Research Article

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Effect of Salt Stress and Irrigation Water on Growth and Development of Sweet Basil (*Ocimum basilicum* L.)

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Abstract: This study was conducted to assess the influence of different salinity and irrigation water treatments on the growth and development of sweet basil (*Ocimum basilicum* L.). Five salinity levels (0.4, 1.00, 2.50, 4.00 and 8.00 dSm^{-1}) and three different irrigation water regimes (80, 100, 120% of full irrigation) were applied in a factorial design with three replications. Dry root weight, aerial part dry weight and aerial part/root ratio were determined and evaluated as experimental parameters at the end of growing period. Results revealed significant decreases in yields with increasing salinity levels. However, basil managed to survive high salt stress. With increasing salinity levels, decreases in growth were higher in roots than in leaves. Changes in the amount of irrigation water also significantly affected the evaluated parameters.

Keywords: Salinity, water deficiency, yield

1 Introduction

The genus *Ocimum* belongs to Lamiaceae family and includes various shrubs and herbs which are widespread in the tropics and sub-tropics of America, Africa and Asia. The sweet or common basin, *O. basilicum* L. is the most important species of the genus. Since these plants are quite rich in essential oils, they are commonly produced for economic purposes (Lawrence 1993; La-Chowicz et al. 1996; Machale et al. 1997). Basils, especially the sweet basil, are commonly used in gastronomy and oral health care (Baritaux et al. 1992; Khatri et al. 1995; Ozcan and Chalchat 2002; Sajjadi 2006). They provide essential oils which are sometimes used in cosmetics. Basil species are also used in folk medicine as galactogogue, carminative, antispasmodic, stomachic and vermifugem. The tea brewed from basil leaves is also used in treatment of flatulence and nausea (Rhoades 1974; Tanji 1990; Bray et al. 2000; Chiang et al. 2005). The basil species are used in pharmaceutics as diuretic, in cosmetics as fragrance (Lauchli and Epstein 1990; Wu et al. 2007; Shao et al. 2008). Literature also reports that basil species has anti-viral and anti-microbial effects (Copeman et al. 1996).

Irrigation is an essential component of agriculture in arid and semi-arid regions. However, irrigations in these regions may result in salt accumulation in soil profile which negatively influence plant growth and yield. Salts accumulated in soil profile through evaporation are usually taken up by growing plants. Special measures should be taken to prevent hazardous salinity levels since each plant has a threshold salinity tolerance. Leaching water supplementation to irrigation water may be sufficient to eliminate hazardous salinity levels from the plant growth ambient (Page et al. 1990; Marschner and Romheld 1994; Flowers and Flowers 2005; Yildirim and Taylor 2005). But, to get the desired benefit from leaching fraction, either the land should have well natural drainage conditions and surface or sub-surface drainage canals should be constructed to discharge saline effluents. Construction of drainage canals can bring an extra cost to agricultural activities (Meiri and Shahavet 1973).

So that the build-up of soluble salts in the soil becomes or is expected to become excessive, the salts have beeen leached by applying more water than that needed by the crop during the growing season.

Salinity is the greatest concern in plant production and may result in serious losses in yields (Morales et al. 1993; Van de Graaff and Patterson 2001; Said-Al Ahl et al. 2010). Salinity may either be caused by natural

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conditions or irrigation practices. Saline irrigation waters may especially raise soil salinity levels over threshold values (dangerous level) in arid and semi-arid sections of the world (Yurtseven et al. 2001). According the latest statistics, saline lands cover around 7% of total land surfaces of the world. Such lands are mostly salinized with saline irrigation waters and chemical fertilizers used in agricultural practices (Woodward et al. 2002). Salinity may reduce osmatic potential of soil matrix and thus create a water or salt stress, nutritional imbalance or lead to all these conditions (Attia et al. 2010). In general, saline soils have quite high values of sodium absorption ratio (SAR) commonly of over 4 dSm^{-1} due to the presence of dominant Na ions, pH and EC levels (Orsini and Maggio 2008). In saline conditions, there is a greater competition for nutrients over the root surfaces, which hinders micronutrient uptake of plants (Yao et al. 2000; Bertoli et al. 2011).

Ramin (2006) pointed out the following mechanisms in which salinity negatively influence plant growth and development: 1) plant growth may recess due to salt-induced reductions in turgor; 2) salinity-induced stress may alter the balance of root and shoot hormones; 3) salt stress also alters chloroplasts and mitochondria structures and thus recess plant growth and development; 4) respiration increases and photosynthetic activity decreases under saline conditions. Ramin (2006) also indicated that sweet basil is moderately tolerant to salinity. Basil species are tolerant to salinity especially in germination and emergence phases, but further research is needed to elucidate salt tolerance of sweet basil in the other growth stages. However, there aren't any studies carried out in Turkey on salt and water stress tolerance of sweet basil. Therefore, the present study was conducted to assess the effects of different salinity levels and water deficits on growth and development of sweet basil plants.

2 Methods

2.1 Plant material

Sweet basil seeds used in the present experiments were supplied from Aegean Agricultural Research Station. Seeds were germinated in a float system subjected to 16/8 hours light/dark photoperiod. Emerged seedlings were then transplanted to 28 cm diameter pots filled with mixture of peat+perlite+soil in equal ratios. Seedlings were watered daily and the pots with mature seedlings were then transferred to greenhouse conditions.

2.2 Salt and water stress treatments

Municipal water (ECi: 0.4 dS/m) was used in irrigation. To create salt stress treatments, NaCl, $CaCl_2$ and $MgCl_2$ salts were used. Treatments were arranged as S0 (0.4 dS/m), S1 (1.0 dS/m), S2 (2.5 dS/m), S3 (4.0 dS/m) and finally S4 (8.0 dS/m) as recommended by Cirak et al. (2014). To create water stress treatments, initially crop water requirement (W) was determined through weighing the control pots. Then 3 different water stress treatments were created as of W1 (80% of full irrigation), W2 (100% - full irrigation, whole needed water in order to increase the water level to the field capacity) and W3 (120% of full irrigation). The experiment was arranged as a factorial with two factors and three replications. A total of 45 pots were used in the experiment. Experimental factors were combined as presented in Table 1 and a total of 18 irrigations events were performed in 2-3 day intervals.

Salinity is generally expressed in EC (electrical conductivity) and alkalinity is expressed in SAR (Bertoli et al. 2015). While preparing irrigation waters with different salt concentrations (NaCl, $CaCl_2$ and $MgCl_2$), SAR values were tried to be kept around 1 by using the following equation to eliminate sodium effects and to consider only the salinity effects;

$$SAR = \frac{Na^{+}}{\sqrt{\frac{Ca^{++} + Mg^{++}}{2}}}$$

The software "Visual Studio" was used to calculate the chemical quantities to be added to irrigation water to get the desired SAR levels (Camas et al. 2014).

About 15% additional leaching fraction was supplied in each irrigation to meet the leaching requirements.

A total of 18 irrigation events (three per week) were performed throughout the growing season of the plants. The amount of water consumed was recorded in every irrigation event. Experimental treatments are provided in Table 1.

Table 1: Experimental treatments

Salt** \ Water*	80% of RW*	100% of RW	120% of RW
S0	S0W1	S0W2	S0W3
S1	S1W1	S1W2	S1W3
S2	S2W1	S2W2	S2W3
S3	S3W1	S3W2	S3W3
S4	S4W1	S4W2	S4W3

*required water ** salinity levels

At the end of growing season, plants were removed from the pots and washed with tap water. Then the plant materials were separated into underground (roots) and above-ground (stem and leaves) parts dried at room temperature. The dried roots and above-ground parts were weighted separately to determine the root/stem ratio. The ratio reflects potential effects of salt and water stress treatments on plant growth and development.

3 Results and Discussion

Total amount of evapotranspiration for the experiments are shown in Figure 1. Third-degree polynomial relationship was observed between average salt levels (R^2=0.5254).

In this study, different salt concentrations and irrigation water levels had significant effects on growth and development of basil plants. Vegetation process of plants was completed in all treatments. Said-Al Ahl and Mahmoud (2010) indicated *Ocimum basilicum* plants as salt-tolerant and recommended them for saline soils of Egypt. Evapotranspiration rates decreased with increasing salinity levels as shown in Figure 1. Average evapotranspiration values of the treatments are provided in Table 2.

As shown in Table 2, mean evapotranspiration levels were determined as 14607.6, 13173.5, 11988.3, 11108.5 and 9647.3 ml/pot for S0, S1, S2, S3 and S4, respectively. Evapotranspiration levels decreased to 4870, 4977 and 5034 ml/pot in W1, W2 and W3 treatments, respectively with increased salt doses. Since water uptake from the soil becomes difficult due to increasing osmotic pressure of soil solution, such decreased evapotranspiration rates were observed with increasing salinity levels. This phenomenon could also be attributed to decrease in number of stomas and openings. Similarly, the main response to water stress in sweet basil was reported as reduction of transpiration through stomatal closure, even though it could also be optimized through the control of

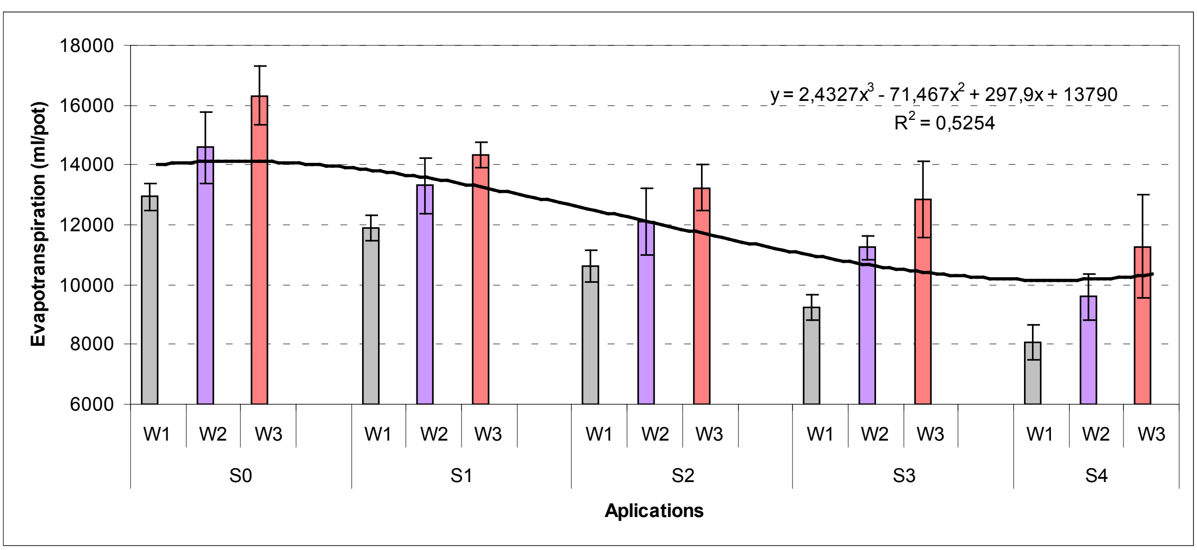

Figure 1: Total amount of evapotranspiration for the experiments

Table 2: Average evapotranspiration rates of treatments

	W1	W2	W3	Total	Average
S0	12930.0	14576.6	16316.1	43822.7	14607.6
S1	11880.0	13315.0	14325.4	39520.4	13173.5
S2	10626.6	12098.7	13239.5	35964.8	11988.3
S3	9250.0	11242.0	12833.5	33325.4	11108.5
S4	8060.0	9600.0	11282.0	28942.0	9647.3
Total	52746.6	60832.2	67996.4		
Average	10549.3	12166.4	13599.3		

stomatal size and density. Mean values of the tested plant growth parameters in response to the experimental factors are provided in Table 3. The results of statistical analyses are also provided in Table 4 and 5.

As shown in Table 4, increasing salt doses significantly affected dry weights of both under and above-ground plant parts and suppressed growth and development. Especially 8 dS/m salt treatment significantly decreased

Table 3: Mean values of the tested parameters

Salinity	Water	Root dry weight (g)	Leaf dry weight (g)	Total dry weight. (g)	Leaf / Root ratio
S0	W1	7.5	27.7	35.2	3.69
	W2	11.4	28.1	39.5	2.48
	W3	10.8	20.2	31.0	1.88
Mean		9.87	25.34	35.22	2.77
S1	W1	7.2	26.7	33.9	3.73
	W2	9.5	27.1	36.7	2.85
	W3	10.6	22.1	32.7	2.08
Mean		9.10	25.30	34.40	3.01
S2	W1	5.3	25.2	30.5	4.72
	W2	9.2	25.6	34.8	2.78
	W3	10.5	23.2	33.7	2.20
Mean		8.35	24.64	33.01	3.25
S3	W1	3.4	25.0	28.4	7.44
	W2	8.2	24.6	32.8	2.98
	W3	9.3	21.2	30.5	2.28
Mean		6.96	23.60	30.57	4.23
S4	W1	2.2	21.7	23.9	9.64
	W2	7.8	23.8	31.6	3.03
	W3	8.8	21.86	30.62	2.50
Mean		6.28	22.43	28.71	5.09

Table 4: Mean values of the tested parameters as affected by different salt doses

Salinity	Root dry weight (g)	Leaf dry weight (g)	Total dry weight (g)	Leaf / Root ratio
S0	9.87 a	25.34 ns	35.22 a	2.77 c
S1	9.10 a	25.30 ns	34.40 a	3.01 c
S2	8.35 ab	24.64 ns	33.01 ab	3.25 c
S3	6.96 bc	23.60 ns	30.57 ab	4.23 b
S4	6.28 c	22.43 ns	28.71 b	5.09 a

*means in the same columns are not significantly different at the P= 0.05 level

*ns= not significant

Table 5: Mean values of the tested parameters as affected by different irrigation water quantities

Water	Root dry weight (g)	Leaf dry weight (g)	Total dry weight. (g)	Leaf / Root ratio
W1	5.12 b	25.25 a	30.38 b	5.92 a
W2	9.23 a	25.84 a	35.08 a	2.89 b
W3	9.99 a	21.69 b	31.69 ab	2.20 c

*means in the same columns are not significantly different at the P= 0.05 level dry matter production. Despite the negative effects of salt treatments, plants were able to complete their life cycles under salt stressed conditions under all treatments. This shows that basil is a salt-tolerant plant as reported previously (Cirak et al. 2012; Cirak and Bertoli 2013). It was also observed that the negative effects of salt treatments on plant development were more distinctive on underground parts. Salt treatments resulted in a slight decrease in dry matter production of over-ground parts, and this was found to be insignificant.

Ramin (2006) reported similar germination and development with the control treatment at lower salinity levels, but reduced germination at salinity levels of over 12 dS/m for sweet basil species.

The effects of water availability on plant development under salt stressed conditions were also found to be significant. As shown in Table 5, plants of W1 treatments were more affected by salt stress and root development was suppressed. It was observed that basil plant could decrease its root development in half under salt stressed conditions.

4 Conclusion

In this study, dry root and leaf weight, yield, root/stem ratio and evapotranspiration rates were determined in sweet basil under different salt and water stress treatments. Both salt and water treatments had significant effects on plant growth and development. Increasing salinity levels resulted in 31%, 34% and 38% decrease in evapotranspiration rates of W1, W2 and W3 treatments, respectively. Increasing salinity levels also resulted in 32%, 20% and 10 % decrease in total yields of W1, W2 and W3 treatments, respectively. It can be concluded that decreasing irrigation water quantities together with increasing salt concentrations much more the plant growth and development is affected.

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