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Effect of Different Irrigation Water Levels on Yield and Quality Parameters of Fodder Beet

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ABSTRACT

The study was carried out at the Agricultural Research and Application Farm of Faculty of Agriculture, Isparta University of Applied Sciencesin 2021, with the aim of determining the effect of different irrigation water levels on the yield and quality parameters of fodder beet by the experiment of randomized complete block design with three replications. The study used Rota fodder beet variety. Applied irrigation water amounts were determined according to Penman-Montheith method by considering the total reference evapotranspiration (ET_o) of ten days for five different ratios (S_1: ET_o×1.20, S_2: ET_o×0.90, S_3: ET_o×0.60, S_4: ET_o×0.30; S_5: ET_o×0.00). Drip irrigation method was used for irrigation. Applied irrigation water amounts ranged between 131.9 mm – 643.6 mm. Crop water consumption (ET) ranged between 337.1 mm – 782 mm. At the end of the treatments, it was observed that fresh leaf yield varied between 570 and 1788.1 kg da^{-1} while these values were from 1865.7 to 7838.8 kg da^{-1} for fresh root yield, from 2435.8 to 9626.9 kg da^{-1} for total fresh yield, from 134.1 to 255.5 kg da^{-1} for leaf dry matter yield, from 469.9 to 1247.6 kg da^{-1} for root dry mater , from 12.2 cm to 25.4 cm for tuber length, and from 6.5 to 12.4 cm for tuber diameter. The yield response factor (ky) was 1.04. The water use efficiency was 72.3 – 145.0 kg ha^{-1} mm^{-1}, the irrigation water use efficiency was ranged from 111.7 to 157.5 kg ha^{-1} mm^{-1}. The S_2 irrigation treatment was the most appropriate irrigation program under adequate irrigation water conditions. In terms of irrigation deficit conditions, results indicated that there may apply irrigation water at 60% or 30% of reference evapotranspiration from S_3 or S_4 irrigation program.

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Keywords
Fodder beet
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Farklı Sulama Suyu Düzeylerinin Yem Pancarının Verim ve Kalite Parametrelerine Etkisi

ÖZET

Çalışma, Isparta Uygulamalı Bilimler Üniversitesi, Ziraat Fakültesi Tarımsal Araştırma ve Uygulama Çiftliği'nde 2021 yılında farklı sulama suyu düzeylerinin yem pancarının verim ve kalite parametrelerine etkisini belirlemek amacıyla tesadüf bloklar deneme desenine göre üç tekrarlamalı olarak yürütülmüştür. Çalışmada Rota çeşidi yem pancarı kullanılmıştır. Sulama suyu miktarının belirlenmesinde Penman-Monteith yöntemine göre hesaplanan kıyas bitki su tüketimi (ET_o) dikkate alınmış, on günlük kıyas bitki su tüketimi toplamının beş farklı oranı (S_1: ET_o×1.20; S_2: ET_o×0.90; S_3: ET_o×0.60; S_4: ET_o×0.30; S_5: ET_o×0.00) sulama suyu olarak uygulanmıştır. Sulamalarda damla sulama yöntemi kullanılmıştır. Deneme konularına uygulanan sulama suyu miktarları 131.9 mm – 643.6 mm arasında, bitki su tüketimi (ET) ise 337.1 mm – 782 mm arasında değişmiştir. Deneme konularına göre yaş yaprak verimi, 570 – 1788.1 kg da^{-1}, yaş yumru verimi, 1865.7 – 7838.8 kg da^{-1}, toplam yaş verim, 2435.8 – 9626.9 kg da^{-1}, yaprak kuru madde verimi, 134.1 – 255.5 kg da^{-1}, yumru kuru madde verimi 469.9 – 1247.6 kg da^{-1}, yumru boyu, 12.2 cm – 25.4 cm, yumru çapı, 6.5 – 12.4 cm arasında değişmiştir Verim tepki etmeni (ky) 1.04 olarak hesaplanmıştır. Su kullanım randımanı 72.3 – 145.0 kg ha^{-1} mm^{-1} arasında iken sulama

Biyosistem Mühendisliği

Araştırma Makalesi

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Anahtar Kelimeler
Yem pancarı
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Su kullanım randımanı
Verim tepki etmeni

suyu kullanım randımanı 111.7 – 157.5 kg ha^{-1} mm^{-1} arasında belirlenmiştir. Deneme koşulları için yeterli sulama suyu koşullarında S_2 konusu en uygun sulama programı olarak belirlenmiştir. Kısıtlı sulama suyu koşullarında ise kıyas bitki su tüketiminin %60'ının ya da %30'unun uygulandığı S_3 veya S_4 konularının sulama programı olarak kullanılabileceği sonucuna ulaşılmıştır.

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INTRODUCTION

Forage crop farming, meadow, and pasture farming are sources that provide the feed needed by animals cheaply and in abundance (Açıkgöz et al., 2005). It is necessary to increase the amount of forage crop production in field agriculture for reducing the grazing pressure on the meadows and pastures (Yılmaz, 2018). Forage crops are defined as roughage, forage contains important nutrients for increasing the reproductive power of animals and providing high–quality animal products (Yolcu & Tan, 2008). Globally, the amount of feed produced by the feed industry has reached an estimated 1 billion tons per year (FAO & IFIF, 2020). Roughage shortage is a serious problem in Central Anatolia and Transition Regions as well as throughout Türkiye (Erdoğdu et al., 2011). Recently, Türkiye has occurred overgrazing (Parlak & Ekiz, 2008). Despite Türkiye being at a good level in terms of livestock, the yield in animal production is quite low (Özdemir & Kökten, 2020). Fodder beet can provide abundant and high–quality forage during meadows and pastures begin to dry up or become insufficient (Erdoğdu et al., 2011). The fodder beet is an alternative plant, which attracts more attention from farmers (Seifu et al., 2020).

Fodder beet is a species from the spinach family that produces tubers (root–stem, hypocotyl) and has a high yield among forage plants (Acar et al, 2020). Fodder beet provides both its leaves and tubers in animal nutrition and is consumed either directly or as silage (Sakr et al., 2014). High crude protein and sugar content make fodder beet a more palatable, nutritious, and energy efficient feed (Dulphy et al., 2000). Fodder beet suits temperate climates (Gemalmaz & Bilal, 2016), resistant to salinity and provides the marginal land economically (Güleş, 2009; Abdallah & Yassen, 2008). According to Howell and Musick (1984), it is possible to irrigate fodder beet economically. Brown et al. (1987) and Martin et al. (1983), Fodder beet is particularly sensitive to drought during germination and early development stage, but drought tolerance increases after the root system develops. However, Clover et al. (1999) stated that the lack of water requirement during the growing period reduces the yield of fodder beet.

Kassab et al. (2012), conducted a study in Egypt for three different irrigation levels according to reference evapotranspiration (ET_o) ratios of 100%, 75%, and 50%, applied irrigation water reported 502 mm, 385 mm and 270 mm, respectively. Chakwizira et al. (2014) in New Zealand, conducted the plant water consumption of 316 mm in non irrigated treatment, 483 mm, and 774 mm for 50% and full irrigation (100% of ET_o), respectively. Yılmaz (2018) reported the fresh leaf yield of 1760 kg da^{-1} – 2548 kg da^{-1} in Sakarya–Pamukova conditions, 2913.1 kg da^{-1} – 3270.0 kg da^{-1} in Tokat conditions (Karadağ et al., 2014), and from 1592 kg da^{-1} to 1917 kg da^{-1} in Konya conditions (Özköse, 2013). Fresh root yields, obtained by Albayrak and Çamaş (2006) varied between 9060 kg da^{-1} – 8690 kg da^{-1} for Ecdogelb and Ecdorot cultivars in Central Black Sea conditions. Sarag (2013) reported 5313 kg da^{-1}, 5944 kg da^{-1} and 6821 kg da^{-1} in Voroshenger cultivar and 5746 kg da^{-1}, 6345 kg da^{-1} and 7260 kg da^{-1} in Rota varieties by applying irrigation water of 50%, 75% and 100% based on the field capacity, respectively. Mofeeda et al. (2019) applied irrigation water of 100%, 80%, and 60% of evaporation pan by drip irrigation method in Egypt. The total fresh yields reported from these irrigation treatments were 7012.6 kg da^{-1}, 6670.5 kg da^{-1}, and 4846.1 kg da^{-1}, respectively.

This study has aimed to determine the water–yield relations of fodder beet in Isparta ecological conditions. The main objectives of the study were to determine the water consumption, irrigation water requirement, the most appropriate irrigation water level, and the effects of different irrigation water levels on yield and quality parameters of fodder beet grown.

MATERIAL and METHODS

The study was carried out in Isparta University of Applied Sciences, Faculty of Agriculture, Agricultural Research and Experimental Farm (37º 45' N, 30º 33' E) with elevation of 1020 m during 2021. The experimental area was located in the Lakes Region with transition features between the Mediterranean and the Central Anatolia climate. According to long–term climate data records, average temperature of the region was 12.1 °C, the average relative humidity was 62%, and the average annual total precipitation was 524 mm. During the study, the lowest and highest average temperature recorded in both February and December with 3.8 °C, and August with 24 °C. However, the lowest and highest relative humidity was 36% and 83.6%, obtained in August and January, respectively. In 2021, the total precipitation measured 362 mm, while the rainfall measured in the trial period was 137.6 mm.

Soil samples taken from experimental area indicated the soil bulk density of 1.42 g cm^{-3} and 1.45 g cm^{-3}, field capacity of 22.74% (96.9 mm) and 21.08% (91.7 mm), wilting point 11.83% (50.4 mm) and 11.92% (51.8 mm), available water holding capacity of 10.90% (45.4 mm) and 9.16% (39.9 mm), which determined from 0-30 cm and 30-60 cm soil profiles, respectively. The percentages of clay, silt and sand at 0-30 cm soil depth are 28.95%, 34.97% and 36.07%, respectively, and these values are 30.28%, 32.61% and 36.76% at 30-60 cm soil depth. Therefore, the soil texture in both layers determined is Clay Loam (CL) (Table 1).

Table 1. Some characteristics of the soils of the trial area
Çizelge 1. Deneme alanı topraklarının bazı özellikleri

Characteristics	Unit	Results		
Soil depth	cm	0-30	30-60	0-60
Soil bulk density	g cm^{-3}	1.42	1.45	
Field capacity	%	22.74	21.08	
	mm	96.9	91.7	188.5
Wilting point	%	11.83	11.92	
	mm	50.4	51.8	102.2
Available water	%	10.9	9.2	
holding capacity	mm	46.4	39.9	86.3
Clay	%	28.95	30.28	
Silt	%	34.97	32.61	
Sand	%	36.07	36.76	
Soil texture class		CL	CL	

Irrigation water used in the experiment was characterized by the electrical conductivity (EC) of 0.54 dS m^{-1}, pH of 7.74, and SAR value of 0.78. The cations used were Ca^{2+}, Mg^{2+}, Na^{+} and K^{+} with values of 4.72 me L^{-1}, 0.17 me L^{-1}, 1.22 me L^{-1} and 0.28 me L^{-1}, respectively. However, the anions used were $CO2^{2-}$, HCO^{3-}, Cl^{-} and $SO4^{2-}$ with values of 0.0 me L^{-1}, 6.27 me L^{-1}, 0.11 me L^{-1}, and 0.01 me L^{-1}, respectively. Therefore, the quality of irrigation water is classified in C_2S_1 (Uçar et al., 2020). Irrigation water was taken from the hydrant, which is located next to the trial area and serves to irrigate the farm land, and was applied with the drip irrigation method. The control unit consisted of a sieve filter, pressure regulators and a fertilizer tank that provides fertilizer. The main pipes in the irrigation system were used PE pipes with an outer diameter of 50 mm and an operating pressure of 6 atm, while the manifold pipes were used PE pipes with an outer diameter of 32 mm and an operating pressure of 4 atm. In the study, lateral pipes with 16 mm outer diameter, 40 cm dripper spacing and 2 L h^{-1} dripper flow were used. A lateral was placed in each row of plants. The system also included water meters and manometers and ball valves to measure and control water. Various agricultural practices were done during the trial such as ploughing, weed control, pest control, and fertilizer applications. Fertilizer application to the fodder beet was applied according to the study recommendation of Türk (2010).

Experimental Design

Five different irrigation water levels were created based on reference evapotranspiration (ET_o) that was taken from the meteorology station (Pessl Instruments, Metos 3.3) of Isparta University of Applied Sciences, Agricultural Research and Practice Farm, which is located from the experimental area. ET_o values were calculated according to the Penman – Monteith method with irrigation interval of 10 days (Table 2) (Tarı et al., 2016). Randomized Complete Block (RCB) design with three replications was used as an experimental design. The irrigation treatment plots were arranged in 10 m long and 3 m width. The fodder beet was planted in 20 March 2021 at 60 cm between rows, and 25 cm within the row. Each irrigation plot had five plant rows (Figure 1).

Table 2. Irrigation treatments used in experiment
Çizelge 2. Denemede kullanılan sulama konuları

Irrigation treatments	ET_o ratio	Irrigation interval (days)
S_1	120%	
S_2	90%	
S_3	60%	10
S_4	30%	
S_5[1]	0%	

[1]Only apply the same amount of irrigation water as other treatments during the germination and emergence

Applied Irrigation Water Amount

Applied irrigation water amount was calculated by using Equation 1 according to the rates of reference evapotranspiration of cumulative daily ET_o values in 10-day intervals (Tarı et al., 2016). The crop cover percentage was calculated with the help of Equation 2 (Ertek and Kanber, 2001).

$$I = A \, x \sum ET_o \; x \, P \, x \, R \tag{1}$$

$$P = \frac{a}{b} \, x \, 100 \tag{2}$$

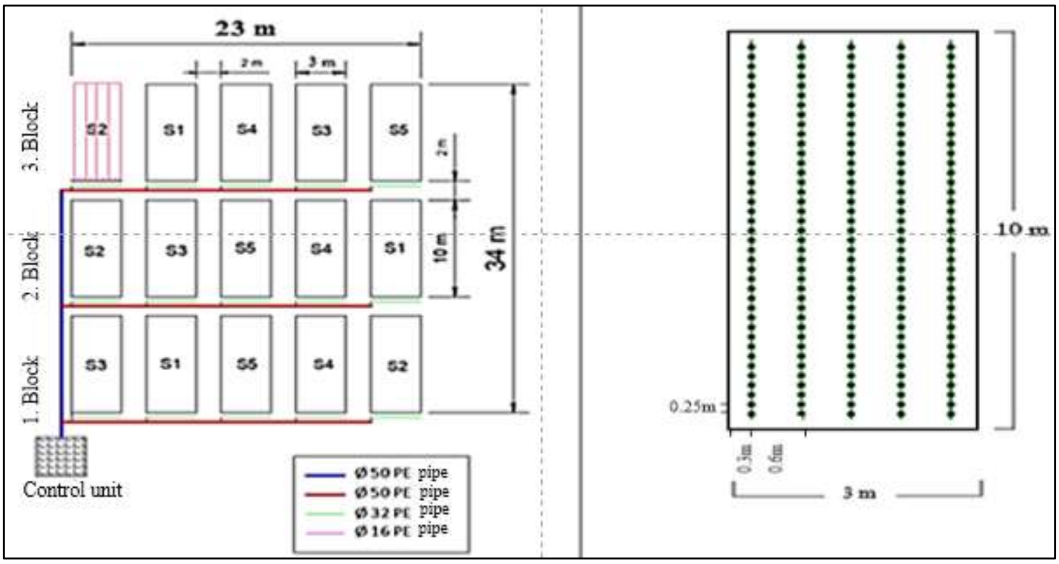

Figure 1. Layout of experimental design and parcel detail
Şekil 1. Deneme yerleşim düzeni ve parsel detayı

Where, I: Irrigation water (liter), A: Parcel area (m^2), ΣET_o: Total reference evapotranspiration (mm), P: Crop cover percentage (%), R: ET_o ratio, a: Plant leaf shadow width (cm) and b: Row spacing (cm)

Crop Water Consumption (ET_c)

The effective root depth (D) of fodder beet is 60 cm (Heikal, 2008; Sakr et al., 2014; Khafaga et al., 2017). Therefore, the soil moisture content in root zone of fodder beet was monitored by gravimetric method with an interval of ten days between 20.04.2021 and 22.10.2021, from 0 – 60 cm soil depth to calculate the crop water consumption (ETc). The ETc for each experimental treatment was calculated by using Equation 3 (James, 1988).

$$ET = I + P + C_p - D_p \pm R_f \pm \Delta S \tag{3}$$

Where; ET: Crop water consumption (mm), I: Applied irrigation water (mm), P: Precipitation measured over a ten-day period (mm), C_p: Capillary rise (mm), D_p: Deep percolation (mm), R_f: Surface runoff (mm) and ΔS: Change of water content in soil profile (mm). Since the experimental area consisted of deep soils without problems of drainage and salinity (Akgül & Başayiğit, 2005), C_p and R_f values were neglected during calculations of ETc.

Water -Yield Relationships

Yield response factor (ky) was determined according to the Stewart model. Equation 4 was used in the calculation (Stewart et al.,1976, Doorenbos and Kassam,1979).

$$[1 - (Y_a/Y_m)] = ky\,[1 - (ET_a/ET_m)] \tag{4}$$

Where; ky : Yield response factor, Y_a : Actual yield of total fresh yield (kg da^{-1}), Y_m: The highest total fresh yield (kg da^{-1}), ET_a : Actual water consumption (mm) and ET_m : Maximum water consumption (mm).

Water Use Efficiencies

Irrigation water and water use efficiencies were determined with the help of Equations 5 and 6 (Howell et al., 1990; Ertek et al., 2007).

$$IWUE = (Y - Y_{ni})/I \tag{5}$$

$$WUE = Y/ET \tag{6}$$

Where; IWUE: Irrigation water use efficiency (kg ha^{-1} mm^{-1}), WUE: Water use efficiency (kg ha^{-1} mm^{-1}), Y: Total fresh yield (kg ha^{-1}), Yni: Total fresh yield obtained in rainfed conditions (kg ha^{-1}), I: Irrigation water (mm), ET: Plant water consumption (mm).

Yield and Quality Parameters

The fodder beet was harvested after 183 days of planting. The harvested area in each irrigation treatment was remained as 16.2 m^2 (1.8 m x 9 m) after leaving one row at each edge of each trial plot and two plants from the beginning and end as an edge effect. During the yield observations and measurements, 30 fodder beet were selected randomly from each irrigation treatment (Acar, 2000). The length of tubers (cm) were determined by measuring 30 fodder beet that selected randomly in each plot. The diameter of tubers (cm) were determined by dividing the fodder beet into two part and measured using a ruler. The part of the root above the ground (cm) is the part above the surface level of soil. This parameter measured in each plot by using a meter. The length of fodder beet was expressed in cm. The ratio of the root-stem to the total root-stem was expressed in percentage. Above ground root-stem ratio (%) was calculated by taking the length of fodder beets left in above the ground to the total length of fodder beets. For leaf dry matter ratio (%), after harvesting, at least 100 gram of leaf samples were taken from each plot and dried in a closed place where the sun did not come into direct contact. Then after, they putted in paper bags and dried in an oven at 65 °C until they reached a constant weight, and then dry matter ratios were determined by calculating the ratio of weight of dry leaves to the weight of fresh leaves. The leaf dry matter yield (kg da^{-1}) was calculated by multiplying the dry matter rate and the fresh leaf yield in kg obtained in each plot. For dry matter ratio in root-stem (%), tuber samples were cutted into thin slices and dried in an oven at 70 °C until they reached a constant weight, and then dry matter weights of the tubers were determined. Dry matter ratios of tubers were calculated by proportioning dry weight to wet weight. Root-stem dry matter yield (kg da^{-1}) was calculated by multiplying the dry matter rate determined for root-stem in each plot with the fresh root-stem yield in that plot. For determining the leaf yield (kg da^{-1}), the fodder beet leaves in the harvest plot were separated from their root-stems and weighed. The fodder beets in the harvest plot were harvested by hand and then the root-stems separated from the leaves and weighed to determine the tuber yield per decare (Güleş, 2009).

Statistical Analysis

Variance analysis of the obtained data was done with the "Minitab 17" computer software according to experimental design. Duncan multiple comparison test with significance level of 5% was applied, if the differences between the treatments were significant different. However, the regression analysis was made for determining irrigation water application, yields, and quality of yield parameters.

RESULTS and DISCUSSIONS

Reference Crop Evapotranspiration

Reference crop evapotranspiration (ET_o) and precipitation values taken from the meteorology station located 500 m away from the experimental area during period of 10 days. The growing period of the fodder beet under the experimental conditions was 183 days. The total precipitation recorded during experiment was 137.6 mm. The ET_o values between 82nd days after planting and 111st days after planting were high, reached the value between 51.6 mm – 57.4 mm. However, it gradually decreased in the period starting from 112nd days after planting until the harvest. When the completely growing period was taken into account, the relative humidity was the lowest between the 72nd and 142nd days after planting, while ET_o reached its highest values (Figure 2).

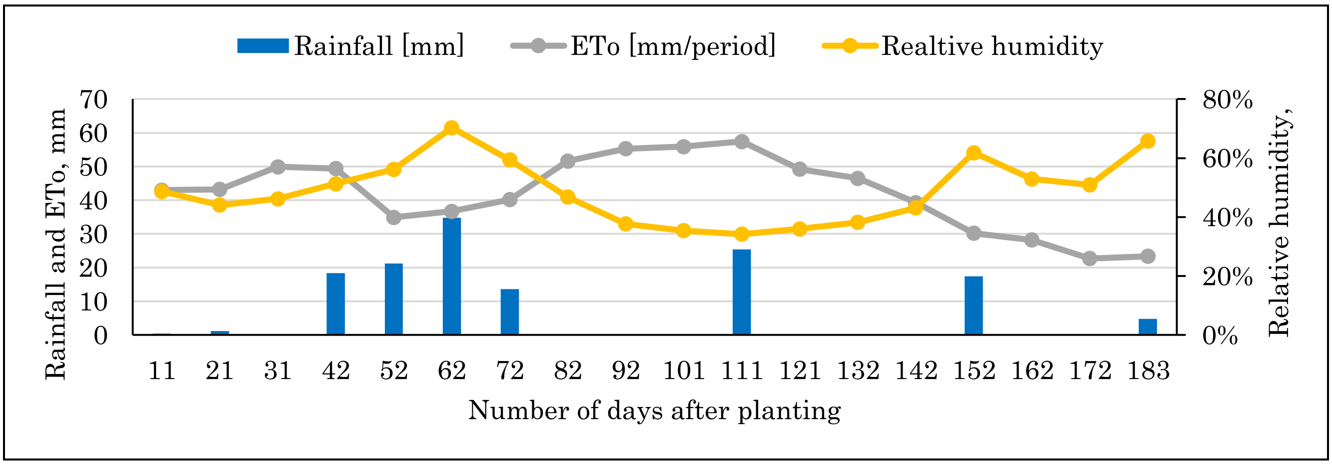

Figure 2. ET_o, precipitation and relative humidity
Şekil 2. ET_o yağış ve bağıl nem

Applied Irrigation Water Amount

The same irrigation water amount was applied to all irrigation treatments during the germination and emergence period. During this period, 131.9 mm of irrigation water was applied equally to all irrigation treatment. The total amounts of irrigation water applied to S_1, S_2, S_3, S_4 and S_5 were 643.6 mm, 515.7 mm, 387.8 mm, 259.8 mm and 131.9 mm, respectively (Table 3).The amount of irrigation water applied gradually increased until 111st days after planting where it has seen that the highest average temperature. When there increases air temperature,

ET_o also increases. Khafaga et al. (2017) applied irrigation water amount to the fodder beet of 765.3 mm and 751.5 mm for sprinkler and furrow irrigation methods in 2011, respectively, and 962 and 934 mm of irrigation water in 2012. In Spain, the amount of irrigation water applied was 690 mm and 585 mm in 2011 and 2012, respectively (Noreldin et al., 2016), while the value obtained in New Zealand was 537 mm (Chakwizira et al., 2014). In Egypt conditions, irrigation water amounts were reported as 502 mm, 385 mm and 270 mm for water deficit ratio by 100% ET_o, 75% ET_o and 50% ET_o (Kassab et al., 2012). Irrigation water may differ from place to another due to the differences in the climate, the method taken into account, the cultivar growing management as well as the different irrigation method.

Soil Moisture Content

Twelve irrigations times were applied during the growing season (Figure 3).

Table 3. The amount of irrigation water applied to the irrigation treatment, mm
Çizelge 3. Deneme konularına uygulanan sulama suyu miktarları, mm

Date	S_1	S_2	S_3	S_4	S_5
Irrigation water applied during germination and emergence period, mm					
20/04/2021-20/06/2021			131.9		
Irrigation water applied after starting scheduled irrigation program, mm					
30/06/2021	26.5	19.9	13.3	6.6	0
10/07/2021	41.5	31.2	20.8	10.4	0.0
20/07/2021	53.8	40.4	26.9	13.5	0.0
31/07/2021	61.6	46.2	30.8	15.4	0.0
10/08/2021	68.9	51.7	34.4	17.2	0.0
20/08/2021	59.0	44.3	29.5	14.8	0.0
31/08/2021	55.8	41.9	27.9	14.0	0.0
10/09/2021	47.2	35.4	23.6	11.8	0.0
20/09/2021	36.2	27.2	18.1	9.1	0.0
30/09/2021	33.8	25.4	16.9	8.5	0.0
10/10/2021	27.2	20.4	13.6	6.8	0.0
Total (during scheduled irrigation program, mm)	511.7	383.8	255.9	127.9	0.0
Seasonal Irrigation water applied, mm	643.6	515.7	387.8	259.8	131.9

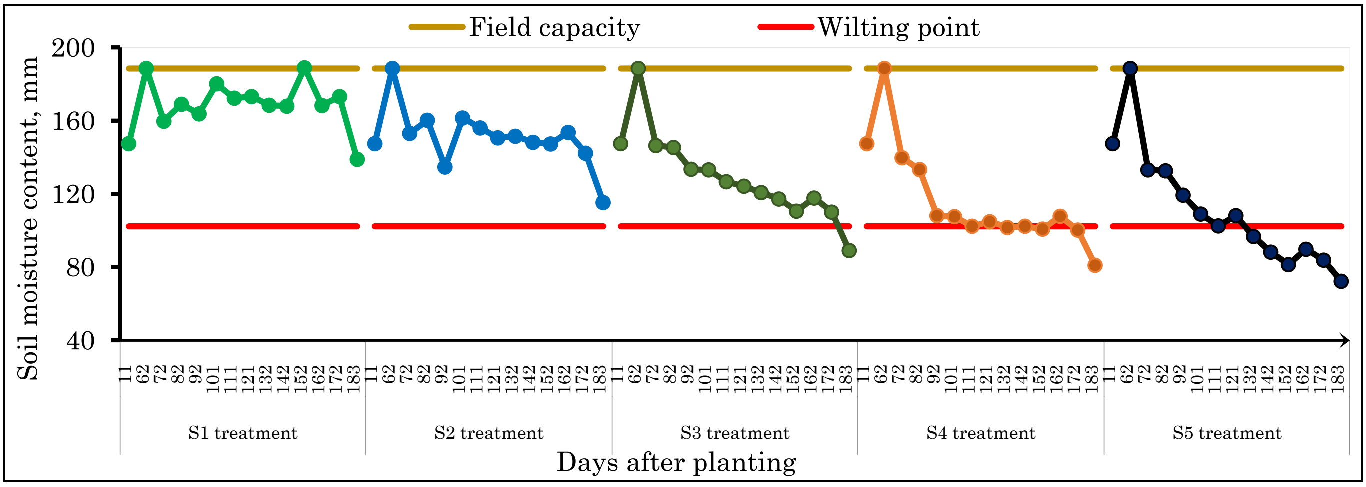

Figure 3. Soil moisture content according to irrigation treatments
Şekil 3. Deneme konularına göre toprak nemi içeriği

Soil moisture content in S_1 was close to field capacity, while in S_2 it generally varied between field capacity and wilting point, except for the last irrigation. On the other hand, S_3 was between field capacity and wilting point at the beginning of the trial, similar to S_2, but towards the end of the trial, it approached to the wilting point. While it was generally around the wilting point in S_4, it started to fall below the wilting point in S_5 from the middle of the trial. Therefore, in this trial, the leaves of the plants turned yellow and dried after 132nd days after planting.

Crop Water Consumption (ET_c)

The ET_c measured in all irrigation treatment was 163.9 mm before the scheduled irrigations. After the irrigation program was started, the ET_c values measured in S_1, S_2, S_3, S_4 and S_5 treatments were 618.1 mm, 513.7 mm, 412.1 mm, 286.3 mm and 173.2 mm, respectively, while seasonal ET_c measured in the same irrigation treatments were 782.0 mm, 677.7 mm, 576.0 mm, 450.2 mm and 337.1 mm, respectively (Table 4). Compared to S_1, where the most irrigation water was applied, the reduction rate of ET_c in S_2, S_3, S_4 and S_5 was 13%, 26%, 42% and 57%, respectively. Chakwizira et al. (2014) in New Zealand reported the ET_c of 316 mm in non-irrigated treatment, and 483 mm and 774 mm in irrigation treatments where 50% and 100% of the ET_o were applied. Mofeeda et al. (2019) measured ETc under full irrigation conditions of 573.3 mm for the first year of the experiment and 680.9 mm for the second year in Egypt conditions. The seasonal ET_c measured in this study shows that there was no difference from previous studies.

Table 4. Crop water consumption (ET_c)
Çizelge 4. Bitki su tüketimi (ET_c)

Irrigation treatments	S_1	S_2	S_3	S_4	S_5
ETc during germination and emergence period, mm					
20 April-20 June			163.9		
ETc after starting irrigation program, mm					
June (20-30)	101.3	93.0	90.8	85.9	69.6
July	181.0	142.5	110.8	77.0	30.1
August	191.7	154.7	115.8	65.9	39.7
September	109.8	96.5	73.4	43.9	22.0
October	34.3	27.1	21.2	13.5	11.8
Total ETc after starting irrigation program, mm	618.1	513.7	412.1	286.3	173.2
Seasonal ETc, mm	782.0	677.7	576.0	450.2	337.1

Effect of Different Irrigation Water Levels on Yields and Quality of Fodder Beet

According to variance analysis results, different irrigation water levels statistically significantly affected the yields and quality of fodder beet ($p<0.01$) (Table 5). Results indicated that when irrigation water decreased lead fresh root yield, fresh leaf yield, total fresh yield, leaf dry matter yield, root dry matter ratio, root dry matter yield, leaf dry matter ratio, leaf dry matter yield, total dry matter yield, root length, root diameter, upper root length and upper ground root ratio of fodder beet also decreased accordingly. In order hand, when the amount of applied irrigation water decreased, the rate of leaf dry matter and tuber dry matter increased accordingly.

Table 5. Effect of different irrigation levels on Yield and Quality parameters of Fodder beet
Çizelge 5. Farklı Sulama Suyu Düzeylerinin Yem Pancarının Verim ve Kalite Parametrelerine Etkisi

Yield and Quality parameters of Fodder beet[1]					
Irrigation treatment	S_1	S_2	S_3	S_4	S_5
Irrigation water applied (mm)	643.63	515.7	387.8	259.8	131.9
Fresh root yield (kg da^{-1})	7838.8 ± 103^a	7336.2 ± 50.2^a	6945.1 ± 742^a	5421.3 ± 474^b	1865.7 ± 6.70^c
Fresh leaf yield (kg da^{-1})	1788.1 ± 2.94^a	1373.9 ± 36.6^b	1242.0 ± 73.6^c	1106.4 ± 58.6^d	570.0 ± 26.2^e
Total fresh yield (kg da^{-1})	9626.9 ± 106^a	8710.0 ± 30.4^{ab}	8187.1 ± 679^b	6527.7 ± 421^c	2435.8 ± 21.9^d
Root DM ratio (%)	16.0 ± 0.78^c	16.0 ± 0.53^c	18.0 ± 1.18^c	18.3 ± 1.03^c	21.8 ± 0.88^b
Root DM yield (kg da^{-1})	1247.6 ± 50.6^a	1319.2 ± 31.4^a	1259.6 ± 83.0^a	1181.1 ± 117^a	469.9 ± 16.1^b
Leaf DM ratio (%)	14.3 ± 0.04^d	16.4 ± 0.56^c	$18.1 \pm 0.34b^c$	18.6 ± 0.70^b	23.5 ± 0.68^a
Leaf DM yield (kg da^{-1})	255.5 ± 1.12^a	225.9 ± 5.88^{ab}	225.2 ± 15.7^{ab}	207.3 ± 17.4^b	134.1 ± 7.50^c
Total DM yield (kg da^{-1})	1503.1 ± 50.0^a	1545.2 ± 37.2^a	1484.8 ± 72.7^a	1388.3 ± 102^a	604.0 ± 17.8^b
Root length (cm)	25.4 ± 0.20^a	24.7 ± 0.27^a	21.0 ± 0.38^b	17.3 ± 0.04^c	12.2 ± 0.24^d
Root diameter (cm)	12.4 ± 0.01^a	11.5 ± 0.36^b	10.2 ± 0.08^c	9.1 ± 0.13^d	6.5 ± 0.25^e
Upper root length (cm)	15.3 ± 0.02^a	14.9 ± 0.20^a	11.9 ± 0.49^b	8.4 ± 0.01^c	5.3 ± 0.06^d
Upper root ratio (%)	60.1 ± 0.38^a	60.3 ± 0.21^a	56.5 ± 1.48^b	48.7 ± 0.05^c	43.6 ± 0.74^d

[1]Means with the same letter are no significantly difference, DM: Dry Matter,

Fresh root yield was determined as 7838.8 kg da^{-1}, 7336.2 kg da^{-1}, 6945.1 kg da^{-1}, 5421.3 kg da^{-1} and 1865.7 kg da^{-1} in S_1, S_2, S_3, S_4 and S_5, respectively. Compared to the non-irrigated S_5 treatment, there were the increasing the fresh tuber yield in S_4, S_3, S_2 and S_1 as 65.6%, 73.1%, 74.6% and 76.2%, respectively. Albayrak and Çamaş (2006) determined fresh root yield of 9060 kg da^{-1} – 8690 kg da^{-1} in Ecdogelb and Ecdorot cultivars under Central Black Sea conditions. Abdallah and Yassen (2008) found the fresh yield as 7797.6 kg da^{-1}, 6983.3 kg da^{-1} and 5069 kg da^{-1} in the combination of the fertilizer and irrigation interval (14, 21, 28 days), respectively in Egypt. Sarag (2013) applied 50%, 75% and 100% of the water to Voroshenger and Rota varieties, and the results were 5313 kg da^{-1}, 5944 kg da^{-1} and 6821 kg da^{-1}, and 5746 kg da^{-1}, 6345 kg da^{-1} and 7260 kg da^{-1}, respectively. These results are closed to the results of our study.

Fresh leaf yield was determined as 1788.1 kg da^{-1}, 1373.9 kg da^{-1}, 1242 kg da^{-1}, 1106.4 kg da^{-1} and 570 kg da^{-1} in S_1, S_2, S_3, S_4 and S_5, respectively. Compared to the non-irrigated S_5 treatment, fresh leaf yields of S_4, S_3, S_2 and S_1 were increased by 48.5%, 54.1%, 58.5% and 68.1%, respectively. Yılmaz (2018) reported the fresh leaf yield varied 1760 – 2548 kg da^{-1} in Sakarya-Pamukuva. Karadağ et al. (2014) reported the fresh leaf yield of 2913.1 – 3270.0 kg da^{-1} in Tokat condition. Özköse (2013) reported fresh leaf yield of 1592 – 1917 kg da^{-1} in Konya. Erdoğdu et al.(2011) in Eskişehir conditions, reported the fresh leaf yield of 1676 kg da^{-1} and 1436 kg da^{-1} in Rota and Nedimbey cultivars. The fresh leaf yields reported by Güleş (2009) varied between 1200 -1514 kg da^{-1} from Magnum, Kyros, Rota, Feldher and Amerilla Bures varieties in Ankara conditions.

The total fresh yields obtained were 9626.9 kg da^{-1}, 8710.0 kg da^{-1}, 8187.1 kg da^{-1}, 6527.7 kg da^{-1} and 2435.8 kg da^{-1} in S_1, S_2, S_3, S_4 and S_5, respectively. Compared to the rainfed treatment, fresh tuber yield increased in S_4, S_3, S_2 and S_1 by 62.7%, 70.2%, 72.0% and 74.7%, respectively. Mofeeda et al. (2019) applied 100%, 80% and 60% of the water evaporated from the evaporation pan by drip irrigation method in Egypt and reported 7012.6 kg da^{-1}, 6670.5 kg da^{-1} ve 4846.1 kg da^{-1} of total fresh yield. Sakr et al. (2014), obtained total fresh yields of 8347.6 kg da^{-1}, 7367.9 kg da^{-1}, 5875.0 kg da^{-1} and 4432.1 kg da^{-1} by irrigating interval 7, 6, 5 and 4 times during the irrigation season, respectively. Kassab et al. (2012) obtained total fresh yield of 5285 kg da^{-1}, 4171 kg da^{-1} and 3076 kg da^{-1} by irrigation water levels at 100%, 75% and 50% of ET_o, respectively. While the total yield values obtained from the experiment were similar to Mofeeda et al. (2019). However, Sakr et al. (2014) reported high yield than obtained in this study. In other hand, the total yields obtained in this study were less than yield reported by Kassab et al. (2012).

The lowest and highest tuber dry matter ratios were determined as 16% and 25.2% in S_1 and S_5, respectively. Compared to the S_5 treatment, the reduction rate of tuber dry matter in S_4, S_3, S_2 and S_1 was 13.5%, 27.2%, 28.7% and 36.5%, respectively. Judson et al. (2016) examined the tuber dry matter ratio by considering the upper, middle and lower parts of the tuber and determined the dry matter ratio as 19%, 19% and 19.2% in the upper, middle and lower parts of the tuber, respectively.

The lowest and highest leaf dry matter ratios of fodder beet (14.3% and 23.5%) were determined as S_1 and S_5 treatments. Compared to the S_5 treatment, the decreases in leaf dry matter rate in S_4, S_3, S_2 and S_1 were 20.8%, 23.1%, 30.2% and 39.2%, respectively. Yılmaz (2018) stated that leaf dry matter ratio determined in Rekord, Rota, Ursus and Zentuar cultivars were 12.5%, 13.5%, 13.5% and 12.4%, respectively. Judson et al. (2016) reported between 7% – 18%, Karadağ et al. (2014) found it to be between 13.05 and 13.62%.

The maximum and minimum tuber dry matter yields were determined as 1319.2 kg da^{-1} and 469.9 kg da^{-1} in S_2 and S_5, respectively. Compared to the S_5 treatment, tuber dry matter yield increased in S_4, S_3, S_2 and S_1 by 60.2%, 62.7%, 64.4% and 62.3%, respectively. Milne et al. (2014) reported root dry matter yield of 1500 – 1800 kg da^{-1} in New Zealand, while Yılmaz (2018) obtained 1781.2 kg da^{-1}, 2348.6 kg da^{-1}, 2855.3 kg da^{-1}, 1536.2 kg da^{-1} from Rekord, Rota, Ursus and Zentua, respectively. Albayrak and Çamaş (2005) reported 1525 kg da^{-1} and 1529 kg da^{-1} in 2002 and 2003 in Çarşamba ecological condition, respectively. Sarag (2013) in Egypt, determined the tuber dry matter yield in Voroshenger cultivar of 865 kg da^{-1}, 1045 kg da^{-1} and 1666 kg da^{-1}, and Rotta cultivars of 946 kg da^{-1}, 1287 kg da^{-1} and 1707 kg da^{-1} at irrigation water levels of 50%, 75% and 100% of field capacity, respectively.

The highest and least leaf dry matter yields were determined as 255.5 kg da^{-1} and 134.1 kg da^{-1} in S_1 and S_5, respectively. Compared to the S_5 treatment, there were increased in S_4, S_3, S_2 and S_1 of 35.3%, 40.5%, 40.7% and 47.5%, respectively. Leaf dry matter yields reported in previous study were 154.2 kg da^{-1} in Rota variety, 232.5 kg da^{-1} in Rekord cultivar, 304 kg da^{-1} in Rota cultivar, 344 kg da^{-1} in Ursus, and 218.2 kg da^{-1} in Zentuar cultivar (Özdemir and Kökten, 2020).

Total dry matter yield was determined as 1503.1 kg da^{-1}, 1545.2 kg da^{-1}, 1484.8 kg da^{-1}, 1388.3 kg da^{-1} and 604.0 kg da^{-1} in S_1, S_2, S_3, S_4 and S_5, respectively. Milne et al. (2014) reported that the highest dry matter yields of 13 different beet varieties in New Zealand were 1937 kg da^{-1}, 1898 kg da^{-1}, 1783 kg da^{-1}, 1754 kg da^{-1} and 1739 kg da^{-1} in Enermax, Magnum, Bangor, Troy and Kyros varieties, respectively. They stated that the minimum dry matter yields were 1400 kg da^{-1} and 1515 kg da^{-1} in Brigadier and Feldherr varieties, respectively. Heikal (2022) determined the dry matter yield of 2230 – 2370 kg da^{-1} for non-irrigation treatment (control treatment), 2320 – 2450 kg da^{-1} for 75% of ET_o, and 2480 – 2770 kg da^{-1} for 100% ET_o in Voroshenger variety.

Tuber sizes of S_1, S_2, S_3, S_4 and S_5 were determined as 25.4 cm, 24.7 cm, 21.0 cm, 17.3 cm and 12.2 cm, respectively. Tuber sizes obtained by Mofeeda et al. (2019), Khafaga et al. (2017), Sarag, (2013), Karadağ et al. (2014), Güleş (2009), and Acar (2000) were less than obtained in this study, while the similar to

Abdallah and Yassen (2008).

Tuber diameters measured from S_1, S_2, S_3, S_4 and S_5 were 12.4 cm, 11.5 cm, 10.2 cm, 9.1 cm and 6.5 cm, respectively. The tuber length percentage increased to S_4, S_3, S_2 and S_1 was 28.9%, 36.8%, 43.9% and 47.8%, respectively, when compared to the S_5 treatment. Mofeeda et al. (2019) reported the largest tuber diameter of 15.3 cm in 100% irrigation water, followed by 12.9 cm with 80%, and the smallest diameter fodder beet of 10.8 cm from 60%. Khafaga et al. (2017) reported root diameter of 14.2 cm and 12.9 cm by applying sprinkler and furrow irrigation method, respectively. Karadağ et al. (2014) reported 8.8 cm, 9.2 cm, 10.6 cm and 10.3 cm for Rozsa, Voroshengel, Rota and Brigadier cultivars, respectively.

The length of the tube above the ground was measured as 15.3 cm, 14.9 cm, 11.9 cm, 8.4 cm and 5.3 at S_1, S_2, S_3, S_4 and S_5, respectively. Güleş (2009) reported 7.82 cm, 7.61 cm, 7.29 cm, 6.92 cm and 6.73 cm for Magnum, Kyros, Rota, Feldher ve Amerilla Bures cultivars, respectively, which less than obtained in experiment.

The above-ground-subsoil ratio of the highest and lowest tuber were determined as 60.3% and 43.6% in S_2 and S_5, respectively. Compared to the S_5 treatment, the increases in the aboveground-subsoil ratio of the tuber in S_4, S_3, S_2 and S_1 were 10.3%, 22.7%, 27.6% and 27.4%, respectively. Jbawi (2020) stated that about 50% of fodder beet tubers tend to grow above ground.

It can conclude that the difference yield and quality parametersof fodder beet differ due to the amount of irrigation water, the variety of fodder beet grown, irrigation method and climatic local conditions.

Water-Yield Relationships

The polynomial relationships between the amount of irrigation water and the total fresh yield of fodder beet was determined as $y = -0.00003x^2 + 0.04x - 1.77$ ($R^2 = 0.98^*$) (Figure 4). However, the regression analysis indicated that the a statistically significant linear relationshipbetween the ETc and fresh yield, as $y = 0.015x - 1.3509$ ($R^2 = 0.87^*$) (Figures 5). According to the results obtained, the fresh yield of fodder beet increased in case irrigation water amount increase as well as the ETc. Seasonal yield response factor (ky) for fodder beet under experimental conditions was determined as 1.04 (Figure 6). When ky is greater than 1 indicates that the plant is more vulnerable to water stress, while a ky less than 1 indicates that the plant is more resistant to water stress (Savva and Frenken, 2002). The value of 1.04 found in this study for fodder beet can be considered as an indication that this plant is moderate resistant to water deficit.

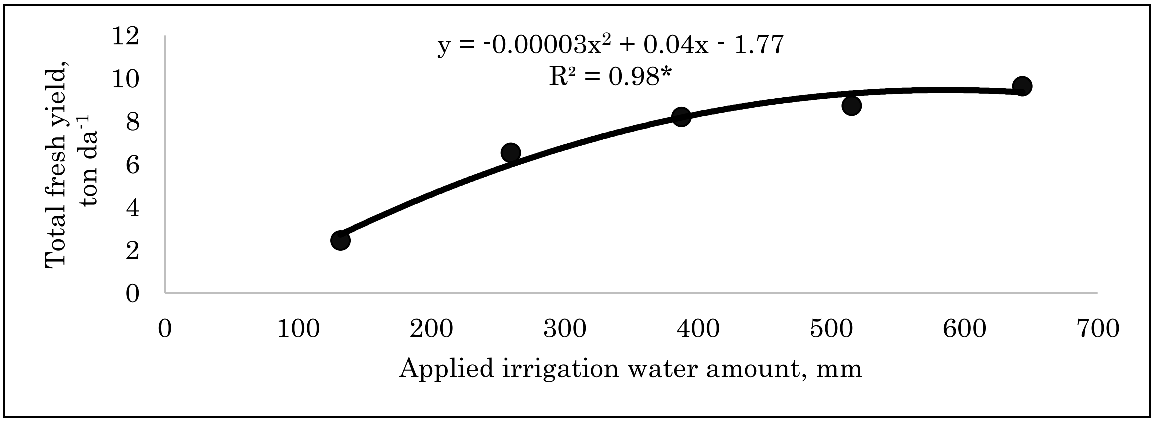

Figure 4. Relationship between the amount of irrigation water and the total wet yield
Şekil 4. Sulama suyu miktarı ve toplam yaş verim arasındaki ilişki

Water Use Efficiency and Irrigation Water Use Efficiency

The water use efficiency was highest in S_4 (145.0 kg ha^{-1} mm^{-1}), followed by S_3 (142.1 kg ha^{-1} mm^{-1}), S_2 (128.5 kg ha^{-1} mm^{-1}), S_1 (123.1 kg ha^{-1} mm^{-1}) and S_5 (72.3 kg ha^{-1} mm^{-1}). Similarly, the highest irrigation water use efficiency was determined in S_4 with 157.5 kg ha^{-1} mm^{-1}, followed by S_3 (148.3 kg ha^{-1} mm^{-1}), S_2 (121.7 kg ha^{-1} mm^{-1}) and S_1 (111.7 kg ha^{-1} mm^{-1}) (Figure 7). Khafaga et al. (2017) found IWUE values of 114.7 kg ha^{-1} mm^{-1} and 162.2 kg ha^{-1} mm^{-1}, respectively, in furrow and sprinkler irrigation method. In a study on fodder beet conducted by Heikal (2008), the highest IWUE was determined for the irrigation treatment applied as 50% of the ET, and the lowest for the full irrigation (108.6 kg ha^{-1} mm^{-1}). In another study, IWUE values at three different water levels (control, 75% and 100% irrigation) were 156.4 kg ha^{-1} mm^{-1}, 258.1 kg ha^{-1} mm^{-1} and 215.4 kg ha^{-1} mm^{-1}, respectively (Heikal, 2022). Noreldin et al. (2016) reported that the water use efficiency in Spain was between 110-115 kg ha^{-1} mm^{-1}. Hasanli et al. (2010) reported the highest IWUE of 90 kg ha^{-1} mm^{-1} and the lowest IWUE of 38 kg ha^{-1} mm^{-1} by considering root yield of fodder beet. Sakr et al., (2014) determined WUE at four different irrigation intervals (7, 6, 5 and 4 times irrigation), and reported as 169 kg ha^{-1} mm^{-1}, 172.5 kg ha^{-1} mm^{-1}, 158.3 kg ha^{-1} mm^{-1} and 145.3 kg ha^{-1} mm^{-1}, respectively. Hussein and Hanan (2014) determined IWUE between 164 - 233 kg ha^{-1} mm^{-1}, and WUE between 162.9 – 168.8 kg ha^{-1} mm^{-1} for three different irrigation treatments. The WUE and IWUE values obtained from the experiment were similar to the WUE and IWUE values stated in the previous studies, although it was grown under different regions and cultivation techniques.

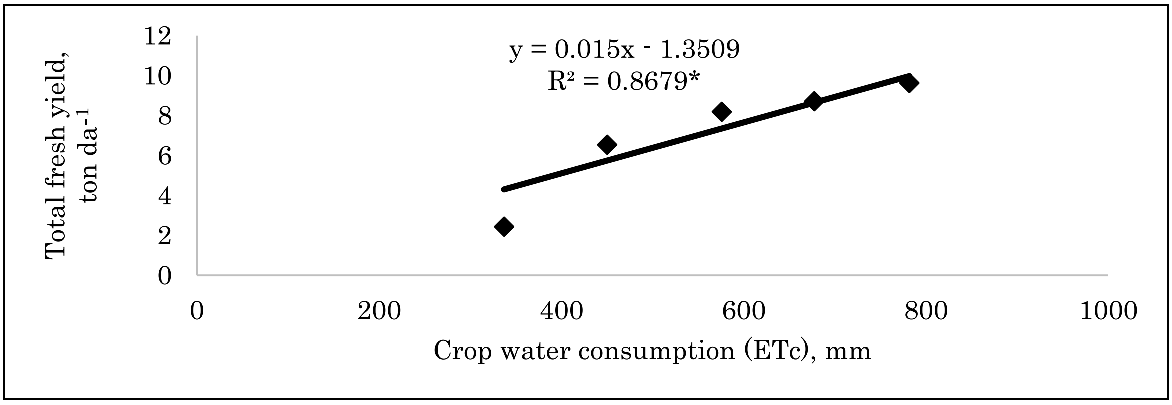

Figure 5. Relationship between plant water consumption and total wet yield
Şekil 5. Bitki su tüketimi ve toplam yaş verim arasındaki ilişki

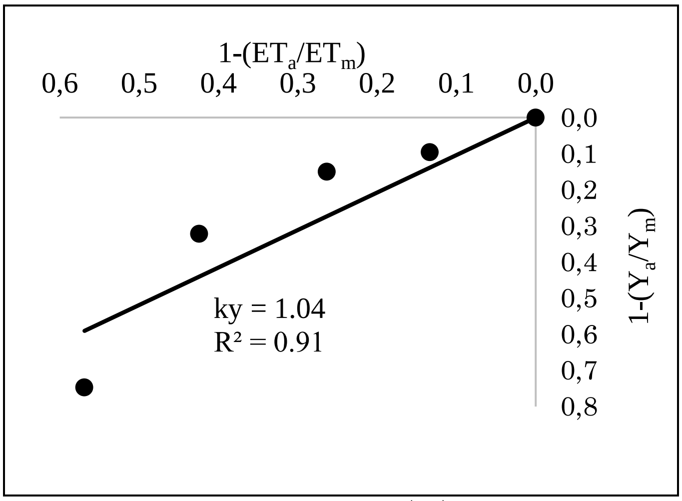

Figure 6. Yield Response Factor (ky)
Şekil 6. Verim tepki etmeni (ky)

CONCLUSIONS

In the experimental conditions, the length of the growing period of the fodder beet was determined as 183 days. While the total amount of irrigation water applied in the experimental conditions was 643.6 mm, 515.7 mm, 387.8 mm, 259.8 mm and 131.9 mm in S_1, S_2, S_3, S_4 and S_5 treatments, seasonal crop water consumption was 782.0 mm, 677.7mm, 576.0 mm, 450.2 mm and 337.1 mm in S_1, S_2, S_3, S_4 and S_5 treatments, respectively. Maximum and minimum dry leaf yield was 255.5 and 134.1 kg da^{-1}. Maximum and minimum fresh leaf yield was 1865.7 kg da^{-1} and 570 kg da^{-1}. Maximum and minimum fresh tuber yield was 7838.8 kg da^{-1} and 1788.1 kg da^{-1}. Maximum and minimum total fresh yield was 9626.9 kg da^{-1} and 2435.8 kg da^{-1}. All whose values above have been determined in S_1 and S_5 irrigation treatments, while maximum and the least dry tuber (root) yield of 1319.2 kg da^{-1} – 469.9 kg da^{-1} obtained in S_2 and S_5 irrigation treatments..

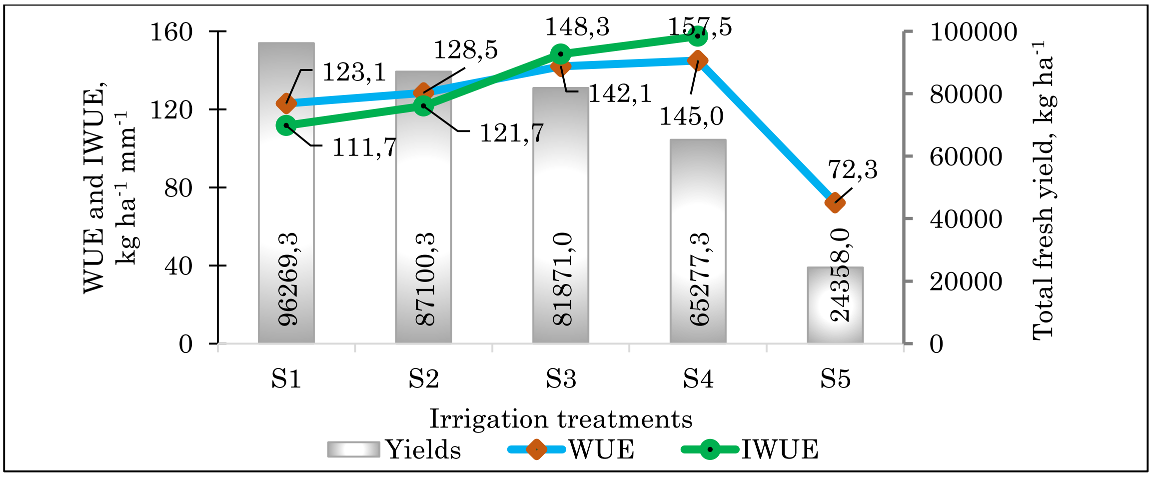

Figure 7. WUE, IWUE and total fresh yield
Şekil 7. WUE, IWUE ve toplam yaş verimi

Seasonal yield response factor (ky), which is an indicator of the sensitivity of plants to water, was determined as 1.04. The ky value determined for fodder beet, considered as an indicator of the medium resistance of this plant against water deficiency. The highest water use efficiency and irrigation water use efficiency in fodder beet were calculated as 145.0 kg ha^{-1} mm^{-1} and 157.5 kg ha^{-1} mm^{-1} for S_4, respectively. The lowest water use efficiency was obtained from S_5 with 72.3 kg ha^{-1} mm^{-1}, while the lowest irrigation water usage efficiency was obtained from S_1 with 111.7 kg ha^{-1} mm^{-1}. According to these results, S_2 irrigation treatment has been evaluated as the most appropriate irrigation level under adequate irrigation water conditions. While, it is possible to use S_3 or S_4 irrigation levels in terms of water deficit conditions. S_3 and S_4 in this study has difference of approximately to 6.4% in yield.

Contribution of the Authors

Authors declare the contribution of the authors is equal.

Statement of Conflict of Interest

Author has declared no conflict of interest.

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