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Effect of Different Salt Concentrations and Temperatures on Seed Germination and Seedling Characters in Safflower (*Carthamus tinctorius* L.) Genotypes

Rahim Ada, Zamari Temory, Hasan Dalgiç

***Abstract*—**Germination and seedling responses of seven safflower seed genotypes (Dinçer, Remzibey, Black Sun2 cultivars and A19, F4, I1, J19 lines) to different salinity concentrations (0, 5, 10 and 20g l^{-1}) and temperatures (10 and 20°C) evaluated in Completely Randomized Factorial Designs in Department of Field Crops of Selcuk University, Konya, Turkey. Seeds in the control (distilled water) had at 10 and 20°C the highest germination percentage (93.88 and 94.32%), shoot length (4.60 and 8.72cm) and root length (4.27 and 6.54cm) shoot dry weight (22.37mg and 25.99mg) and root dry weight (2.22 and 2.47mg). As the salt concentration increased, values of all characters were decreased. In this experiment, in 20g l^{-1} salt concentration found germination percentage (21.28 and 26.66%), shoot (1.32 and 1.35cm) and root length (1.04 and 1.10cm) shoot (8.05mg and 7.49mg) and root dry weight (0.83 and 0.98mg) at 10 and 20°C.

***Keywords*—**NaCl, Safflower, Temperature.

I. Introduction

SALINITY is one of the most important abiotic stresses limiting crop production in arid and semi-arid regions, where soil salt content is naturally high and precipitation can be insufficient for leaching [1]. Its affects many morphological, physiological and biochemical processes, including seed germination, plant growth, and water and nutrient uptake [2]. Germination ability of plants under salinity stress can be understood of the best in arid and semi-arid conditions, so necessity of evaluation of salt resistance cultivars is important at primary growth stage [3]. Thus, breeders are looking for water and salt stress-resistant plants [4].

First stage of development of plants may be sensitive to salinity [5]. According to a soil map from FAO-UNESCO, approximately 2-2.5 million ha of arable land in Turkey suffers from salinity problems [6].

Safflower (*Carthamus tinctorius* L.) is one of the prospective oil-seed crops, because it yields about 32-40% seed oil [7]. Its oil is extensively utilized in industries [8].

One of the most important aspects for safflower seed production is related to rapid emergence and good seedling establishment in the field. In the other hand germination and emergence are important issues in plant production and they have significant effect on the next stages of plant growth [9].

Although salinity stress adversely affects the growth of safflower at all growth stages [10], [11]. Germination of safflower seed occurs at temperatures as low as 2-5ºC [12].

Safflower seeds germinate at temperatures from 5 to 35°C, with the optimum being about 25°C [13].

Several investigators [10], [14]-[16] have studied the relative salt tolerance of safflower genotypes during this phase of seedling. However, there is little information available on the interaction of salinity and temperature on seed germination and seedling of safflower.

In present studies the combined effects of temperature and salinity (NaCl) on safflower genotypes (*Carthamus tinctorius* L.) were carried out.

II. Material and Methods

This experiment was carried out at Department of Field Crops of Selcuk University, Konya, Turkey. An experiment was conducted in factorial form, by using a "Completely Randomized Factorial Designs" with four replications. In this experiment, seven safflower genotypes which consisted from Dinçer, Remzibey, Black Sun 2, A19, F4, I1 and J19 were evaluated in four levels of salt applications (distilled water as control, 5g l^{-1}, 10g l^{-1}, 20g l^{-1}) by using different NaCl concentrations and two temperature levels (10 and 20°C). The seeds were sterilized by soaking in a 10% solution of sodium hypochlorite for 5min. After the application, the seeds were washed several times with distilled water. The containers which were used in the research were rectangle, locked and transparent to easier counting of plant number and observations. A thickness of 1cm perlite was layed in the containers. Then, the sodium chloride which was prepared with distillated water was added. A total of 25 seeds were sown to every single application. After sowing, the upper sides of the containers were covered by stretch film to avoid moisture losing and the covers were locked*. The locked containers were put into an incubator for 14 days at a temperature of 10 and 20°C. After 14 days from incubation, germination percentage, shoot length, root length, shoot and root dry weights were determined. When reaches to 2mm of

Rahim Ada is with the Department of Field Crops, Faculty of Agriculture, Selcuk University, Konya, Turkey (e-mail: rahimada@selcuk.edu.tr).
Zamary Temory is a master student in Selcuk University, Konya, Turkey.
Hasan Dalgiç is with the Konya Metropolitan Municipality, Konya, CO 42060 Turkey (phone: 332-2333877; fax: 332-2410108; e-mail: hasan_dagic@hotmail.com).

radicle length, seeds were considered germinated. Dry weights were measured after samples were dried at 70°C for 48h in the oven. Germination percentage was calculated by using the following formula: GP= (SGN/SNT) x 100. Where GP is germination percentage, SNG is the number of germinated seeds, and SNT is total number of seeds [9].

According to "Completely Randomized Factorial Designs", analysis of variance was performed using "JUMP" computerized statistical program.

III. Results and Discussion

Analysis of variance showed that, there were significant difference between genotypes, NaCl concentrations, temperatures and their interaction. The results of this study reveal that NaCl and temperature significantly affected all the characters.

Salt concentrations promoting and temperature decreasing resulted in a decline of germination percentage, shoots and root height and dry weight.

TABLE I
MEAN SQUARES FROM ANALYSES OF VARIANCE FOR GROWTH AND GERMINATION PERCENTAGE OF SAFFLOWER (*CARTHAMUS TINCTORIUS* L.) SEEDLINGS WHICH WERE GROWN UNDER CONCENTRATION OF NACL AND TEMPERATURES

Source	DF	Germination Percentage	Shoot Length	Root Length	Shoot Dry Weight	Root Dry Weight
Common	223	-	-	-	-	-
Temperature (A)	1	4289.16**	92.283**	18.4831**	28.659**	21.6443**
Concentration of NaCl (B)	3	56646.37**	132.604**	59.78797**	247.1024**	145.1436**
A*B	3	2351.8**	22.2366**	5.536567**	3.802767**	0.858267
Genotypes (C)	6	85.205**	0.681367**	1.079233**	2.39295**	3.724517**
A*C	6	90.44167**	0.271133	0.312667	2.040667**	2.9582**
B*C	18	66.23556**	0.093983*	0.211383**	0.444683**	0.819717**
A*B*C	18	86.60111**	0.058133	0.079211	0.449044**	0.97935**

** $p < 0.01$, * $p < 0.05$

TABLE II
EFFECTS OF DIFFERENT NACL CONCENTRATIONS ON GERMINATION PERCENTAGE OF SEVEN SAFFLOWER GENOTYPES

		Concentration of NaCl				
Temperatures (°C)	**Genotypes**	**Control**	**5 g l^{-1}**	**10 g l^{-1}**	**20 g l^{-1}**	**Mean**
	Dinçer	93.50	87.00	70.48	24.63	68.90
	Remzibey	95.10	86.38	65.65	22.50	67.41
	Black Sun2	94.20	87.05	48.15	16.20	61.40
10	**A19**	94.18	88.25	42.25	20.65	61.33
	F4	91.42	88.90	68.30	22.35	67.74
	I1	93.65	87.95	48.45	20.23	62.57
	J19	95.08	88.85	47.13	22.40	63.36
	Mean	93.88	87.7	55.77	21.28	64.67
	Dinçer	93.75	88.93	82.43	28.60	73.43
	Remzibey	94.53	90.03	83.92	27.07	73.89
	Black Sun2	94.73	88.88	85.38	22.98	72.99
20	**A19**	95.43	88.85	87.20	26.80	74.57
	F4	94.00	88.68	82.08	26.97	72.93
	I1	94.23	89.00	81.08	25.38	72.42
	J19	93.58	88.88	83.78	28.81	73.76
	Mean	94.32	89.03	83.69	26.66	73.42
	Common Mean	94.09	88.40	69.73	23.97	

Lsd values: Concentration of NaCl: 1.711, temperature x concentration of NaCl: 2.420, genotypes: 2.264, temperature x genotypes: 3.202, concentration of NaCl x genotypes: 4.528, temperature x concentration of NaCl x genotypes: 6.403

The salt tolerance of plants varies with the type of salt of the medium [17]. High content of NaCl in the solution increases its osmotic potential. In addition, high absorption of Na and Cl ions, toxicity in for the cell, and thus causes a decline of germination [18]. In the present study, salt stress and low temperature adversely affected the germination percentage, shoot and root length and dry weights of seedlings of all 7 genotypes of safflower.

Seeds in the control (distilled water) at 10 and 20°C had the highest germination percentage (93.88 and 94.32%), and as the salt concentration increased, germination percentage decreased up to 20g l^{-1} NaCl concentration (Table II). A higher germination percentage of genotypes at control (0g l^{-1} NaCl) were due to lack of salt in the medium (Table II).

The results revealed a decreasing on germination percentage in the genotypes as parallel reducing of the temperature from 20°C to 10°C. On the other hand, all safflower genotypes germinated better at 20°C than 10°C.

In the research, while the highest germination percentage at 10°C and 20g l^{-1} NaCl concentration was found from Dinçer (68.90%), the lowest was obtained from A19 line (61.33%).

Salinity affects germination in two ways: The salt may be toxic to the embryo [19]. Our results corresponded to these [10] that germination was delay germination to the salt concentration of the medium.

Shoot and root lengths was significantly affected by NaCl concentrations x genotypes and NaCl concentrations x genotypes x temperatures interaction (Table I).

When triple interaction is examined, the highest shoot length was obtained in control (distilled water) with A19 line (10.30cm) on 20C, the lowest was obtained from Black Sun 2 cultivars at 10°C and 20g l^{-1}(1.18cm).

Under salt stress conditions growth of shoots may decrease by low water potential [20] and seedlings may not be established well due to weak shoot and root growth. Reduced seedling growth has also been reported by Huang and Reddman [21] on barley and Bayuelo - Jiménez et al. [22] on phaseolus under salt stress conditions.

TABLE III
EFFECTS OF DIFFERENT CONCENTRATIONS OF NACL ON SHOOT LENGTH (CM) OF SEVEN SAFFLOWER GENOTYPES

		Concentration of NaCl				
Temperatures (°C)	**Genotypes**	**Control**	**5 g l^{-1}**	**10 g l^{-1}**	**20 g l^{-1}**	**Mean**
	Dinçer	5.55	3.75	1.93	1.33	3.14
	Remzibey	5.33	3.53	2.05	1.38	3.07
	Black Sun2	4.03	1.93	1.78	1.18	2.23
10	**A19**	4.88	3.40	1.75	1.26	2.82
	F4	3.50	2.70	1.70	1.39	2.32
	I1	5.00	3.95	1.60	1.41	2.99
	J19	3.93	3.23	1.35	1.27	2.44
	Mean	4.60	3.21	1.74	1.32	2.71
	Dinçer	10.00	4.70	1.83	1.39	4.48
	Remzibey	7.73	3.65	2.08	1.41	3.72
	Black Sun2	9.38	3.85	1.65	1.23	4.03
20	**A19**	10.30	3.43	1.85	1.35	4.23
	F4	8.08	3.13	1.80	1.39	3.59
	I1	8.23	3.73	1.70	1.34	3.75
	J19	7.33	2.95	1.80	1.36	3.36
	Mean	8.72	3.63	1.81	1.35	3.88
	Common Mean	6.65	3.42	1.78	1.33	

Lsd values: concentration of NaCl: 0.4461, temperature x concentration of NaCl: 0.6308, genotypes: 0.5901, concentration of NaCl x genotypes: 0.8942

TABLE IV
EFFECTS OF DIFFERENT NACL CONCENTRATIONS ON ROOT LENGTH (CM) OF SEVEN SAFFLOWER GENOTYPES

		Concentration of NaCl				
Temperatures (°C)	**Genotypes**	**Control**	**5 g l^{-1}**	**10 g l^{-1}**	**20 g l^{-1}**	**Mean**
	Dinçer	2.95	3.10	1.60	1.07	2.18
	Remzibey	4.05	3.35	2.40	0.89	2.67
	Black Sun2	2.15	2.43	1.63	0.91	1.78
10	**A19**	7.00	3.15	2.78	1.20	3.53
	F4	5.33	3.20	2.70	0.94	3.04
	I1	4.58	3.55	2.38	0.99	2.87
	J19	3.85	3.20	2.08	1.29	2.60
	Mean	4.27	3.14	2.22	1.04	2.67
	Dinçer	5.60	3.23	2.25	1.10	3.04
	Remzibey	3.78	3.13	2.38	1.10	2.59
	Black Sun2	6.08	3.10	1.88	1.00	3.01
20	**A19**	7.90	3.25	2.28	1.15	3.64
	F4	7.68	3.13	2.10	1.12	3.51
	I1	9.26	3.25	2.25	1.16	3.98
	J19	5.47	3.20	2.33	1.09	3.02
	Mean	6.54	3.18	2.21	1.10	3.26
	Common Mean	5.41	3.16	2.21	1.07	

Lsd values: Concentration of NaCl: 0.5058, temperature x concentration of NaCl: 0.7153, genotypes: 0.6691, concentration of NaCl x genotypes: 1.338

TABLE V
EFFECTS OF DIFFERENT NACL CONCENTRATIONS ON SHOOT DRY WEIGHT OF SEVEN SAFFLOWER GENOTYPES

		Concentration of NaCl				
Temperatures (ºC)	**Genotypes**	**Control**	**5 g l^{-1}**	**10 g l^{-1}**	**20 g l^{-1}**	**Mean**
	Dinçer	20.25	20.03	13.75	7.88	15.48
	Remzibey	21.05	16.92	19.95	9.57	16.878
	Black Sun2	27.10	23.22	16.53	6.92	18.45
10	**A19**	28.40	21.70	20.60	7.74	19.61
	F4	15.85	18.18	16.10	6.78	14.23
	I1	14.18	15.43	18.60	8.80	14.25
	J19	29.75	20.30	20.38	8.63	19.77
	Mean	22.37	19.39	17.99	8.05	16.95
	Dinçer	19.80	21.15	22.25	7.79	17.75
	Remzibey	25.75	20.53	20.53	7.60	18.60
	Black Sun2	27.55	20.48	17.28	6.65	17.99
20	**A19**	28.23	21.03	21.97	7.25	19.62
	F4	27.23	21.95	16.05	7.27	18.12
	I1	27.75	21.40	17.25	8.06	18.62
	J19	25.60	20.38	16.58	7.83	17.60
	Mean	25.99	20.99	18.84	7.49	18.33
	Common Mean	24.18	20.19	18.41	7.7695	

Lsd values: Concentration of NaCl: 0.9481, temperature x concentration of NaCl: 1.341, genotypes: 1.254, temperature x genotypes: 1.774, concentration of NaCl x genotypes: 2.509, temperature x concentration of NaCl x genotypes: 3.548

TABLE VI
EFFECTS OF DIFFERENT NACL CONCENTRATIONS ON ROOT DRY WEIGHT OF SEVEN SAFFLOWER GENOTYPES

		Concentration of NaCl				
Temperatures (ºC)	**Genotypes**	**Control**	**5 g l^{-1}**	**10 g l^{-1}**	**20 g l^{-1}**	**Mean**
	Dinçer	3.98	1.73	1.68	1.04	2.10
	Remzibey	1.05	1.13	1.78	1.12	1.27
	Black Sun2	1.20	1.40	1.45	0.74	1.20
10	**A19**	3.30	2.15	1.65	0.66	1.94
	F4	1.40	2.53	1.75	0.62	1.57
	I1	2.50	2.08	1.63	0.85	1.76
	J19	2.10	1.43	1.80	0.77	1.52
	Mean	2.22	1.78	1.68	0.83	1.62
	Dinçer	2.35	1.83	1.70	0.99	1.72
	Remzibey	2.32	1.83	1.75	0.87	1.69
	Black Sun2	2.54	1.85	1.53	0.90	1.70
20	**A19**	2.44	1.843	1.95	1.03	1.82
	F4	2.54	1.89	1.75	1.00	1.79
	I1	2.49	1.84	1.68	1.02	1.76
	J19	2.63	1.79	1.80	1.03	1.81
	Mean	2.47	1.84	1.74	0.98	1.76
	Common Mean	2.35	1.81	1.71	0.90	

Lsd values: Concentration of NaCl: 0.1052, genotypes: 0.1392, temperature x genotypes: 0.1969, concentration of NaCl x genotypes: 0.2784, temperature x concentration of NaCl x genotypes: 0.3937

The highest root length at 10°C was taken from control with 7.00cm in A19 line, the lowest value was 0.89cm in 20g L^{-1} NaCl concentration from Remzibey cultivar. Whereas the I1 (1.16cm) at 20°C showed the best performance in the highest dose of salt.

In temperature x NaCl concentration x genotype interaction, the highest root length was found with 9.26cm in I1 line at 20°C while the lowest was obtained with 0.89cm from Black Sun 2 cultivars at 10°C.

In the present study, significance of interaction between salinity and temperature on germination percentage, shoot and root length, and shoot dry weight showed different trends of them under these factors.

Root length is one of the most important characters for salinity stress. For this reason, root length shows an important clue to the response of plants to salinity stress [23]. It can be concluded that to select cultivars for better salt stress tolerance at seedling stage, shoot and root elongation may be used as breeding criteria for safflower.

Salt stress was found to be more toxic to seedling growth than to germination. Root length and shoot height was significantly reduced with increasing NaCl concentration in

growing media. There was considerable variation in toxicity among the genotypes [16].

In the present study, significance of interaction between salinity and temperature on germination percentage, shoot and root length, and shoot dry weight showed different trends of them under these factors.

As for Pirzad et al. [24] in safflower, in parallel with our results, has been reported that significance of interaction between salinity and temperature on germination percentage, shoot and root length, and shoot dry weight showed different trends of them under these factors.

Although a considerable magnitude of variation for salt tolerance and temperature was observed in a set of 7 genotypes of safflower while screening them at both germination and seedling stages. Shoot and root dry weights of genotypes were negatively affected by increasing salt and decreasing temperature treatments.

The average shoot dry weight of genotypes was 24.18mg plant-1 at control and this value gradually decreased throughout the increasing salt concentrations, and reached to 7.77mg plant-1 at 20g l^{-1} NaCl concentration. The genotypes at 10^{o}C were arranged as following: J19 > A19 > Black Sun 2 > Remzibey > Dinçer >I1>F4 (Table V). As at 20^{o}C were arranged as following: A19 > I1 > Remzibey> F4 > Black Sun 2 > Dinçer > J19. The average value in 20^{o}C (18.33mg plant-1) was more than 10^{o}C (16.95mg plant-1).

Root dry weight of genotypes decreased significantly as the concentration of NaCl increased from 0 to 20g l^{-1}. Thus, while the highest root dry weight was determined from J19 line at control (2.63mg plant-1) at 20^{o}C and at 10^{o}C the lowest root dry weight was obtained from F4 line (0.62 mg plant-1) and at the highest NaCl concentration (20g l^{-1}). When temperature values are examined in Table VI, the average of dry root was 1.76mg plant-1 in 20^{o}C, this value was found 1.62mg plant-1 in 10^{o}C.

Increasing of the temperature from 10^{o}C to 20^{o}C, cause to reducing in root dry weight of some genotypes.

For example, root dry weights of Dinçer and Black Sun 2 cultivars in 10^{o}C were realized 2.10 and 1.94mg plant-1 respectively, while it was realized 1.72 and 1.70mg plant-1 in 20^{o}C of temperature.

As in this study, Maftoun and Sepaskhah [25] reported salinity effects interact with temperature. At the optimum temperatures for germination, seeds were more tolerant to higher salinity levels in safflower.

From the above mentioned results, for all genotypes, all characters was higher at the control (distilled water). Also, in terms of early spring-sown at the low temperatures for safflower may be recommended Dincer cultivars according to germination percentage.

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