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Effects of Different Soil Salinity Levels on Germination and Seedling Growth of Safflower (*Carthamus tinctorius* L.)

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Abstract: Safflower (*Carthamus tinctorius* L.) is rated as moderately salt tolerant and it can produce profitable crops on saline soils. It is slightly more tolerant of salinity than barley but is more tolerant than wheat. Because salinity reduces germination and delays emergence, safflower stands tend to be irregular and crop yield is depressed. However, some varieties are less affected by salinity than others. In this study, we aimed to determine the effects of soil salinity levels (0.8, 2.5, 5.1, 8.7, 13.0, 15.2 and 23.0 dS m^{-1}) on germination and seedling growth of three safflower varieties, one of which is spiny (5-154 cv.) and two of which are spineless (Yenice 5-38 and Dinçer 5-118 cv.). Emergence rate, root and shoot length, root and shoot dry weight, root/shoot dry weight ratio, root and shoot dry weight salt stress index were investigated. The results showed that the highest values for the investigated traits were obtained from variety 5-154 (spiny), while they diminished with increasing soil salinity in all cultivars. Among the varieties, the highest emergence rate, root length, shoot length, root dry weight, shoot dry weight and root/shoot dry weight ratio at 23.0 dS m^{-1} were determined from 5-154 cv. with 23.35%, 3.54 cm, 4.97 cm, 7.23 mg, 26.73 mg and 20.77%, respectively. Moreover, 5-154 cv. gave the higher root and shoot dry weight salt stress index, especially at high salinity levels. The seedling growth of varieties was inhibited by 5.1 dS m^{-1} although they showed varying responses. At the first development stage, the root growth of safflower was more adversely affected compared to shoot growth by soil salinity. If the cultivation of safflower on saline soils is required, spiny varieties should be preferred.

Key Words: Safflower (*Carthamus tinctorius* L), germination, salinity, seedling growth

Aspir'de (*Carthamus tinctorius* L.) Çimlenme ve Fide Gelişimi Üzerine Topraktaki Tuz Seviyelerinin Etkileri

Özet: Aspir (*Carthamus tinctorius* L.) orta derecede tuza toleranslı bir bitkidir ve tuzlu topraklarda yeterli ürün verebilmektedir. Aspir, arpadan daha az ancak buğdaydan daha fazla tuza toleranslıdır. Tuzluluk çimlenmeyi azalttığı, çıkışı geciktirdiği için bitki çıkışı düzensiz olmakta ve bunun sonucunda verim düşmektedir. Bununla birlikte bazı çeşitler tuzdan daha az etkilenmektedir. Bu araştırmada, biri dikenli (5-154) ikisi dikensiz (Yenice 5-38 ve Dinçer 5-118) olan üç yerli aspir çeşidinin çimlenme ve fide gelişimi üzerine farklı toprak tuzluluk seviyelerinin (0.8, 2.5, 5.1, 8.7, 13.0, 15.2 ve 23.0 dS m^{-1}) etkilerini belirlemek amaçlanmıştır. Çalışmada, kök ve toprakÜstü uzunlukları, kök ve toprakÜstü kuru ağırlıklar, kök/toprakÜstü kuru ağırlık oranı ile kök ve toprakÜstü kuru ağırlık stres indeksleri incelenmiştir. Sonuçlar, incelenen özellikler bakımından en yüksek değerlerin 5-154 (dikenli) çeşidinden elde edildiğini ancak, bu özelliklerin artan tuz seviyelerinde azaldığını göstermiştir. Çeşitler arasında 23 dS m^{-1} tuzluluk seviyesinde en yüksek çıkış oranı, kök uzunluğu, toprakÜstü uzunluğu, kök ve toprakÜstü kuru ağırlıklar ile kök/toprakÜstü kuru ağırlık oranı sırasıyla % 23.35, 3.54 cm, 4.97 cm, 7.23 mg, 26.73 mg ve % 20.77 olarak 5-154 çeşidinden belirlenmiştir. Bununla birlikte, özellikle yüksek tuz seviyelerinde, 5-154 çeşidi daha yüksek kök ve toprakÜstü tuzluluk stres indekslerini vermiştir. Çeşitler tuz seviyelerine değişik tepkiler göstermesine rağmen 5.1 dS m^{-1} seviyesindeki tuzluluk çeşitlerin fide gelişimini engellemiştir. İlk gelişme döneminde aspir köklerinin gelişimi toprak tuzluğundan daha fazla etkilenmiştir. Tuzlu topraklarda aspir tarımı yapılacaksa, dikenli çeşitler tercih edilmelidir.

Anahtar Sözcükler: Aspir (*Carthamus tinctorius* L.), çimlenme, tuzluluk, fide gelişimi

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Introduction

Raw plant oils, refined oils and margarines are obtained from sunflower, cottonseed, rapeseed, safflower and maize in Turkey. In recent years, the shortage of plant oil has equalled 700,000 t in this country. The lack of oil has been met by imports that have entailed considerable costs (Kolsarıcı et al., 2000). To make up for the lack of oil in Turkey, oil seed production can be increased by growing salt and drought tolerant safflower in Central Anatolia in regions where annual precipitation is not adequate (Kolsarıcı and Güney, 2002). Safflower (*Carthamus tinctorius* L.) is an important oilseed crop with 35-40% oil content. It has been used as a source of edible oil and dying since ancient times. It has a well-defined tap root that generally penetrates up to a depth of 2-3 m. This deep-rooting characteristic allows the plant to absorb moisture and nutrients from different volumes of soil (Weiss, 1983).

According to a soil map from FAO-UNESCO, approximately 2-2.5 million h of arable land in Turkey suffers from salinity problems (Munsuz et al., 2001). The salinity problem is common in arid and semi-arid regions where rainfall is insufficient to leach salts out of the root zone. These areas often have high evaporation rates, which can encourage an increase in salt concentration at the soil surface (Meiri, 1984; Pessaraklı, 1999). Under saline conditions, it is important to maintain and/or improve soil water availability to crops (Van Hoorn and Van Alpen, 1990). This can be accomplished through several strategies such as leaching salts from the soil profile, maintaining high soil water content in the root zone, selecting more salt tolerant plants and improving cropping systems (Meiri, 1984).

Our research focused on detecting root and shoot growth and determining the response of safflower varieties (two spineless, one spiny) to saline conditions at germination stage so as to better understand which part of the safflower seedling was influenced by soil salinity. Therefore, this study was undertaken using artificially salinised soil to determine the effects of salinity on the early growth stages of the safflower.

Materials and Methods

Three safflower varieties grown in Turkey, Yenice 5-38, Dinçer 5-118 and 5-154, and field soil were used as the seed and soil material, respectively. Seeds of the three varieties were obtained from the Department of Field Crops, Faculty of Agriculture, Ankara University. Seven soil samples were adjusted to salinity levels of 0.8, 2.5, 5.1, 8.7, 13.0, 15.2 and 23.0 dS m^{-1} by using different NaCl concentrations. Different root zone soil salinity levels were constituted by applying water with various NaCl concentrations. Soil salinity levels were determined as mentioned in Rhoades et al. (1992). Clay-loam textured field soil was used as control EC_e (Electrical conductivity of saturation extract of the soil) = 0.8 dS m^{-1}. Soil samples were obtained at a depth of 0-20 cm from the experimental fields of the Department of Field Crops, Faculty of Agriculture, Ankara University. Seeds belonging to the cultivars were sown in pots 12 x 10 cm large. The pots were incubated in a naturally lit greenhouse at 25 °C and relative humidity was 65%. After the emergence percentage was determined from 30 seeds (Ghorashy et al., 1972), the seedlings were thinned to five plants per pot. All observations and measurements were performed from the five seedlings. Samples were taken after 21 days of emergence. The soil-root sample was suspended in water and cleaned by hand over sieves of 0.5 mm^2 mesh size (Böhm, 1979). Shoot length and dry weight, and root length and dry weight, and root/shoot dry weight ratio traits were investigated (Bray, 1963). Dry weights were measured after drying samples at 70 °C for 48 h in an air oven (Schuurman and Goedewaagen, 1971; Veli et al., 1994). The evaluation of the root and shoot dry weight salt stress index [(dry weight of salt stressed seedling/dry weight of control seedlings) x 100] was calculated as described by Sopha et al. (1991).

The experiment was established using a randomized complete block design with three replications. The varieties were placed in the main plots, with the salt concentrations in submain plots. Analysis of variance was performed using standard techniques and differences between the means were compared through Duncan's multiple range test ($P < 0.05$) using the MSTAT-C program.

Results

The experimental data are presented in the Table. The control showed clear genetical differences among the varieties regards emergence percentage, and such differences were statistically significant. Among the

Table. Effects of different soil salinity levels on emergence percentage and seedling characteristics of three safflower varieties.

Varieties	Emergence Percentage (%)							Mean
	0.8dSm^{-1}	2.5dSm^{-1}	5.1dSm^{-1}	8.7 dSm^{-1}	13.0 dSm^{-1}	15.2 dSm^{-1}	23.0 dSm^{-1}	
Yenice 5-38	87.7ab1	66.6b2	72.2b23	61.1c3	51.1b4	51.0a4	20.0a5*	58.5 b
Dinçer 5-118	82.0b1	82.0a1	83.1a1	83.3a1	60.8a2	49.7a3	21.7a4	66.1 a
5-154	91.1a1	86.6a1	77.7ab2	72.2b2	56.7ab3	48.9a4	23.35a5	65.2 a
Mean	87.0 *1*	78.4 *2*	77.7 *2*	72.2 *3*	56.2 *4*	49.8 *5*	21.7 *6*	
				Root Length (cm)				
Yenice 5-38	11.25a1	10.45b12	9.52a2	5.59c3	3.98 b4	2.89b45	2.39 b5	6.58 b
Dinçer 5-118	13.43 a1	11.67 a2	9.57 a3	8.40 a4	4.24 ab5	3.95 b6	1.63 b6	7.55 a
5-154	12.83 a1	9.93 b2	8.72 a3	6.74 b4	5.28 a5	4.68 a5	3.54 a6	7.39 a
Mean	12.50 *1*	10.68 *12*	9.27 *2*	6.91 *3*	4.50 *4*	3.84 *4*	2.52 *5*	
				Shoot Length (cm)				
Yenice 5-38	9.84	9.88	7.38	6.01	5.30	4.59	4.31	6.76 b
Dinçer 5-118	11.18	9.87	9.32	7.49	4.66	4.30	4.43	7.32 ab
5-154	11.52	10.68	10.03	7.86	6.64	5.79	4.97	8.22 a
Mean	10.85 *1*	10.14 *12*	8.91 *2*	7.12 *3*	5.53 *4*	4.89 *4*	4.57 *4*	
				Root Dry Weight (mg)				
Yenice 5-38	29.37 b1	18.07 c2	19.23 a2	9.67 a3	5.13 b4	4.80 a4	2.83 b4	12.73 b
Dinçer 5-118	30.13 b1	21.13 b2	17.47 a3	9.63 a4	9.47 a4	5.60 a5	3.60 b5	13.87 b
5-154	35.10 a1	35.73 a1	17.87 a2	11.77 a3	10.47 a34	7.77 a45	7.23 a5	17.99 a
Mean	31.53 *1*	24.98 *2*	18.19 *3*	10.36 *4*	8.36 *5*	6.06 *6*	4.56 *6*	
				Shoot Dry Weight (mg)				
Yenice 5-38	66.87 b1	46.07 c2	37.43 c3	33.13 c4	25.27 b5	27.30 b5	23.53 a5	37.09 c
Dinçer 5-118	72.97 a1	68.40 a2	62.13 a3	47.10 b4	47.17 a4	40.47 a5	23.50 a6	51.66 a
5-154	57.10 c1	55.40b12	54.20b12	53.10 a2	47.03 a3	39.07 a4	26.73 a5	47.52 b
Mean	65.64 *1*	56.62 *2*	51.26 *3*	44.44 *4*	39.82 *5*	35.58 *6*	24.59 *7*	
				Root/Shoot Dry Weight Ratio (%)				
Yenice 5-38	43.90 b2	39.17 c3	51.13 a1	29.07 a5	20.20 a5	17.53 ab5	11.93 b6	30.42 b
Dinçer 5-118	45.80 b1	30.90 b2	28.07 b2	20.33 b3	20.00 a3	13.83 b4	15.17 b4	24.87 c
5-154	62.50 a2	67.43 a1	32.23 b3	22.07 b5	22.20 a45	21.13 a5	20.77a4	36.33 a
Mean	50.73 *1*	45.83 *2*	37.14 *3*	23.82 *4*	20.80 *5*	17.50 *6*	17.96 *6*	

* Different figures at the same line and different letters at the same coloum show significant differences at 0.05 level.

safflower varieties, 5-154 had the highest emergence proportion of 91.1% for the control treatment while Dinçer 5-118 had the highest emergence proportion of 83.1% and 83.3% at 5.1 and 8.7 dS m^{-1} salinity levels, respectively. At the highest salt concentration, the maximum emergence proportion was recorded in variety 5-154 with 23.3% (Table). At salinity levels of 0.8 and 2.5 dS m^{-1}, the highest emergence proportions were attained from variety 5-154. In contrast, the highest emergence proportion in increasing salinity levels were measured on Dinçer 5-118. The maximum fall in emergence proportion was detected in Yenice 5-38 with 77.2%, while the minimum was observed in variety Dinçer 5-118 with 73.5%.

Root length is one of the most important characters for salt stress because roots are in contact with soil and absorb water from soil. For this reason, root length provides an important clue to the response of plants to salt stress. Among the varieties, the longest root length was determined in variety 5-154 at 23.0 dS m^{-1} with 3.54 cm while Dinçer 5-118 gave the shortest root length with 1.63 cm at 23.0 dS m^{-1}. Generally, increasing salinity levels decreased root length, and 5-154 exhibited the greater performance in respect of root length. The rate of decline in root length for the varieties was more marked in variety 5-154 with 72.4% and variety Dinçer 5-118 with 87.9%.

Mean shoot length varied between 6.76 and 8.22 cm in the varieties and 4.57 and 10.85 cm for salinity levels (Table). Mean shoot length was 10.85 cm at 0.8 dS m^{-1} while it decreased linearly to 4.97 cm at 23 dS m^{-1}. Among the varieties, Yenice 5-38 was affected the least by soil salinity because it gave the lowest reduction rate for shoot length. The rate of reduction in shoot length in comparison with the control was detected from variety Yenice 5-38 as 56.2%, variety Dinçer 5-118 as 60.4% and variety 5-154 as 56.9%, which means that varieties 5-154 (spiny) and Yenice 5-38 were more tolerant to soil salinity in the early development stages in terms of shoot length. In general, shoot length diminished with increasing salinity levels in all cultivars, although no statistically differences were found at the highest three salinity levels.

Increasing salinity levels caused remarkably decreases in shoot dry weight (Table). Although our varieties showed different responses to each salinity level, the highest values in all salinity levels were usually obtained from Dinçer 5-118 except for 8.7 and 23.0 dS m^{-1}. As expected, salt levels had a significant effect on the shoot dry weight of all varieties. Salt concentrations resulted in a decline of both shoot length and shoot dry weight. Decreasing shoot dry weight resulted in the decline of shoot length in all varieties, but the reduction which occurred in Yenice 5-38 and 5-154 was lower than that in Dinçer 5-118. 5-154 cv. gave a lower shoot length and this was attributed to higher shoot dry weight at higher salinity levels, meaning that variety 5-154 could acculumate more dry matter in high soil salinity levels. In addition, it was clearly determined that there were no statistical differences between Dinçer 5-118 and 5-154 at high salinity levels.

Root dry weight diminished drastically with increasing salinity levels, as seen in Table, while the effects of salinity varied with concentration. The dry weight of the roots of the varieties declined as root length fell, but the decline of root dry weight was lower than that of root length. In all salinity levels, 5-154 gave the highest root dry weight while the lowest values were determined on Yenice 5-38. There was a sharp drop in root dry weight at 8.7 dS m^{-1}. The decline in root dry weight between the control and final salinity levels was the lowest in 5-154 with 79.4% while the highest reduction was determined on Yenice 5-38 with 90.4%.

The varieties could tolerate soil salinity levels up to 8.7 dS m^{-1} in terms of root dry weight, because a decreasing rate occurring between 0.8 and 8.7 dS m^{-1} was considered negligible. However, at higher doses the root dry matter and salt tolerance levels of the varieties dropped. In the study, the roots of 5-154, which gave the highest values in respect of both root length and root dry weight, grew better under saline conditions.

Safflower varieties investigated in the first development stage showed different responses to the salinity levels applied in terms of root/shoot dry weight ratio. Generally, the ratio declined with increasing salinity levels, which showed that a greater reduction in root dry matter occurred than that in shoot dry weight. On the other hand, it means that the roots were more adversely affected than shoots by soil salinity.

Among the varieties, 5-154 gave a higher root/shoot dry weight ratio at all salinity levels except at 5.1 dS m^{-1} and 8.7 dS m^{-1}. It was also observed that 5-154 attained higher values at the second salinity level than the first salinity level. These results show similarities to findings determined for root dry weight.

Salinity stress is an important characteristic when selecting a variety for salinity tolerance (Konak et al., 1999). As shown Figures 1 and 2, while the varieties could tolerate the effects of salinity levels up to 5.1 dS m^{-1} in terms of root dry weight while higher levels reduced sharply it under 50%, which means that limit of the salt stress for investigated varieties with respect to root dry weight was 5.1 dS m^{-1}. In terms of the shoot dry weight salt stress index (as seen in Figure 1), our varieties showed different responses to salt levels while Yenice 5-38 had the lowest percentage of all. The best results were obtained from Dinçer 5-118 and 5-154 as their

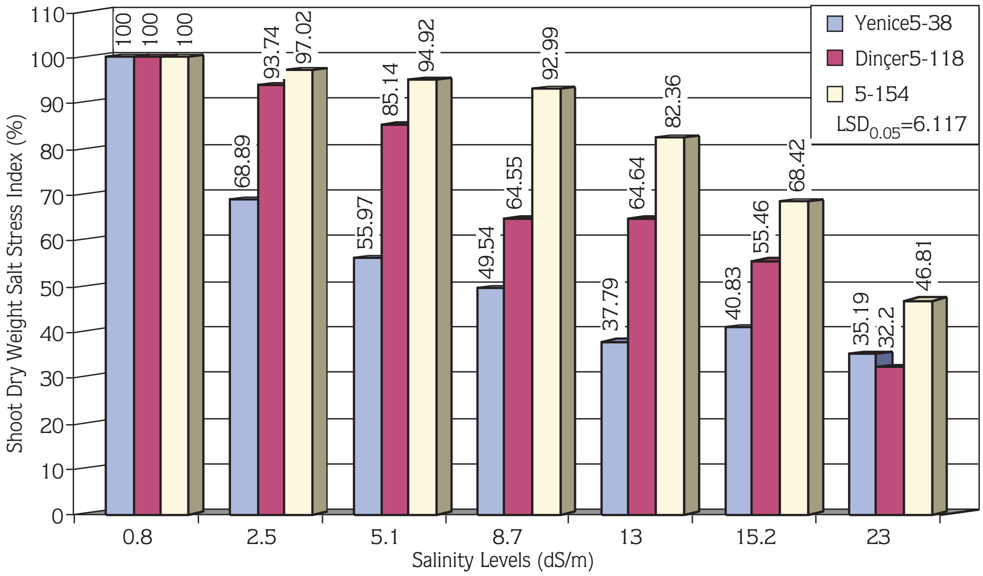

Figure 1. Effects of different soil salinity levels on shoot dry weight salt stress index of three safflower varieties grown 21 days after emergence.

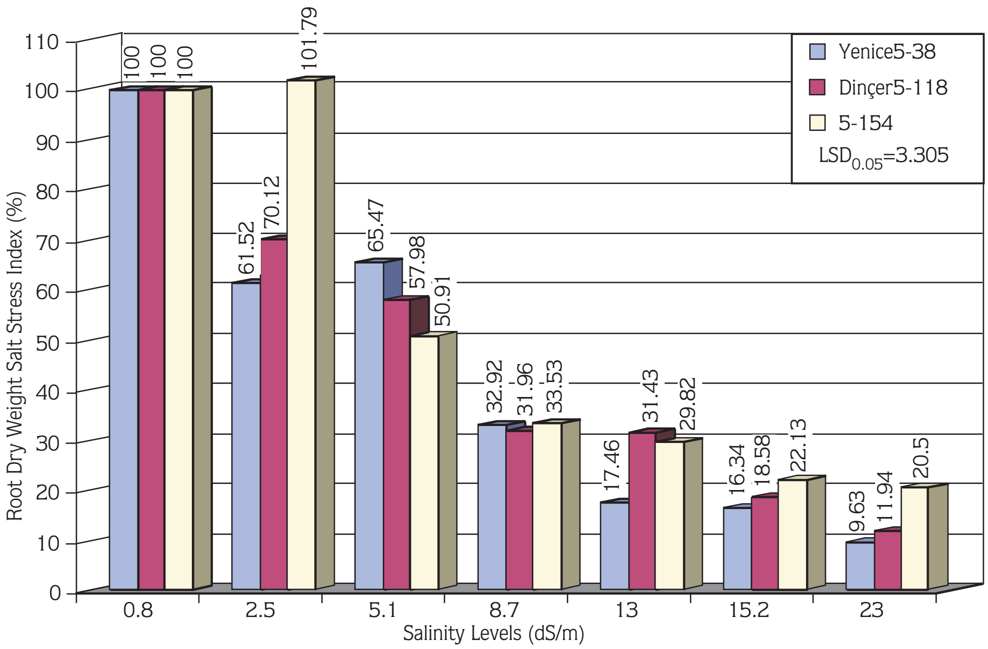

Figure 2. Effects of different soil salinity levels on root dry weight salt stress index of three safflower varieties grown 21 days after emergence.

shoot dry weight salt stress index was considered acceptable up to 15.2 dS m^{-1}. Therefore, the 5-154 had the overall best values for all the salt levels studied.

Discussion

This study revealed that traits in the early growth period of the investigated safflower varieties were significantly influenced by salt concentrations in soil. However, the responses of these varieties to salt concentration were different. Our findings agree with those of Gadallah and Ramadan (1997), Gadallah (1996), Prakash et al. (1995), Prakash et al. (1998), Francois and Bernstein (1964) and Yılmaz and Konak (2000), who observed that there were differences between varieties regards soil salinity tolerance. The control treatment showed there existed clear variation between the varieties in terms of emergence percentage, root dry weight and shoot dry weight. These results were similar to those observed by Chandru et al. (1993) in the sunflower, Özdemir and Engin (1994), Özcan at al. (2000) in the chickpea, and Ghorashy et al. (1972) and Yermanos et al. (1964) in the safflower. In addition, the results obtained from root/shoot dry weight ratio showed that safflower roots were inhibited severely by salinity levels more than the shoots. In earlier studies, Hussain and Rehman (1995, 1997) and Ghorashy et al. (1972) found that the roots of seedlings were more sensitive than the shoots. Basically, dry weights decreased as shoot and root length declined after salinity levels increased. In our study, the safflower varieties we used could keep up with the soil salinity up to 5.1 dS m^{-1} during the emergence and early growth stages, though, both the emergence percentage and shoot growth fell at higher salinity levels. In addition, root dry weight salt stress index decreased at salinity levels higher than 5.1 dS m^{-1}. Veli et al. (1994), Özdemir and Engin (1994) and Konak et al. (1999) found that higher salt stress index characters resulted in higher resistance to salt stress.

In conclusion, in the emergence and seedling growth stages there were differences between the varieties for salt tolerance; 5-154 (spiny) was more resistant to high salt concentrations than the other varieties (spineless) while Yenice 5-38 was the most susceptible. Moreover, the roots of the safflower appear more sensitive than the shoots. The results suggest that if the cultivation of safflower on saline soils is required, the spiny varieties should be preferred.

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