

EFFECTS OF DIFFERENT IRRIGATION WATER SALINITY LEVELS ON GERMINATION OF DIPLOID, TETRAPLOID AND HEXAPLOID WHEAT

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Abstract

The present study was conducted with diploid (Einkorn), tetraploid (Ege 88, Akçakale 2000, Alibaba, Tüten, Şölen 2002) and hexaploid (Kaşifbey 95, Menemen, Saar, Cumhuriyet 79, Basribey 95) wheat cultivars to investigate the effects of different irrigation water salinity (ECi) levels (0.5 [control], 2, 4, 8, 12, 16, 20, 30, 40 dS/m) generated as to have a SAR value below 3 on germination ratio and germination power. Experiments were conducted in randomized plots design with 3 replications.

Variance analyses revealed that irrigation water salinity levels, wheat ploidy levels, cultivars, “cultivar x salinity level” and “salinity level x ploidy level” interactions had significant effects on germination ratio and germination power ($p < 0.05$). Effects of irrigation water salinity levels on germination ratio and germination power varied with cultivars and decreasing germination ratio and germination power values were observed in cultivars with increasing salinity levels. Considering the greatest irrigation water salinity level of 40 dS/m, it was observed that hexaploid cultivars had the greatest tolerance and they were respectively followed by tetraploid and diploid wheat cultivars.

Key words: wheat, ploidy, salinity, germination, emergence

1. INTRODUCTION

As it is in the entire world, wheat is the most common cereal produced and consumed in Turkey. Besides uses as human food as macaroni, bulgur, bread and other baked products, wheat is also used raw material in feed industry and bio-ethanol production. Within Triticum cultivar of Poaceae family, there are wheat cultivars at 3 different ploidy levels (*Triticum monococcum* (diploid: AA), *Triticum turgidum* L. (tetraploid: AABB) and *Triticum aestivum* L. (hexaploid: AABBDD)). Economic tetraploid and hexaploid wheat production are widely performed throughout the world. On the other hand, diploid wheat is locally produced in small quantities in Turkey and some Middle-East countries.

Low quality irrigation waters have various negative impacts on both cultivation lands and plants. Salinity has osmotic and toxic effects on plants and significantly effects plant nutrient uptake (Lewitt 1980). While the osmotic and plant nutrient uptake effects are considered as secondary impacts, toxic effects are considered as primary salt damages. Besides osmotic and ionic stress, salinity also results in hormonal imbalance and negatively affects plant growth and development (Ashraf and Foolad 2007). Kanber and Ünlü (2010) indicated increasing difficulties in plant water uptake from the soil with increasing soil salt concentrations and reported degraded soil structure and regressed plant growth with salinity. In culture crops, increasing ambient salinity result in reduced yield and plant resistance levels. Ayers and Westcot (1989) reported threshold ECi value as 4 dS/m for salt-resistant bread wheat cultivars and as 3.8 dS/m for durum wheat cultivars. The threshold ECi value at which yield loss reaches to 50% was reported as 8.7 dS/m for bread wheat cultivars and as 10 dS/m for durum wheat cultivars. Considering the soil salinity (ECe), the threshold value without a yield loss was indicated as 6 dS/m for bread wheat cultivars and as 5.7 dS/m for durum wheat cultivars. The ECe value for 50% yield loss was reported as 13 dS/m for bread wheat cultivars and as 15 dS/m for durum wheat cultivars.

The reasons for yield losses in plants grown over saline lands are indicated as distortions in plant ion balance with the toxic impacts of excessive Na and Cl concentrations, the problems experienced in nutrient uptake and transport to different regions of the plant, distortions in photosynthesis, respiration and other physiological processes (Flowers and Yeo 1981, Leopold and Willing 1984, Kalefetoğlu and Ekmekçi 2005). In plants under salt stress, excess Na accumulation may restrict K intake (Siegel et al. 1980), Cl may hinder NO₃ intake (İnal et al. 1995) and ultimately alter the plant ion balance. Salt stress may sometimes result in total die out of plants, may hinder plant growth based on salt stress and plant resistance and may result in necrosis over leaves, chlorosis, pollination disorders, small fruit sizes, low quality and yield losses (Özcan et al. 2001). Soil salt concentration effect plant growth at different levels and different plants may present different responses against soil salinity (Kara et al. 2011). Salinity is one the most significant environmental factors effecting simultaneous germination in arid and semi-arid regions (Demir et al. 2003). In salinity researches carried out to determine plant response to salt stress, germination and seedling developing stages were much considered (Van Hoorn et al. 2001). The present study was conducted to investigate the effects of different irrigation water salinity levels on germination ratio and germination power of wheat cultivars with different ploidy levels.

2. MATERIAL AND METHOD

The present study was conducted in 2015 at experimental laboratory of Lapseki Vocational Collage of Çanakkale Onsekiz Mart University. The diploid (Einkorn), tetraploid (Ege 88, Akçakale 2000, Alibaba, Tüten, Şölen 2002) and hexaploid (Kaşifbey 95, Menemen, Saar, Cumhuriyet 79, Basribey 95) wheat cultivars were used as the plant material of the study. Experiments were conducted in randomized plots design with 3 replications.

Different irrigation water salinity levels (0.5 [control], 2, 4, 8, 12, 16, 20, 30, 40 dS/m) were generated by using different salt sources (NaCl, MgCl₂, CaCl₂) as to have a SAR value less than 3. Ca/Mg ratio was also tried to be less than 1. For each genotype, 20 seeds were placed in petri dishes (9 cm diameter) with Whatman No.1 filter paper. Then, 10 ml salt solutions with different salinity levels were added to petri dishes and they were sealed with parafilm to prevent evaporation. Seeds were kept in petri dishes with different salt concentrations for 7 days under laboratory conditions and germinated seeds were counted in every day. Observations were performed at the same hour of the day. The seeds were accepted as germinated when 3 rootlets were observed at least in 1 cm. Germination ratios were calculated for each petri dish (Atak et al. 2006). The germination ratio of the third day was considered as germination ratio and the germination ratio of the seventh day was considered as germination power.

Resultant data were subjected to variance analysis with JMP 5 statistical software and treatments means were compared with Tukey test.

3. RESULTS

Variance analyses revealed that irrigation water salinity levels, wheat ploidy levels and “salinity level x ploidy level” interaction had significant effects on germination ratio and germination power ($p < 0.05$) Mean groupings of Tukey test are provided in Table 1 and 2.

Effects of irrigation water salinity levels on germination ratio and germination power of diploid wheat were found to be significant ($p < 0.05$). Tukey test groups are provided in Table 3.

Irrigation water salinity levels, cultivar and “cultivar x salinity level” interactions had significant effects on germination ratio and germination power of tetraploid wheat ($p < 0.05$). Tukey test groups are provided in Table 4 and 5.

Variance analyses revealed that irrigation water salinity levels, cultivar and “cultivar x salinity level” interactions had significant effects on germination ratio and germination power of hexaploid wheat ($p < 0.05$). Tukey test groups are provided in Table 6 and 7.

With regard to germination ratio, when the “salinity level x ploidy level” interactions were assessed, it was observed that hexaploid wheat was more tolerant than diploid and tetraploid wheat. While hexaploid wheat was negatively affected from the greatest dose of 40 dS/m, diploid and tetraploid wheat were negatively affected from 30 and 40 dS/m levels. Considering the germination ratio of ploidy levels, it was observed that hexaploid wheat had the greatest tolerance and it was respectively followed by diploid and tetraploid wheat (Table 1, 2). With regard to germination power, when the “salinity level x ploidy level” interactions were assessed, it was observed that hexaploid, diploid and tetraploid wheat were negatively affected at the greatest EC_i level of 40 dS/m. Considering the germination power of ploidy levels, it was observed that hexaploid wheat had the greatest tolerance and it was respectively followed by diploid and tetraploid wheat (Table 1, 2).

The effects of different irrigation water salinity levels on germination ratio and germination power of diploid wheat varied based on cultivars. Increasing irrigation water salinity levels decreased germination ratio and germination powers. The EC_i levels of 30 and 40 dS/m had the greatest impact on germination ratio and 40 dS/m irrigation water salinity level had the greatest impact on germination power (Table 3).

The effects of different irrigation water salinity levels on germination ratio and germination power of tetraploid wheat also varied based on cultivars and decreasing germination ratio and germination powers were observed with increasing irrigation water salinity levels. With regard to germination ratio, the cultivars Akçakale 2000 and Alibaba exhibited higher tolerance to increasing irrigation water salinity levels and the greatest effects were observed in cultivars Tüten, Ege 88 and Şölen 2002. With regard to germination power, the cultivars Akçakale 2000, Alibaba, Ege 88 and Tüten exhibited greater tolerance to increases in irrigation water salinity levels than the cultivar Şölen 2002 and the greatest effects were observed in cultivar Şölen 2002. The irrigation salinity levels with the greatest effects both on germination ratio and germination power were identified as 30 and 40 dS/m for Şölen 2002 cultivar and as 40 dS/m for the other cultivars (Table 4, 5).

The effects of different irrigation water salinity levels on germination ratio and germination power of hexaploid wheat varied based on cultivars and decreasing germination ratio and germination powers were observed with increasing irrigation water salinity levels. The cultivars Kaşifbey 95, Saar, Cumhuriyet 79 and Basribey 95 exhibited higher tolerance to increasing irrigation water salinity levels than the cultivar Menemen and the greatest effects were observed in Menemen cultivar. The irrigation salinity levels with the greatest effects both on germination ratio and germination power were identified as 30 and 40 dS/m for Menemen cultivar and as 40 dS/m for the other cultivars (Table 6, 7).

Considering the greatest irrigation water salinity level of 40 dS/m, the hexaploid cultivars were identified as the most tolerant ones and they were respectively followed by tetraploid wheat and diploid wheat (Table 1, 2).

In general, contrary to findings of previous researchers indicating that regress in germination ratio was observed at lower salinity levels (Mesta 1995, Çavdar 1997, Konak et al. 1999, Kara et al. 2011), the regress started at 30 dS/m salinity level in this study and this was considered to be resulted from low SAR values (SAR < 3 dS/m) of the present study.

4. DISCUSSION

The different responses to salinity levels were mostly because of genetics of the cultivars. The primary reason for negative effects of high salt concentrations in germination period was the inhibition of water intake of seed for germination (Mansour 1994).

It was indicated in previous studies that normal cell metabolism was hindered by reactive oxygen species formed under salt stress, lipids and proteins were impaired and DNA mutations were observed under salt stress (Dat et al. 2000, Implay 2003), salt stress also resulted in cell nucleus deformations (Katsuhara and Kawasaki 1996), activation or inactivation of genes required for some proteins (Alfieri and Petronini 2007), structural deformations in nucleus (Werker et al. 1983). The damages exerted on

cell nucleus and chromosomes negatively affect cell division and consequently germination of the seeds.

SAR values, one of the most significant parameter in assessment of irrigation water quality, were mostly disregarded in majority of previous salinity researches. These studies mostly focused on sodium damage. However, there are other salt types in natural irrigation waters (like $MgCl_2$, $MgCO_3$, $MgSO_4$, $CaCl_2$, $CaCO_3$, $CaSO_4$) other than sodium salt ($NaCl$).

Current findings comply with the results of previous researchers (Pujol et al. 2000, Tobe et al. 2001, Rubio-Casal et al. 2003, Datta et al. 1999, Mamoodzadeh et al. 2013, Yang et al. 2014) indicating decreasing germination ratios with increasing salinity levels.

Current findings were also supported by the results of earlier studies (Dubcovsky and Dvorak 2007, Munns and Tester 2008, Feldman et al. 2012, Yang et al. 2014) indicating increasing physiological and ecological adaptation with increasing ploidy levels in wheat and reporting higher adaptation capacities for hexaploid wheat than for diploid and tetraploid wheat.

As to conclude, when the irrigation water SAR value was kept under 3 dS/m, negative effects of irrigation water salinity on germination ratio and germination power started at 30 dS/m level and hexaploid wheat was more tolerant to salinity and it was followed respectively by tetraploid and diploid wheat.

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Table 1. Tukey groups of germination ratio (%) at different ploidy levels of wheat under different salinity levels of irrigation water

Salinity Levels (dS/m)	Ploidy levels			Means
	Hexaploid	Tetraploid	Diploid	
0	100,00 a*	100,00 a	98,67 a	99,56 A***
2	100,00 a	100,00 a	98,00 a	99,11 A
4	100,00 a	100,00 a	95,67 a	98,33 A
8	100,00 a	100,00 a	95,33 a	98,11 A
12	100,00 a	100,00 a	92,00 a	97,11 A
16	100,00 a	100,00 a	97,33 a	98,56 A
20	100,00 a	96,67 a	89,67 a	94,56 A
30	99,00 a	66,67 b	66,00 b	73,89 B
40	40,33 c	23,33 d	8,33 e	24,00 C
Means	91,33 A**	87,41 B	82,33 C	

* Levels not connected by same letter are significantly different, Alpha=0,05 Q=3,89741

** Levels not connected by same letter at same line are significantly different, Alpha=0,05 Q=2,40999

*** Levels not connected by same letter at same column are significantly different, Alpha=0,05 Q=3,23076

Table 2. Tukey groups of germination power (%) at different ploidy levels of wheat under different salinity levels of irrigation water

Salinity Levels (dS/m)	Ploidy levels			Means
	Hexaploid	Tetraploid	Diploid	
0	100,00 a*	100,00 a	100,00 a	100,00 A
2	100,00 a	100,00 a	100,00 a	100,00 A
4	100,00 a	100,00 a	100,00 a	100,00 A
8	100,00 a	100,00 a	100,00 a	100,00 A
12	100,00 a	100,00 a	100,00 a	100,00 A
16	100,00 a	100,00 a	100,00 a	100,00 A
20	100,00 a	100,00 a	100,00 a	100,00 A
30	99,00 a	100,00 a	89,00 ab	96,00 A
40	76,67 b	36,67 c	17,33 d	43,56 B***
Means	97,30 A**	92,96 B	89,60 C	

* Levels not connected by same letter are significantly different, Alpha=0,05 Q=3,89741

** Levels not connected by same letter at same line are significantly different, Alpha=0,05 Q=2,40999

*** Levels not connected by same letter at same column are significantly different, Alpha=0,05 Q=3,23076

Table 3. Tukey groups of germination ratio (%) and germination power (%) of diploid wheat under different salinity levels of irrigation water

Salinity levels (dS/m)	Germination ratio (%)	Germination power (%)
	100,00 a*	100,00 a*
2	100,00 a	100,00 a
4	100,00 a	100,00 a
8	100,00 a	100,00 a
12	100,00 a	100,00 a
16	100,00 a	100,00 a
20	96,67 a	100,00 a
30	66,67 b	100,00 a
40	23,33 c	36,67 b

Alpha= 0,050 Q=3,50384 * Levels not connected by same letter at same column are significantly different

Table 4. Tukey groups of germination ratio (%) of tetraploid wheat varieties under different salinity levels of irrigation water

Salinity levels (dS/m)	Varieties				
	Akçakale 2000	Alibaba	Tüten	Ege 88	Şölen 2002
0	100,00 a*	100,00 a	100,00 a	100,00 a	93,33 a
2	100,00 a	100,00 a	100,00 a	96,67 a	93,33 a
4	100,00 a	100,00 a	96,67 a	93,33 a	88,33 ab
8	98,33 a	100,00 a	96,67 a	86,67 ab	90,00 ab
12	100,00 a	76,67 a-c	93,33 a	100,00 a	96,67 a
16	96,67 a	96,67 a	100,00 a	96,67 a	96,67 a
20	98,33 a	83,33 a-c	96,67 a	83,33 a-c	86,67 ab
30	81,67 a-c	81,67 a-c	60,00 cd	66,67 bc	40,00 de
40	3,33 g	0,00 g	30,00 ef	6,67 g	1,67 g

Alpha=0,050 Q= 4,0857 * Levels not connected by same letter are significantly different

Table 5. Tukey groups of germination power (%) of tetraploid wheat varieties under different salinity levels of irrigation water

Salinity levels (dS/m)	Varieties				
	Akçakale 2000	Alibaba	Tüten	Ege 88	Şölen 2002
0	100,00 a*	100,00 a	100,00 a	100,00 a	100,00 a
2	100,00 a	100,00 a	100,00 a	100,00 a	100,00 a
4	100,00 a	100,00 a	100,00 a	100,00 a	100,00 a
8	100,00 a	100,00 a	100,00 a	100,00 a	100,00 a
12	100,00 a	100,00 a	100,00 a	100,00 a	100,00 a
16	100,00 a	100,00 a	100,00 a	100,00 a	100,00 a
20	100,00 a	100,00 a	100,00 a	100,00 a	100,00 a
30	100,00 a	100,00 a	90,00 a	90,00 a	65,00 b
40	3,33 d	6,67 d	43,33 c	30,00 c	3,33 d

Alpha=0,050 Q= 4,0857 * Levels not connected by same letter are significantly different

Table 6. Tukey groups of germination ratio (%) of hexaploid wheat varieties under different salinity levels of irrigation water

Salinity levels (dS/m)	Varieties				
	Saar	Basribey 95	Cumhuriyet 79	Kaşifbey 95	Menemen
0	100,00 a*	100,00 a	100,00 a	100,00 a	96,67 a
2	100,00 a	100,00 a	100,00 a	100,00 a	96,67 a
4	100,00 a	100,00 a	100,00 a	100,00 a	96,67 a
8	100,00 a	100,00 a	100,00 a	100,00 a	95,00 a
12	100,00 a	100,00 a	100,00 a	100,00 a	96,67 a
16	100,00 a	100,00 a	100,00 a	100,00 a	91,67 a
20	100,00 a	96,67 a	100,00 a	98,33 a	90,00 a
30	100,00 a	86,67 a	86,67 a	81,67 a	65,00 b
40	53,33 b	43,33 bc	56,67 b	18,33 b	30,00 cd

Alpha=0,050 Q= 4,0857 Levels not connected by same letter are significantly different

Table 7. Tukey groups of germination power (%) of hexaploid wheat varieties under different salinity levels of irrigation water

Salinity levels (dS/m)	Varieties				
	Saar	Basribey 95	Cumhuriyet 79	Kaşifbey 95	Menemen
0	100,00 a*	100,00 a	100,00 a	100,00 a	100,00 a
2	100,00 a	100,00 a	100,00 a	100,00 a	100,00 a
4	100,00 a	100,00 a	100,00 a	100,00 a	100,00 a
8	100,00 a	100,00 a	100,00 a	100,00 a	100,00 a
12	100,00 a	100,00 a	100,00 a	100,00 a	100,00 a
16	100,00 a	100,00 a	100,00 a	100,00 a	100,00 a
20	100,00 a	100,00 a	100,00 a	100,00 a	100,00 a
30	100,00 a	100,00 a	100,00 a	100,00 a	95,00 ab
40	90,00 b	90,00 b	86,67 b	41,67 d	75,00 c

Alpha=0,050 Q= 4,0857 Levels not connected by same letter are significantly different