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Original Contribution

SALINITY EFFECTS ON SEED GERMINATION AND SEEDLING GROWTH OF BREAD WHEAT CULTIVARS

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ABSTRACT

Salinity effects were evaluated on seed germination and seedling growth of six bread wheat cultivars (*Triticum aestivum* L) including Hirmand, Chamran, Hamoon, Bolani, Sorkhtokhm and Kavir. The seeds were grown in pots and subjected to six levels of electrical conductivity (Ec) 0, 2.5, 5, 7.5, 10 and 12.5 ds/m. The measured factors consisted of water uptake, germination percentage, shoot and root dry weight, shoot and root lengths and Na^+ and K^+ uptake amounts by seeds. The experimental design was randomized complete block design used as factorial arrangement of treatments (cultivars and NaCl levels) with three replicates. Water uptake by seeds showed to have a direct relationship with increases in NaCl levels. The highest water uptake level was recorded in Hamoon and Kavir cultivars. By increasing NaCl concentration, seed germination delayed and decreased in all cultivars. The lowest germination percentage took place in Chamran and Bolani cultivars and the highest germination in Kavir and Hamoon cultivars. The largest shoot length was observed in the controls of Sorkhtokhm and Bolani cultivars. The largest root length obtained in Hamoon, Hirmand, Chamran cultivars and the lowest in Kavir cultivar. Increasing NaCl concentrations adversely affected shoot dry weight in each cultivar; shoot dry weight fluctuated by varying NaCl concentrations. The lowest value found in Chamran cultivar. Differences in root dry weight were not significant in different cultivars; the highest root dry weight was found in Chamran and Hamoon cultivars. The root to shoot dry weight ratio changed in different NaCl levels. High NaCl levels caused a remarkable increase in the root to shoot dry weight ratio. The highest ratio was obtained in Hamoon cultivar and the lowest ratio in Sorkhtokhm and Kavir cultivars. Seedling dry matter decreased by increasing salinity. Salinity increased the accumulation of Na^+ and decreased the K^+ content in roots and shoots. The Na^+ content of germinated seeds gradually increased, while the K^+ level diminished. Hamoon, Sorkhtokhm and Bolani cultivars appeared to be more tolerant to salt stress than the others. It was concluded that the delay in germination was mainly due to higher Na^+ accumulation in the seeds rather than osmotic stress in wheat cultivars.

Key words: Germination percentage; Seedling growth; Salinity; Bread wheat

INTRODUCTION

Salinity is one of the most important abiotic stresses limiting crop production in arid and semiarid regions, where soil salt content is naturally high and precipitation can be insufficient for leaching (1, 2). Salinity affects many morphological, physiological and biochemical processes, including seed germination, plant growth, and water and nutrient uptake (3). Wheat (*Triticum aestivum* L.) is the staple foods for more than 35% of world population (4). Marginal environments include any environmental conditions that negatively affect the expression of genetic potential for growth, development and reproduction. Wheat grain yield is depressed, among other factors, by environmental stresses such as drought, heat, low temperatures, low fertility (especially nitrogen) and soil salinity (5). Seed germination and seedling growth of wheat, like other crops, were negatively

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affected by drought (6) and salinity stresses (7). Any effect that drought might have should be most considerable under salt-stressed conditions, because salinity can affect germination and seedling growth either by creating an osmotic pressure (OP) that prevents water uptake or by toxic effects of sodium and chloride ions on the germinating seed (5). Salt accumulation in soils affects plant growth to different degrees (8). However, in the same saline environment, different plant species may exhibit different growth responses (5). A prerequisite for successful production is a well stand establishment. One of the major environmental stress factors which adversely affect on uniform germination is salinity in arid and semi-arid regions (9).Many researchers have reported that several plants are sensitive to high salinity during germination and the seedling stage (10). The source of the sensitivity to salinity is not fully understood. Some researchers have indicated that the main reason for germination failure was the inhibition of seed water uptake due to a high salt concentration (5), whereas others have suggested that germination was affected by salt toxicity (5, 11).

Wheat is the major crop in Iran (12). It is cultivated over a wide range of environments, because of wide adaptation to diverse environmental conditions. It is a moderately salt-tolerant crop (13, 2). In Iran, 6.2 million hectares are under wheat cultivation, of which 33% is irrigated and 67% is rain fed, the irrigated wheat growing areas (2 million hectares) are located mostly in southern, central and eastern of Iran (12).

The objective of this research was to determine the effects of salinity on water uptake, seed germination, seedling growth, Na^+ and K^+ uptake rate by seeds of bread wheat cultivars during germination at various concentrations of NaCl, and selection of saline tolerant cultivars for breeding programs.

MATERIALS AND METHODS

Seed materials

Seeds of six bread wheat cultivars (*Triticum aestivum* L.) including Hirmand, Chamran, Hamoon, Bolani, Sorkhtokhm and Kavir were used for the study. The seeds were obtained from the Agricultural Research Center of Zabol. The cultivars were introduced in Sistan area (14). Before cultivation, seeds were sterilized in 1% sodium hypochlorite solution for 3 min, and then were rinsed with sterilized water and were air-dried.

Preparation of NaCl solutions

The solutions were prepared based on methods by (15) with electrical conductivity (Ec) of 0 (as control), 2.5, 5, 7.5, 10 and 12.5 ds/m.

Experimental details

To estimate salinity effects on seed germination and seedling growth of six bread wheat cultivars a randomized complete block design was used with a factorial arrangement of treatments (cultivars and NaCl levels) with three replicates.

Water uptake

Water uptake was recorded at 12 and 24 hours after planting. Water uptake percentage was calculated by the formula given below (16).

Water uptake % = (W2 –W1/W1)100

W1 = Initial weight of seed

W2 = Weight of seed after absorbing water in particular time

Germination test

The experiment was carried out in three replicates where 20 seeds from each cultivar were separately germinated on two sheets of Whatman No.1 filter paper placed in 9-cm diameter Petri dishes. Priority, 10 ml from one respective test solution was poured into the plate. The papers were altered once after every 2 days to prevent salt accumulation (17). The plates were placed into an incubator at 25 ± 2°C in darkness for 8 days (18). Germination percentages were recorded every 24 h for 4 days. Mean germination was calculated to assess the germination rate (19).

Emergence test

The experiment was carried out in pots filled with sand. Twenty seeds from each cultivar were separately sown per pot at the depth of 3cm. The experiment had three replications. The pots were placed in a green house. The data for the shoot length (cm), root length (cm), root/shoot ratio, dry weight of root (g) and dry weight of shoot (g) were measured eighth days after germination (20). Dry weights were measured after drying at 70°C for 48 h into an oven (21).

Data analysis

The data were analyzed using the Fisher’s analysis of variance technique under randomized complete block design and the treatment means were compared by Least

Significant difference (LSD) test at 0.05 probability levels.

RESULTS

Water uptake

A direct relationship was observed between water uptake by seeds and increase of NaCl concentration up to 10 ds/m **(Figure 1)**. When NaCl concentration increase to 12.5 ds/m the water uptake ability decrease in comparison to controls. It decreased to 8.26%, 9.36%, 8.19%, 8.61%, 10.21% and 7.61% after 24 hours in Hirmand, Chamran, Hamoon, Bolani, Sorkhtokhm and Kavir cultivars, respectively. Maximum water uptake was recorded in Hamoon and Kavir cultivars. Based on water uptake the cultivars can be arranged in the following order:

Hamoon> Kavir> Bolani> Chamran> Hirmand > Sorkhtokhm

Seed germination

Effect of increasing NaCl levels on germination percentage after 48 and 96 hours (final germination) is shown in **Figure 2**. Results showed by increasing NaCl concentration, germination is delayed and decreased germination in all cultivars. The maximum germination percentage was observed in Kavir and Hamoon cultivars and the lowest in Chamran and Bolani. Based on germination the cultivars can be arranged in the following order:

Kavir> Hamoon> Hirmand> Sorkhtokh> Bolani >Chamran

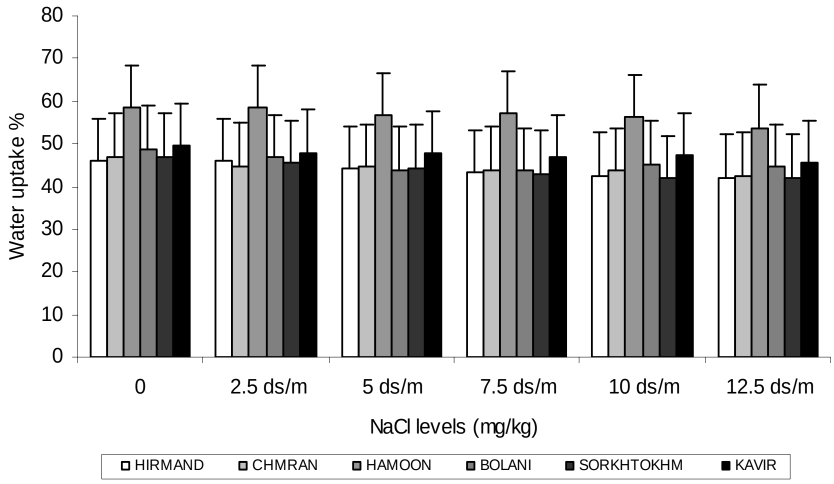

Figure 1. Effects of NaCl concentration on water uptake by wheat seeds after 12 hours. The bar on each column shows the standard error

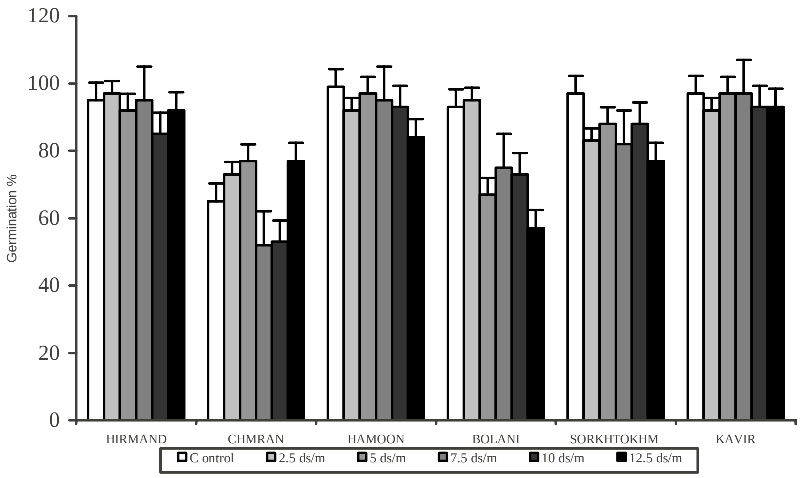

Figure 2. Mean germination of wheat cultivars in different NaCl levels. The final germination percentage is shown after 96 hours .The bar on each column shows the standard error

Seedling growth

Mean of shoot length varied between 11.525 and 17.207 cm at various NaCl concentrations. The longest shoot length was observed in the control of Sorkhtokhm and Bolani cultivars. By increasing NaCl concentrations, shoot length of Chamran, Hamoon, Bolani, Hirmand, Sorkhtokhm and Kavir cultivars decreased to 17%, 14%, 16%, 13%, 19% and 17% respectively. Results showed that the shoot growth of Chamran, Hamoon and Hirmand were more affected by NaCl levels **(Table 1)**.

Mean of root length varied between 7.73 and 11.525 cm in various NaCl concentrations. As was expected, the control and the highest NaCl concentration had the longest and shortest root length respectively. Generally, root length decreased as NaCl concentration increased. The largest root length was 10.165 cm obtained in Hamoon cultivar. In Chamran and Kavir cultivars root lengths were significantly decreased by increasing NaCl levels **(Table 1)**.

Increasing NaCl concentrations adversely affected shoot dry weight **(Table 2)** although 2.5 ds/m gave the highest value of 0.119 gr/plant. Shoot dry weight fluctuated in different NaCl concentrations. The lowest value (0.064) was determined at 12.5 ds/m in Hirmand cultivar.

Difference in root dry weight was not significant in different cultivars. However, it adversely affected by different NaCl levels. Higher NaCl concentrations resulted in a significant reduction in root dry weight **(Table 2).** Results showed that Hamoon and Sorkhtokhm cultivars with 0.111 and 0.106 gr/plant, respectively, had more root dry weights than others.

There were significant differences among the cultivars at NaCl levels for root to shoot dry weight ratio. The more NaCl levels, the higher root to shoot dry weights. The highest ratio was 1.25 ds/m obtained at 12.5 ds/m. Sorkhtokhm and Hamoon cultivars had ratios that were 1.02 and 1.009; respectively **(Table 2)**. The lowest ratios were 0.82 and 0.88 for Hirmand and Chamran cultivars, respectively. Seedling dry matter deceased by increasing salinity. The highest dry matter was obtained in Hamoon and Sorkhtokhm cultivars and the lowest in Kavir cultivar **(Table 2)**.

Table 1. *Mean of seedling characteristics of wheat cultivars affected by different levels of NaCl*

Shoot length (cm)

Cultivar	**0.0**	**2.5ds/m**	**5.0ds/m**	**7.5ds/m**	**10ds/m**	**12.5ds/m**	**Mean**
Hirmand	15.610 a	15.217 a	14.050 a	13.107 a	12.997 a	10.167 a	13.524
Chamran	15.993 a	15.053 a	14.497 a	12.333 a	11.107 a	11.000 a	13.331
Hamoon	15.663 a	15.553 a	13.887 a	12.443 a	11.830 a	11.333 a	13.452
Bolani	21.663 a	20.263 a	19.717 a	19.107 a	14.107 a	13.997 a	18.140
Sorkhtokhm	22.110 a	21.163 a	19.663 a	17.887 a	13.883 a	12.377 a	17.847
Kavir	16.777 a	15.993 a	13.330 a	13.497 a	12.303 a	10.273 a	13.696
Mean	17.969	17.207	15.587	14.729	12.705	11.525	

Root length (cm)

Cultivar	**0.0**	**2.5ds/m**	**5.0ds/m**	**7.5ds/m**	**10ds/m**	**12.5ds/m**	**Mean**
Hirmand	13.210 a	10.777 a	10.720 a	8.663 ab	7.997 ab	7.553 ab	9.820
Chamran	10.607 b	10.390 ab	10.290 a	7.053 b	6.943 b	5.876 b	8.525
Hamoon	12.273 a	10.110 ab	9.997 a	9.943 a	9.443 a	9.220 a	10.164
Bolani	11.500 ab	10.610 ab	10.387 a	10.017 a	7.747 ab	7.730 ab	9.665
Sorkhtokhm	11.493 ab	11.013 a	9.933 a	9.7700 a	9.273 a	8.200 a	9.948
Kavir	10.387 b	8.883 b	7.497 b	9.847 a	8.430 a	7.700 ab	8.791
Mean	11.578	10.297	9.804	9.217	8.306	7.713	

Values were compared using a Duncan multiple range test at the 5% level

***Table 2.** Mean of seedling characteristics of wheat cultivars affected by different levels of NaCl*

Shoot dry weight (mg/plant)

Cultivar	0.0	2.5ds/m	5.0ds/m	7.5ds/m	10ds/m	12.5ds/m	Mean
Hirmand	0.121 a	0.113 a	0.110 a	0.115 a	0.073 a	0.064 a	0.099
Chamran	0.115 a	0.120 a	0.110 a	0.104 a	0.072 a	0.071 a	0.099
Hamoon	0.126 a	0.117 a	0.113 a	0.103 a	0.103 a	0.096 a	0.110
Bolani	0.120 a	0.122 a	0.110 a	0.098 a	0.079 a	0.082 a	0.102
Sorkhtokhm	0.127 a	0.122 a	0.105 a	0.093 a	0.087 a	0.083 a	0.103
Kavir	0.114 a	0.117 a	0.095 a	0.088 a	0.068 a	0.065 a	0.091
Mean	0.121	0.119	0.107	0.100	0.080	0.078	

Root dry weight (mg/plant)

Cultivar	0	2.5ds/m	5ds/m	7.5ds/m	10ds/m	12.5ds/m	Mean
Hirmand	0.089 a	0.093 a	0.082 a	0.078 a	0.075 a	0.080 a	0.082
Chamran	0.101 a	0.104 a	0.086 a	0.080 a	0.075 a	0.081 a	0.088
Hamoon	0.123 a	0.125 a	0.117 a	0.106 a	0.092 a	0.105 a	0.111
Bolani	0.105 a	0.102 a	0.103 a	0.101 a	0.087 a	0.088 a	0.098
Sorkhtokhm	0.125 a	0.110 a	0.112 a	0.099 a	0.096 a	0.089 a	0.106
Kavir	0.104 a	0.107 a	0.098 a	0.080 a	0.070 a	0.075 a	0.089
Mean	0.108	0.107	0.099	0.091	0.083	0.086	

Root/Shoot dry weight ratio

Cultivar	0.0	2.5ds/m	5.0ds/m	7.5ds/m	10ds/m	12.5ds/m	Mean
Hirmand	0.74 a	0.82 a	0.745 b	0.678 b	1.02 a	1.25 a	0.82
Chamran	0.88 a	0.87 a	0.781 ab	0.769 ab	1.04 a	1.14 a	0.88
Hamoon	0.98 a	1.07 a	1.035 a	1.029 a	0.89 a	1.09 a	1.009
Bolani	0.88 a	0.84 a	0.98 a	1.03 a	1.10 a	1.07 a	0.96
Sorkhtokhm	0.98 a	0.90 a	1.066 a	1.06 a	1.10 a	1.07 a	1.02
Kavir	0.91 a	0.91 a	1.031 a	0.90 a	1.02 a	1.15 a	0.097
Mean	0.89	0.090	0.092	0.091	1.03	1.10	

Values were compared using a Duncan multiple range test at the 5% level

Mineral analysis

The more NaCl concentration, the higher Na^+ and K^+ accumulation in seedling roots and shoots of the investigated cultivars **(Table 3)**. In all cultivars, the Na^+ accumulation was more than K^+ compared to the controls. The Na^+ accumulated in shoot was less than roots **(Table 4)**.In general, total K^+ accumulation in the seeds decreased as NaCl concentration increased **(Table 5)**. The Cultivars revealed different responses to Na^+ and K^+ uptake. The highest Na^+ and K^+ uptake respectively, took place in roots of Hamoon and Hirmand cultivars when 12.5ds/m NaCl was applied. In the same conditions, the highest Na^+ uptake was observed in Sorkhtokhm cultivar and the highest K^+ uptake in Kavir and Hirmand cultivars.

***Table 3.** Effects of sodium (Na^+) and potassium (K^+) amounts (g/kg) in roots of wheat cultivars germinated at different NaCl concentrations.*

Cultivar / NaCl Conc. (ds/m)	Hirmand		Chamran		Hamoon		Bolani		Sorkhtokhm		Kavir	
	Na^+	K^+	Na^+	K^+	Na^+	K^+	Na^+	K^+	Na^+	K^+	Na^+	K^+
0.0	2.41f	0.79e	1.67f	0.78f	1.91f	0.80d	2.08f	0.80d	2.15f	0.64e	1.95f	0.79c
2.5	3.11e	0.80e	2.26e	0.74e	2.21e	0.79d	2.96e	0.78e	2.75e	0.70d	2.72e	0.78c
5.0	3.10d	1.04d	3.10d	0.97d	3.30d	0.93c	3.52d	0.67f	2.96d	0.63f	2.58d	0.79c
7.5	3.49b	1.09c	3.21c	1.04c	3.46c	0.94c	3.54c	0.81c	3.70b	0.79c	3.08c	0.94b
10	3.45c	1.24b	3.68a	1.17a	3.68b	1.10a	3.74b	0.83b	3.72a	0.86a	3.45b	1.17a
12.5	3.99a	1.36a	3.57b	1.06b	4.34a	1.03b	3.90a	0.94a	3.64c	0.74b	3.63a	1.18a

Values were compared using a Duncan multiple range test at the 5% level

Table 4. *Effects of sodium (Na^+) and potassium (K^+) amounts (g/kg) in shoots of wheat cultivars germinated at different NaCl concentrations.*

Cultivar / NaCl Conc. (ds/m)	Hirmand		Chamran		Hamoon		Bolani		Sorkhtokhm		Kavir	
	Na^+	K^+	Na^+	K^+	Na^+	K^+	Na^+	K^+	Na^+	K^+	Na^+	K^+
0.0	0.35f	2.61d	0.42e	2.93d	0.34f	2.63f	0.48f	2.93d	0.35e	2.47e	0.44f	3.03b
2.5	1.58e	2.81c	1.40d	2.98c	1.23e	3.39c	1.76e	3.47a	0.99d	3.04a	1.32e	2.74e
5.0	1.79d	2.93b	2.84c	2.77e	2.37c	3.47a	2.12c	2.90e	1.60c	2.77c	1.99d	2.84d
7.5	2.46c	3.05a	2.85c	3.09b	1.91d	3.44b	2.02d	2.97c	1.60c	3.05a	2.49b	3.00c
10	2.92a	2.82c	3.12b	3.33a	2.49b	3.19d	3.24a	2.77f	3.24b	2.84b	2.24c	2.71f
12.5	2.67b	3.05a	3.43a	2.68f	2.93a	2.68e	2.88b	3.00b	3.45a	2.69d	2.88a	3.07a

Values were compared using a Duncan multiple range test at the 5% level

Table 5. *Effects of sodium (Na^+) and potassium (K^+) amounts (g/kg) in germinating seeds of wheat cultivars soaked at different NaCl concentrations.*

Cultivar / NaCl Conc. (ds/m)	Hirmand		Chamran		Hamoon		Bolani		Sorkhtokhm		Kavir	
	Na^+	K^+	Na^+	K^+	Na^+	K^+	Na^+	K^+	Na^+	K^+	Na^+	K^+
0.0	0.24f	0.40a	0.13f	0.35a	0.15c	0.42a	0.14f	0.44a	0.28e	0.43a	0.20f	0.42a
2.5	0.35e	0.42a	0.28e	0.35a	0.35b	0.38a	0.33e	0.42a	0.32d	0.39a	0.37e	0.41a
5.0	0.39b	0.40a	0.44d	0.35a	0.53b	0.38a	0.44d	0.42a	0.46c	0.42a	0.55c	0.42a
7.5	0.45c	0.40a	0.5c	0.34a	0.53b	0.36a	0.57c	0.42a	0.66b	0.38a	0.39d	0.38a
10	0.52d	0.38a	0.61b	0.35a	0.64a	0.38a	0.65b	0.41a	0.46c	0.36a	0.59b	0.39a
12.5	0.76a	0.39a	0.82a	0.33a	0.64a	0.35a	0.66a	0.37b	0.53a	0.40a	0.79a	0.39a

Values were compared using a Duncan multiple range test at the 5% level

DISCUSION

Little researches have been performed regarding seed germination responses of Iranian bread wheat cultivars to salinity stress (2). This research was carried out to observe the effects of salinity on germination and seedling growth of six bread wheat cultivars. The maximum germination percentages were 94.6 and 93.3 that took place in Kavir and Hamoon cultivars and minimum in Chamran and Bolani cultivars where 66 and 75 percent respectively were.

The results showed that by increasing NaCl concentrations, germination in the cultivars delayed and decreased .

Increasing salinity concentrations often cause osmotic and/or specific toxicity which may reduce germination percentage (2). Similar declines in seed germination have been reported in the literatures (22). A slight decrease in water uptake was observed by increasing NaCl levels in the investigated cultivars. The osmotic barrier due to NaCl level affected water uptake and mean germination time but not final germination (5). The research results were similar reported by many researchers (5, 7, 1, 23, 24). They determined that seed germination and seedling growth reduced in saline soils with varying responses for cultivars. NaCl affected seed germination by creating an external osmotic potential preventing water uptake. However, a number of studies have demonstrated that water uptake in bean (5), cotton (23), tomato (24), barley and wheat (25, 2, 13) plants is significantly reduced under salt or water stress conditions. Root and shoot length decreased by increasing NaCl concentration. Furthermore, the shoots were more sensitive than roots. The results are similar to those reported by other researchers (26, 2). As NaCl concentration increased, it antagonistically affected shoot and root dry weight. Reduction of dry weights relatively depended on shoot or root lengths.

The results are similar to those reported by researchers (27, 28). As NaCl levels increased the ratio of root/shoot dry weight remarkably increased. This means that wheat shoots were more severely affected by increasing NaCl concentrations than roots, as was reported by Salim (28). High sodium amount was accumulated in wheat shoots, primarily due to higher rates of net ion transported from roots to shoots. Shoot accumulated less Na^+ than the roots, while the Na^+ content in the shoots was higher than that in the roots. This indicates that Na^+ transportation from roots to shoots was accelerated when NaCl concentration was increased (29). The K^+ concentration highly increased in the roots, while K^+ content in the shoots and seeds decreased relatively as NaCl concentration increased. It seems that Na^+ and K^+ were exchanged by water uptake during seed germination. The K^+ in the seeds was released into the germination medium while Na^+ from medium was absorbed by seeds. It is reported that increasing NaCl concentrations was resulted in increasing K^+ leakage from seeds (17, 5).

In conclusion, our findings revealed that the accumulation of Na^+ in the seeds may have an adverse effect on seed germination resulting in delaying mean germination time in wheat. It seems that the delay in seed germination was related more to Na^+ accumulation in seeds rather than lower water uptake in wheat cultivars. Salinity increased the accumulation of Na^+ and decreased the K^+ content in roots and shoots. The Na^+ content of germinating seeds gradually increased, while K^+ content diminished.

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