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Assessing Growth Performance and Yields of Spinach (*Spinacia Oleracea* L.) Irrigated with Sea Water

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Abstract

This study was carried out to determine the utilization possibility of sea water in spinach plant cultivation, and to evaluate the effect on yield and growth parameters of spinach irrigated with sea water diluted at different rates. The experiment consists of 5 different irrigation water salinity. The tap water was taken as a control (T1; 0.33 dS/m), and 10% (T2;4 dS/m), 20% (T3; 7 dS/m), 30% (T4; 10 dS/m) and 40% (T5; 13 dS/m) rate of sea water diluted with tap water. According to results, the highest average fresh yield and dry matter values were obtained at T2 (%10) seawater treatment. Both T2 (10%) and T3 (20%) seawater treatments lead to increased fresh yields and dry matter compared to control conditions (T1). While using dilution 10% and %20 seawater for irrigation fresh yields increased approximately 27% and 8.5% respectively but when irrigated with 30% and 40% yields decreasing about 28% and 72% respectively. As with the yield results, the 4 dS/m seawater salinity level caused an increase in leaf heights and leaf number compared to the control treatment. In conclusion, this study shows that seawater can be used successfully when diluted 10% with good quality water without affecting the growth parameters and yields of spinach.

Keywords: Sea water irrigation, salt stress, spinach yield, salinity

Deniz Suyuyla Sulanan Ispanağın (*Spinacia Oleracea L.*) Büyüme Performansının ve Veriminin Değerlendirilmesi

Öz

Bu çalışma, deniz suyunun ıspanak yetiştiriciliğinde kullanılabilirliğini belirlemek ve farklı oranlarda sulandırılmış deniz suyu ile sulanan ıspanak bitkisinin verim ve büyüme parametrelerine olan etkisini değerlendirmek amacıyla yapılmıştır. Deneme 5 farklı sulama suyu tuzluluğundan oluşmaktadır. Musluk suyu kontrol olarak alınmış (T1; 0.33 dS/m), ve 10% (T2;4 dS/m), 20% (T3; 7 dS/m), 30% (T4; 10 dS/m) ve 40% (T5; 13 dS/m) oranlarında deniz suyu çeşme suyu ile seyreltilmiştir. Sonuçlara göre; en yüksek ortalama ıspanak verimi ve kuru madde değerleri T2 (%10) deniz suyu konusunda elde edilmiştir. Hem %10 hem de %20 oranlarında seyreltilmiş deniz suyu uygulanan konulardan, kontrol konusuna göre daha yüksek verim ve kuru madde elde edilmiştir. %10 ve %20 oranlarında seyreltilmiş deniz suyu kullanıldığında verim değerleri yaklaşık %27 ve %8.5 artarken, %30 ve %40 oranında sulandırıldığında verim değerleri %28 ve %72 oranında azalmıştır. Verim sonuçlarında olduğu gibi, 4 dS/m deniz suyu tuzluluk seviyesi (T2) kontrol konusuna kıyasla yaprak yüksekliklerinde ve yaprak sayısında artışa neden olmuştur. Sonuç olarak, bu çalışma, deniz suyunun iyi kalite su ile % 10 düzeyinde seyreltildiğinde ıspanağın büyüme parametrelerini ve verimlerini etkilemeden başarıyla kullanılabileceğini göstermektedir.

Anahtar kelimeler: Deniz suyu ile sulama, tuz stresi, ıspanak verimi, tuzluluk

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1. INTRODUCTION

Due to the global warming that has continued to increase in recent years, the whole world is faced with serious problems in terms of water resources. FAO estimates that by 2050, the world will need to produce sixty percent more food to feed its growing human population. In order to increase food production, a fifty percent increase in irrigated cultivation is required. However, existing water resources allow for an increase of only ten percent (FAO, 2017). For this reason, it is necessary to produce different solutions to meet insufficient water resources especially in regions located in arid and semi-arid climate zones such as our country. There is an increasing awareness among scientists and decision makers about the use of seawater (at least diluted) to reduce the supply of fresh water to be used for agricultural irrigation (Farhadi-Machekposhti et al., 2017; Ghassemi Sahebi et al., 2020; Bianciotto et al., 2021).

The high concentration of salts in seawater is the main limiting factor in the utilization of seawater for irrigation. Plants are damaged by salts due to osmotic effects and specific ion toxicity or their combination (Ayers and Westcot, 1989; Nandwal et al., 2000; El-Mahrouk et al., 2010). These factors cause adverse effects on plant growth and yield and these reductions vary according to plant species (Ayers and Wescot, 1976).

Spinach is a moderately salt-tolerant glycophyte and irrigation water salinity threshold level is 2.0 dS/m. According to some studies on spinach, 25% and 50% yield reduction occurs when irrigation water salinity (ECi) is about 3.5 dS/m and 5.7 dS/m respectively. It is determined that almost no yield can be obtained with irrigation water salinity higher than 15 dS/m (Ayers and Westcot, 1989; Hoffman et al., 1992; Grieve et al., 2012).

However, in a study by Ferreia et al. (2018), it was stated that although increasing amounts of Na and Cl accumulate in the leaves according to the physiological and genetic data of the spinach plant applied with salt water, it did not show toxicity even in irrigation water with an ECi of about 10 dS/m.

It is possible to find several scientific papers (Delfine et al., 2003; Ors and Suares, 2016; Erdem and Kale Celik, 2017; Ünlükara et al., 2017; Deveci and Tugrul, 2017; Ferreira et al.,2020; Uçgun et al., 2020) related to biochemical, physiologşical and moleculer mechanisms of spinach growing under salinity stress. Only in recent years, the effects of alternative water sources such as sea water on commercial plants have begun to be investigated. Turan et al., 2014 carried out a study to investigate the effects of irrigating lettuce (*Lactuca sativa* L. cv. Funly) with different concentrations of diluted seawater (0%, 2.5%, 5%, 10%, 15%, 20%) on the fresh yield, marketable yield and quality parameters. The results of this study demonstrated that low concentrations of seawater are suitable for lettuce production and lettuce can be grown successfully using diluted seawater at concentrations of 2.5% and 5%.

In another study, irrigation with diluted seawater improved the nutritional value and quality of cherry tomatoes (Sgherri et al., 2008). In addition, diluted seawater in the growing medium has also been shown to increase plant water use efficiency (Atzori et al., 2017).

The aim of this study determines using possibility of seawater for the cultivation of spinach and evaluate of changes that may occur in yield and growing parameters of spinach irrigated with different diluted seawater.

2. MATERIAL AND METHOD

2.1 Material

The experiment was carried out in a greenhouse located on Agricultural Research and Application Center of Isparta University of Applied Sciences

Table 2.1. Some physical and chemical properties of the experimental soil
Çizelge 2.1. *Deneme toprağının bazı fiziksel ve kimyasal özellikleri*

Parameters	Value
pH	7.15
EC (dS/cm)	0.146
Saturation (%)	45.00
Field capacity (%)	24.30
Wilting point (%)	12.86
Bulk density (g/cm^3)	1.15
Organic matter (%)	1.65
Lime (%)	26.44
Sand (%)	35.00
Clay (%)	41.00
Loam (%)	24.00
Texture	Clay Loam

Table 2.2. Chemical composition of irrigation water
Çizelge 2.2. *Sulama suyunun kimyasal içeriği*

		Soluable cations (meq/L)				Soluable anions (meq/L)				
EC (dS/m)	pH	Ca	Mg	Na	K	CO_3	Cl	SO_4	HCO_3	SAR
33 (seawater)	8.6	20.55	107.5	195	10.55	25	150	110.6	48	24.37
0.3 (tap water)	7.4	0.98	1.2	0.2	0.8	0	0.97	1.01	1.2	0.19
4	8.2	5.89	15.62	19.68	1.78	5.3	28.71	3.08	5.88	6.00
7	8.3	8.60	26.00	32.00	5.20	6.1	41.58	15.53	8.59	7.69
10	8.3	12.20	35.20	52.36	6.20	7.4	49.21	41.57	7.78	10.76
13	8.4	15.20	49.30	68.76	7.80	8.6	42.50	81.86	8.10	12.11

(37°77′ N, 30°54′ E) in Mediterranean Region of Turkey. In the experiment, plastic pots with a diameter of 17 cm and a height of 16 cm (volume 3 liter) were used and filled with 2.5 kg of soil. The experimental soil was taken from Aridisol great soil group. Soil physical and chemical properties were presented in Table 2.1. According to soil fertility analysis results for basal fertilizer, 10 ml NPK (sodium phosphorus potassium, 3.5 % NH4, 5.5 % NO_3, 10 % urea 19N-19P-19K+micro elements) was applied to the pots.

Spinach (*Spinacia Oleracea* L.) of Matador variety was used in this experiment. This variety is a fast growing, spreading, moderately upright growing variety Its leaves range from light green to dark green, and its shape is elongated oval or round. It is resistant to cold weather and moderately tolerant to salt stress. Spinach, whose leaves are eaten and has a very high nutritional value, is from the *chenopodiaoase* family. Its scientific name is *Spinacea oleracea L*. (Oraman, 1968). Three seeds were planted in each pot and irrigated to field capacity with tap water for 15 days and then they were irrigated with various levels of diluted seawater.

The seawater was obtained from Mediterranean Sea in Antalya/Turkey and diluted with tap water. Seawater salinity was measured as 33 dS/m. Portable EC meter (Hanna HI8633) used for measuring irrigation water salinity level before each application. Irrigation water quality parameters were given in Table 2.2.

2.2. Method

The experimental design was completely randomized block design with three replications. The experiment consists of 5 different irrigation water salinity. The tap water was taken as a control, and different rate of sea water diluted with tap water (Table 2.3).

Table 2.3. Salinity treatments
Çizelge 2.3.*Tuzluluk konuları*

Treatments	Dilution ratio	EC (dS/m)
T1	100% Tap water (Control)	0.3
T2	90% Tap water + 10% Sea water	4.0
T3	80% Tap water + 20% Sea water	7.0
T4	70% Tap water + 30% Sea water	10.0
T5	60% Tap water + 40% Sea water	13.0

Pots were weighed regularly and irrigated when soil moisture content decreased below the 50% field capacity. 15% leaching water were applied for all treatments. Plants were irrigated with seawater until harvesting (60 days after sowing). Spinach plant height was measured and plant leaf number were countered before harvesting.

The total weight of the plants was measured, and the total weight was divided by the number of plants to find the average plant fresh yield (gr/plant). Fresh samples were dried in an oven at 70 ºC until they reached a constant weight (approximately 48 hours), and their dry weights were measured.

MINITAB 18 computer package programs were used for statistical analysis of the results from spinach to determine its salinity responses. Three replicates were taken for each measurement and one-way ANOVA was used to identify significant differences according to Tukey's Test ($P \leq 0.05$).

3. RESULTS AND DISCUSSION

In the study, the effects of diluted seawater salinity at different rates on plant fresh and dry weight, plant height and number of leaves were investigated.

3.1. The effect of sea water salinity on plant fresh yield and dry matter

Fresh and dry matters of spinach irrigated with diluted sea water were given in Table 3.1.

Table 3.1. Salinity treatments
Çizelge 3.1. *Tuzluluk konuları*

Treatments	Fresh yield (g/plant)	Dry matter (g/plant)
T1	45.59	3.91
T2	57.97	4.84
T3	49.44	4.24
T4	32.61	3.37
T5	12.76	1.68

There was a significant quadratic relationship between irrigation water salinity and fresh yield and dry matter (Figure 3.1). The correlation coefficient (R2) was found to be 0.98 for both fresh yield and dry matter values, respectively. According to variance analysis of average plant fresh yield and dry matter values differences in the spinach plant due to different concentrations of seawater are important with a probability of 95%. Tukey classification, which is one of the multiple comparison methods used to determine the differences between the level averages of the factors, are given on Figure 3.1 with lower case letter.

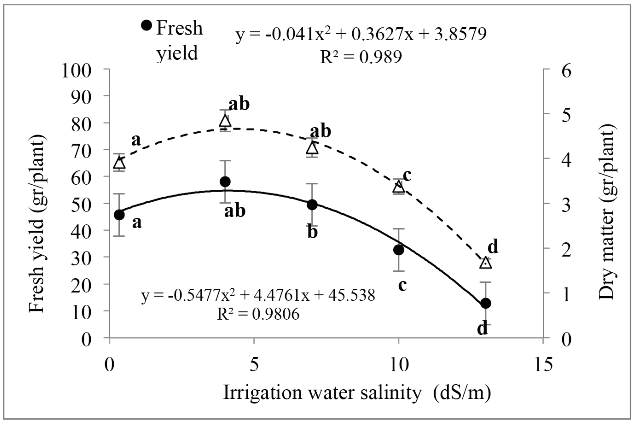

Figure 3.1. Relationships between irrigation water salinity and yield and dry matter
Şekil 3.1. *Sulama suyu tuzluluğu ile verim ve kuru madde arasındaki ilişki*

The highest average fresh yield and dry matter values were obtained at T2 (%10) seawater treatment. Both T2 (10%) and T3 (20%) seawater treatments lead to increased fresh yields and dry matter compared to control conditions (T1). Relative percentage and differences were calculated and presented Figure 3.2.

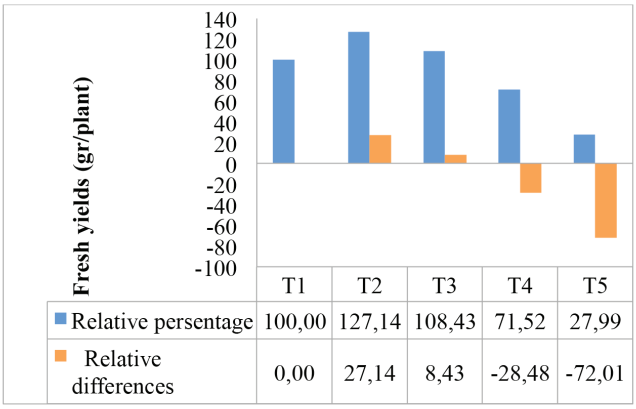

Figure 3.2. Relative percentage and differences of yield according to treatments
Şekil 3.2. *Konulara göre nispi verim ve verim farklılıkları*

While using dilution 10% and 20% seawater for irrigation fresh yields increased approximately 27% and 8.5% respectively but when irrigated with 30% and 40% yields decreasing about 28% and 72% respectively. Study results showed good agreement with other experiments conducted using diluted seawater (Caporratta et al., 2019; Ors and Suarez, 2016; Tomemori et al., 2002; Turan et al., 2014). Some scientist reported that diluted seawater becomes an essential source of micro and macro elements that may have a stimulatory effect on plant growth of spinach (Natsheh et al., 2012; Atzori et al., 2016; El-Nwehy et al., 2020).

3.2. The effect of sea water salinity on plant height

The effects of the applied seawater salinity levels on the plant height were measured and the plant heights according to the treatments were given in Table 3.2.

The increase in the concentration of sea water used as irrigation water caused a decrease in plant height. As seen in Figure 3.3, there is a negative quadratic relationship between treatments and plant height with correlation coefficient 0.86.

Table 3.2. Plant heights values of different seawater salinity levels
Çizelge 3.2. *Farklı deniz suyu tuzluluklarında bitki boyu değerleri*

Treatments	Plant Height (cm)			
	1. Replication	2. Replication	3. Replication	Average
T1	13.0	14.0	14.5	13.8
T2	15.0	16.5	12.0	14.5
T3	10.0	8.5	7.0	8.5
T4	8.5	6.0	9.0	7.8
T5	5.0	6.0	6.0	5.6

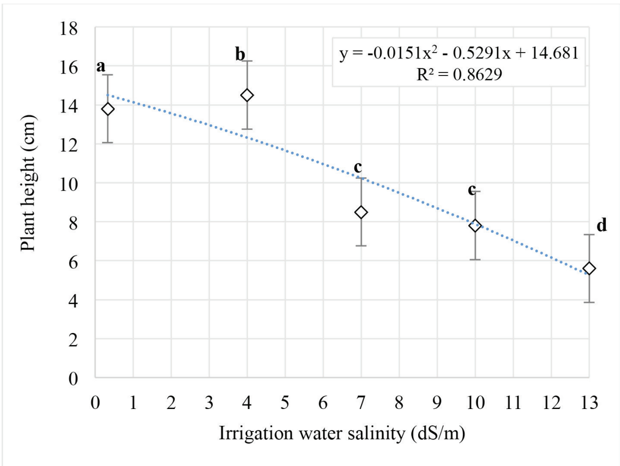

Figure 3.3. Relationships between irrigation water salinity and plant height
Şekil 3.3. *Sulama suyu tuzluluğu ile bitki boyu ilişkisi*

The results of analysis of variance of average plant heights are shown in Table 3.3.

Table 3.3. Variance analysis table of plant height
Çizelge 3.3. *Bitki boyuna ait varyans analizi tablosu*

Source of variation	SD	SS	AS	F	Table F	
					0.05	0.01
Treatments	5	150.93	30.19	73.96*	3.86	
Error	9	18.37	2.04			
General	14	172.93				

*; significant level of 0.05, SD; Standard deviation, SS; Sum of square, AS; Average of square

According to the statistical evaluation, the effect of sea water levels at different concentrations on plant height was found to be significant at the 0.01 level.

3.3. The effect of seawater salinity on the number of leaves

For commercial purposes, leaves are the main component of spinach plant (Atzori et al., 2017; Caparrotta et al., 2019). The effects of seawater salinity levels on the number of plant leaves were evaluated and the average plant leaf numbers according to the subjects are given in Table 3.4.

Table 3.4. The number of plant leaves
Çizelge 3.4. *Bitki yaprak sayısı*

Treatments	The number of plant leaves (cm)			
	1. Replication	2. Replication	1. Replication	Average
T1	12	13	11	12
T2	14	13	12	13
T3	11	10	9	10
T4	8	9	7	8
T5	7	7	7	7

The highest average number of plant leaves was obtained in T2 treatment. The average number of plant leaves was T1 (12), T3 (10), T4 (8), and T5 (7), respectively. The variance analysis results of the average plant leaf numbers are shown in Table 3.5.

Table 3.5. The number of plant leaves variance analysis table
Çizelge 3.5. *Bitki yaprak sayısına ait varyans analizi tablosu*

Source of variation	SD	SS	AS	F	Table F	
					0.05	0.01
Treatments	5	40.93	8.19	32.13*	3.86	
Error	9	11.47	1.27			
General	14	52.93				

*; significant level of 0.05, SD; Standard deviation, SS; Sum of square, AS; Average of square

There is a significant negative relationship between seawater salinity and the number of plant leaves. This situation can be seen in Figure 3.4.

According to the obtained values, the correlation coefficient R^2 = 0.98. As the irrigation water salinity increased, there was a linear decrease in the number of plant leaves. No significant differences in leaves number were assessed among treatments at T4 and T5.

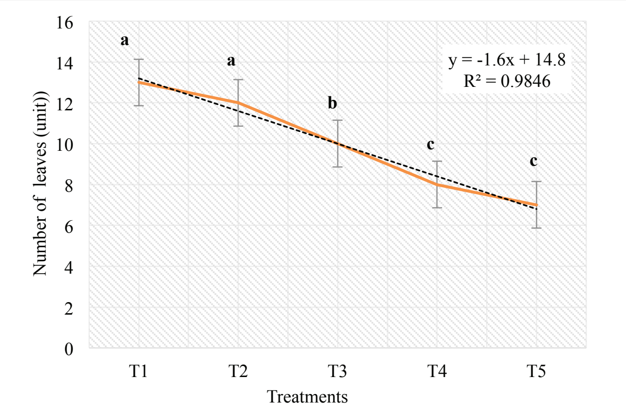

Figure 3.4. Average number of leaves and Tukey classifications

Şekil 3.4. *Ortalama yaprak sayıları ve Tukey sınıflaması*

4. CONCLUSIONS

Experiment results indicated that more than 10% diluted seawater application negatively affected of the spinach plant in terms of fresh and dry yields as compared to the control. Both 10% and 20% seawater treatments lead to increased relative yields (%27 and %8) but 30% and 40% diluted seawater treatments decreased relative yields about 28% and 72% respectively. As in yield results, significant differences in leave heights and number of leaves were observed, with 4 dS/m sea water salinity level (T2) compared to the control.

In conclusion, this study indicates that spinach can be successfully cultivated using sea water with moderate salinity (%10 diluted) without altering its growth parameters and yields.

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