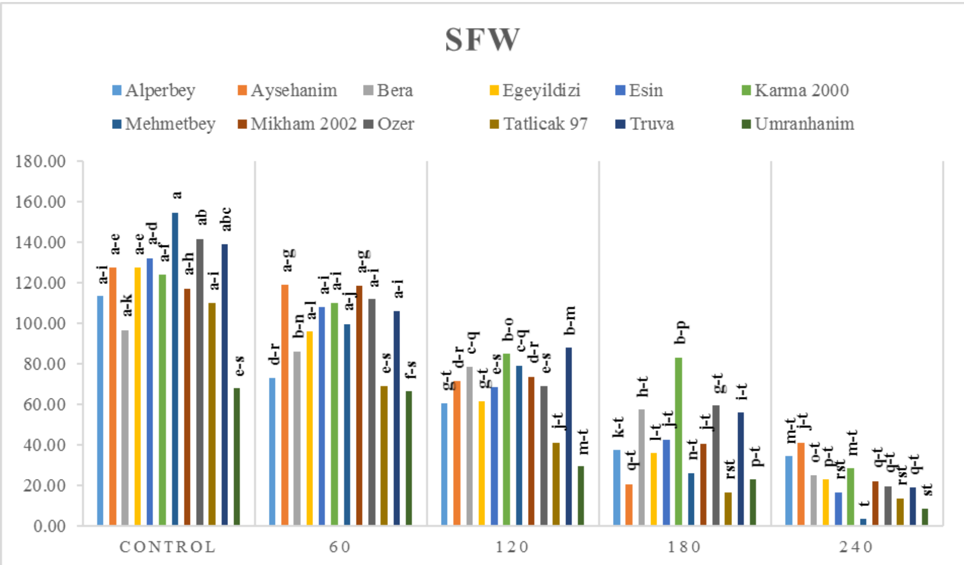

Figure 7. Effects of interactions on shoot fresh weight (SFW) of some Turkish triticale cultivars.

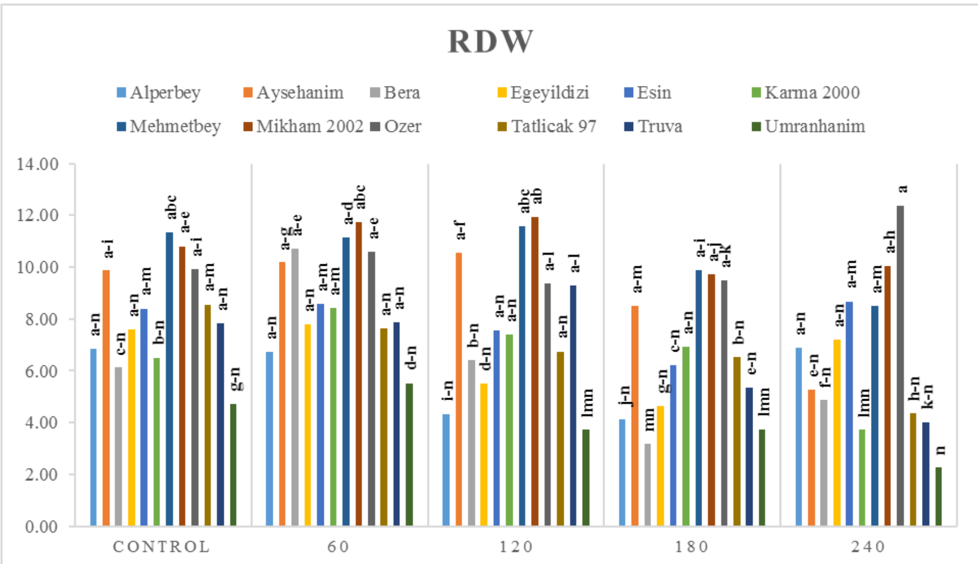

Figure 8. Effects of interactions on root dry weight (RDW) of some Turkish triticale cultivars.

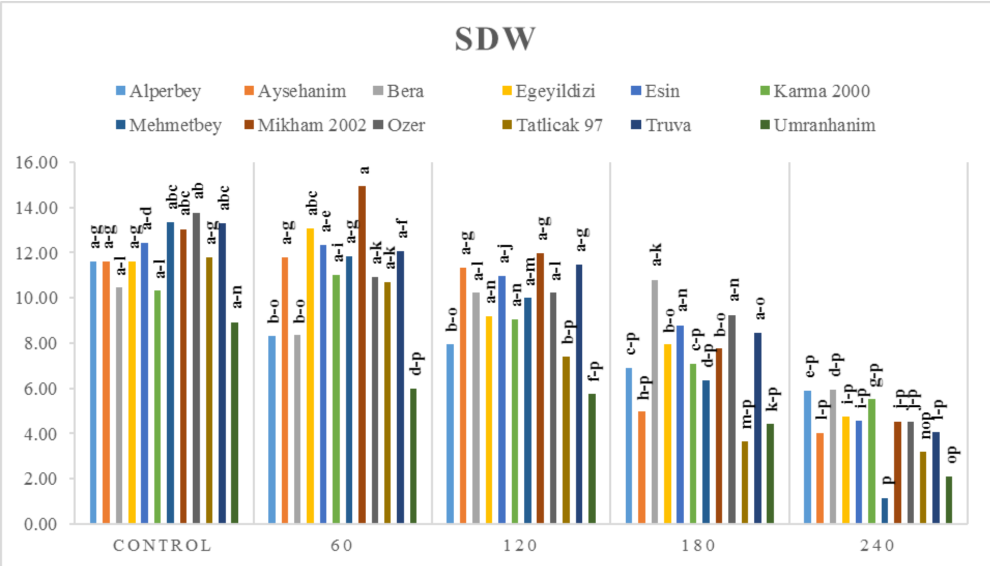

Figure 9. Effects of interactions on shoot dry weight (SDW) of some Turkish triticale cultivars.

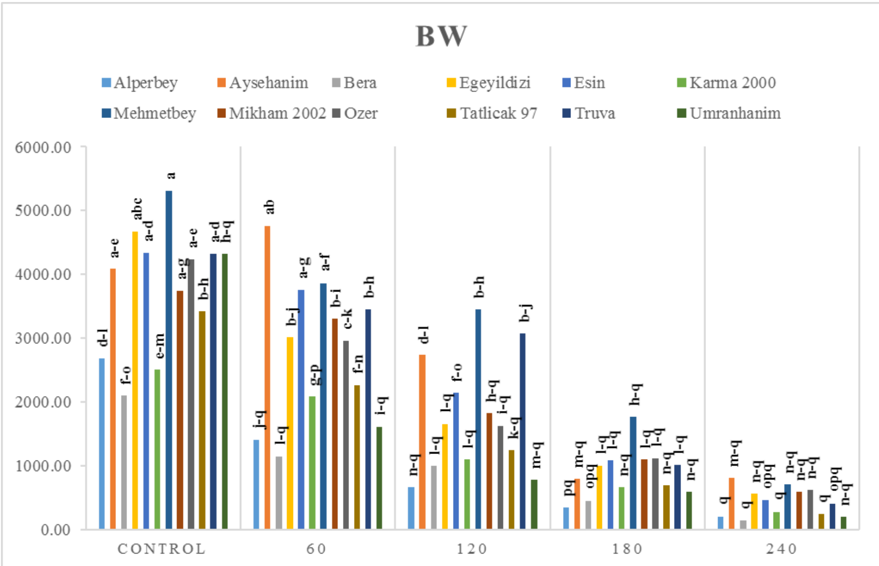

Figure 10. Effects of interactions on biomass weight (BW) of some Turkish triticale cultivars.

The GR values of the cultivars generally decreased with increasing salt doses (Figure 1). Germination ratio is a highly significant parameter for successful production of field crops particularly in salt-affected soils (Farooq et al., 2015). Similar to present germination ratios, it has been generally reported that germination of plants was adversely affected by increasing salt stress levels during the germination stage (Ashraf and Foolad, 2005; Atak et al., 2006; Farsiani and Ghobadi, 2009; Atış, 2011; Konuşkan et al., 2017). The GI values of the cultivars also decreased significantly with increasing salt doses (Figure 2). However, each triticale cultivar yielded different germination index results under different salt stress levels (Table 2). It has been reported in many studies that the germination index of plants decreased significantly with increasing salt doses (Khayatnezhad and Gholamin, 2011; Ologundudu et al., 2014; Ertekin et al., 2017; Süren and Kızılşimşek, 2020). On the other hand, similar to present findings, it was determined that different responses to increased salt stress levels occurred even among the cultivars of different plants (Bybordi and Tabatabaei, 2009; Khayatnezhad and Gholamin, 2011; Ologundudu et al., 2014). Salt stress caused an increase in mean germination time (MGT) characteristic of the cultivars (Figure 3). It has been reported by various research that mean germination time of plants was prolonged due to increasing salt stress doses (Nizam, 2011; Elouaer and Hannachi, 2012; Cokkizgin, 2012). Root and shoot lengths (RL and SL) of triticale cultivars decreased significantly with increasing salt doses. In terms of RL and SL characteristics, there were significant differences among cultivars (Table 2). It has been reported by various studies that increasing salt doses inhibit shoot and root growth of field crops (Rios-Gonzalez et al., 2002; Szalai and Janda, 2009; El Sayed and El Sayed, 2011; Qu et al., 2012). Root and shoot fresh weights (RFW and SFW) decreased as the salt dose increased (Figure 6 and Figure 7). It has been reported that root and shoot growth were significantly reduced in canola due to increasing doses (Bybordi and Tabatabsei, 2009). Although there was a growth regression in the roots at increasing salt stress levels, it was determined that the shoots were more adversely affected than the roots (Munns, 2012). In this study, in terms of root dry weight (RDW), each cultivar yielded different responses to different salt doses (Figure 8). Indeed, it has been reported that some cultivars have increased ion uptake and dry weight due to the salt in the germination medium, while some have no ion uptake and their root dry weights have decreased (Khayatnezhad and Gholamin, 2011; Nizam, 2011; Elouaer and Hannachi, 2012). Shoot dry weight (SDW) property of triticale cultivars was also adversely affected by increasing salt doses (Figure 9). It has been reported by various studies that shoot growth in plants was significantly restricted due to increasing salt doses (Atış, 2011; Ertekin et al., 2017; Ertekin et al., 2018; Ertekin et al., 2022). Biomass weight (BW) of triticale cultivars decreased as the salt dose increased (Figure 10). It has been reported by various studies that growth was restricted and biomass weight decreased in plants under various abiotic stress conditions (Ertekin et al., 2020; Ertekin and Bilgen, 2021; Aygün et al., 2022).

3.4. Evaluation of Cultivars by Principal Component Analysis

Correlation biplots of principle components 1 and 2 of the PCA results obtained from data of germination and early seedling properties of twelve triticale cultivars subjected different NaCl doses are illustrated in Figure 11. Principle component 1 (F1) described 59.46% of the original information and principle component 2 (F2) described 22.25% (81.1% by two principle components). PCA analysis allowed easy visualization of complex data on germination parameters and early seedling parameters of twelve triticale cultivars. To examine the contributors to the principle components, the germination and early seedling characteristics in F1 and F2 were compared. It was clear that GR, GI, RL, RFW, RDW and BW were grouped with positive axis on the upper right side of the biplot, suggesting that these parameters had a positive correlation among themselves. The cultivars clustered in the upper right of the biplot graph were Mehmetbey and Ayşehanim cultivar and thus, it can be said that these cultivars were superior in terms of the characteristics in the upper right. MGT values were clustered on the upper left side of the biplot, while SL, SFW and SDW were found on lower right portion of the biplot. Bera, Esin and Karma 2000 cultivars were further away from GR and GI parameters. Ümranhanim cultivar was found further away from many of the studies traits.

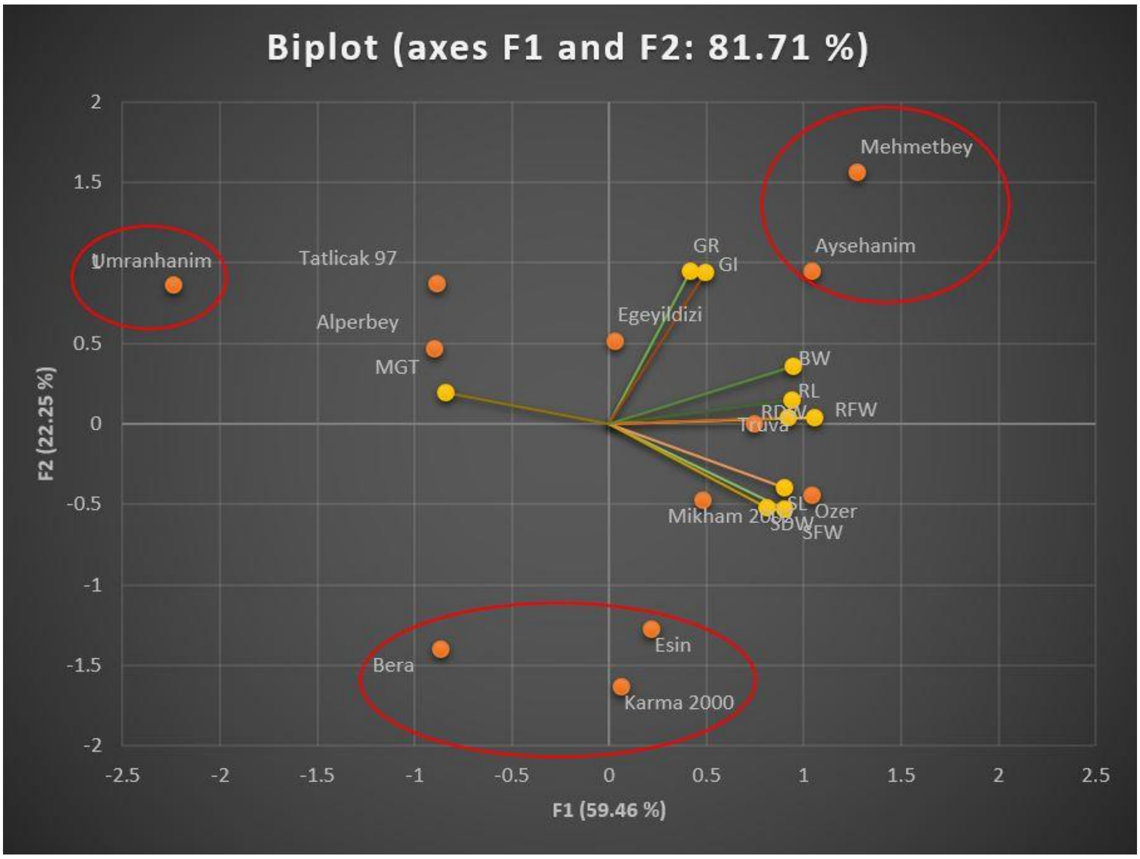

Figure 11. Correlation biplots of principle components 1 and 2 of the PCA results obtained from data on germination parameters and early seedling properties of twelve triticale cultivars subjected to different NaCl doses.

4. Conclusion

In this study, germination parameters and early seedling properties of Turkish triticale cultivars were investigated under different salt stress levels. In general, germination parameters and early seedling stage characteristics of the cultivars were adversely affected by increasing salt doses. Yet, it was determined that the response to increasing salt doses were different among the triticale cultivars. Although Mehmetbey cultivar was adversely affected by increased salt doses, it was found to be more resistant to saline conditions than the other cultivars. On the other hand, Umranhanim cultivar was identified as the most sensitive cultivar to salt stress. After investigating the resistance of Mehmetbey triticale cultivar to salt stress under field conditions, this cultivar can be included into breeding programs or cultivated in areas with salinity problems.

Author Contributions

The percentage of the author(s) contributions is presented below. All authors reviewed and approved the final version of the manuscript.

	M.A.	İ.E.	İ.A.
C	30	40	40
D	50	40	10
S	50		50
DCP	25	50	25
DAI	10	70	20
L	25	50	25
W	30	40	30
CR	40	20	40
SR	30	50	20
PM	60	20	20
FA	30	40	30

C=Concept, D= design, S= supervision, DCP= data collection and/or processing, DAI= data analysis and/or interpretation, L= literature search, W= writing, CR= critical review, SR= submission and revision, PM= project management, FA= funding acquisition.

Conflict of Interest

The authors declared that there is no conflict of interest.

Ethical Consideration

Ethics committee approval was not required for this study because there was no study on animals or humans.

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