Research Article/Araştırma Makalesi

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MEDITERRANEAN AGRICULTURAL SCIENCES
(2019) 32(2): 219-227
DOI: 10.29136/mediterranean.515644

The response of sugar beet to different irrigation levels and foliar application of micronutrients under drip irrigation system

Şeker pancarı bitkisinin damla sulama sistemi ile uygulanan farklı sulama seviyelerine ve mikrobesin elementlerine karşı tepkisi

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ARTICLE INFO

Received 21 January 2019
Received in revised form 29 March 2019
Accepted 10 April 2019

***Keywords*:**

Sugar beet
Drip irrigation
Water stress
Foliar
Micronutrients

ABSTRACT

The present study was conducted to evaluate the response of sugar beet (*Beta vulgaris* L.) cv. esperanza to different water levels and foliar application of micronutrients in 2016. Three irrigation regimes were applied; well watered ($D_{1.00}$), moderate stress ($D_{0.66}$), and severe stress ($D_{0.33}$). In each irrigation treatment, there were two different applications as being foliar application of mixed micronutrients and not. The degree of water deficit had significant effects on the growth, root and sugar yield. Decreasing amount of water from $D_{1.00}$ treatment to $D_{0.33}$ treatment restricted sugar beet development, and caused plants to be small. The amount of irrigation water and evapotranspiration in the full irrigation treatment were 867 mm and 894 mm, respectively. Therefore, compensating full water requirement and foliar application of micronutrients had a significant effect on the root (13 899 kg da^{-1}) and sugar yield (2 246 kg da^{-1}). It is concluded that full water requirement of sugar beet should be met throughout the entire growing season, but if water scarcity exists water may be saved just only in the ripening period to get an economical yield since during the establishment and vegetative periods of sugar beet was more sensitive to limited water supply.

MAKALE BİLGİSİ

Alınış tarihi 21 Ocak 2019
Düzeltilme tarihi 29 Mart 2019
Kabul tarihi 10 Nisan 2019

***Anahtar Kelimeler*:**

Şeker pancarı
Damla sulama
Su stresi
Yaprak
Mikro besin elementleri

ÖZ

Bu çalışmada, farklı sulama seviyelerinde yaprak gübresinin uygulandığı ve uygulanmadığı konularda şeker pancarı (*Beta vulgaris* L.) cv. esperanza bitkisinin gelişimi, kök ve şeker verimi üzerine etkilerini belirlemek için 2016 yılında yürütülmüştür. Bu çalışmada üç farklı sulama seviyesi uygulanmış olup bunlar; tam sulama ($D_{1.00}$), orta stres ($D_{0.66}$) ve aşırı stres ($D_{0.33}$) konularından oluşmuştur. Su kısıtına ek olarak, her bir sulama uygulamasında, mikrobesin maddelerini içeren yaprak gübresinin uygulandığı ve uygulanmadığı konular mevcuttur. Uygulanan su kısıtının şiddeti; bitki gelişimini, kök ve şeker verimini önemli düzeyde etkilemiştir. Tam sulama konusunda ($D_{1.00}$) aşırı su stresinin yaşandığı ($D_{0.33}$) konuya doğru azalan sulama suyu miktarı şeker pancarı gelişimini sınırlamış ve bitkilerin küçük kalmasına neden olmuştur. Tam sulama konusunda sulama suyu miktarı ve bitki su tüketimi sırasıyla 867 mm ve 894 mm olmuştur. Öyleki, sulama suyu ihtiyacının tam karşılanması ve yapraklara mikrobesin maddelerinin uygulanması kök (13 899 kg da^{-1}) ve şeker (2 246 kg da^{-1}) verimi üzerine önemli bir etki yapmıştır. Sonuç olarak, tüm gelişim dönemi süresince, şeker pancarının su ihtiyacı tam karşılanmalıdır, fakat su kısıtı söz konusu ise ekonomik bir verim almak için olgunlaşma döneminde su kısıtına gidilebilir çünkü şeker pancarının çimlenme ve vejetatif gelişme dönemlerinde kısıtlı sulama suyuna karşı çok hassas olduğu gözlenmiştir.

1. Introduction

The world population is now 7 billion and is expected to reach 10 billion by mid-century (Cleland 2013). Agriculture sector needs to produce more crop per drop to feed the growing world population (Howell 2001). Irrigation in the Mediterranean is of vital importance for food safety, employment and economic development (Faber et al. 2016). Water is the most important natural factor for the productivity of any plants (Yildirim 2010) and irrigation is an efficient way of regulating the availability of water in the root zone during the periods when the required amount of water for crops is not sufficiently met by the rainfall. Tognetti et al. (2003), drip irrigation system is advisable particularly in the Mediterranean agro-ecosystems for using less energy and water consumption and also storing nutrients in the root zone. Therefore, the primary goal of irrigation management is to use the available water in the root zone efficiently through managing and controlling the soil moisture around the root zone of the plants. Nutrient management is an another issue to be considered for high yields with desired quality attributes (Masri and Hamza 2015).

Stoma closure seems to be the main factor for decreasing in the photosynthetic rates of plants under mild drought conditions (Chaves et al. 2002). Sugar beet has quite high water requirements (Fabeiro et al. 2003). Drought stress in England caused a serious yield loss in sugar beet production (Richter et al. 2001). Jaggard et al. (1998) reported that drought in climate has recently been an important constraint in the cultivation of sugar beet. Drought stress is one of the most important environmental factors affecting sugar beet yield and quality (Pidgeon et al. 2001). When encountered in drought stress during the growing period of sugar beet, it should be solved with alternative irrigation practices (Tognetti et al. 2003). It is estimated that in the future, the effect of water scarcity will be more severe (Suheri 2007). Mousavi et al. (2013) reported that some micronutrients such as Zn, Fe, B and Mn had an important metabolic role in plant growth so that those elements increase crop yield. Draycott and Christenson (2003) reported that sugar beet was very responsive when the soil availability of B, Mn and Fe fertilizers were low.

Sahin et al. (2014) reported that water use of sugar beet need to be determined in terms of sustainable production strategy in arid and semi-arid regions. Kiziloglu et al. (2006) found deficit irrigation, especially in semi-arid regions, was the major cause of yield loss in both root and leaf yield, also in sugar content. Albayrak (2010) reported that drip irrigation system had a crucial effect on root yield of sugar beet as compared with both sprinkler and furrow irrigation methods. Ozbay and Yıldırım (2018) drip irrigation has a significant effect on the yield of sugar beet to get an economical yield. Dragovic (2000) and Mahmoodi et al. (2008) recommended that the critical moisture level for sugar beet in soil to commence irrigation was when soil moisture was depleted 30% from field capacity. Ertas (1984) and Ayla (1986) reported that water deficit should not exceed 40-45 % of the full water requirement. Masri et al. (2015) reported that sugar beet can be grown with the restricted amount of irrigation water in areas where irrigation water is scarce. Urbano and Arroyo (2000) said water deficit in some phenological periods of sugar beet did not cause significant yield loss and quality of sugar beet. Jaggard et al. (1998) reported that sugar beet was a crop that can tolerate moderate water stress. On the other hand, Tognetti et al. (2003) reported that the highest sucrose content and yield of sugar beet was obtained when full water requirement of it was compensated and it was obtained by drip irrigation system (Hosseinpour et al. 2006). As seen, research results are a little bit confusing since some researchers reported that water stress had no significant effect on the yield and quality of sugar beet, while others indicated that the highest sugar content and yield of it were obtained when full water requirement was met for the entire growing season.

Sugar beet plants in the present experiment were exposed to three irrigation regimes by drip irrigation system. In the control treatment, there was no water stress, though the full evapotranspiration demands of sugar beet were supplied throughout the year. Reduced plant size, leaf area, and leaf area index (LAI) are a major mechanism for moderating water use and reducing injury under drought stress (Mitchell et al. 1998). Therefore, under most arid land conditions, the maximization of soil moisture use is a crucial component of drought resistance (Blum 2005). Improving water use efficiency (WUE) is necessary for securing environmental sustainability of food production (Medrano et al. 2015). Therefore, the aim of this study was to determine physiological changes, water use efficiency and the effect of foliar application of micronutrients on the yield under different irrigation levels by drip irrigation system.

2. Materials and Methods

Experimental site and soil description: The field experiment was carried out in a farmland in Altıntas, Kutahya-Turkey in 2016. Altıntas is located in the 39°41'N latitudes and 29°38'E longitudes west of Turkey and elevation is 1 010 m. Experimental soils had 50% clay, 24% tilt, and 26% sand, soil bulk density was 1.83 g cm^{-3}, infiltration rate was 5.22 mm h^{-1}, field capacity was 46.3% and permanent wilting point was 35.6%.

Climate parameters; temperature, relative humidity, wind speed, rainfall and evaporation from Class-A pan from sowing to harvest for both long term and during the experiment are presented in Table 1. As seen in the table, rainfall amount

Table 1. Some climate parameters of site from sowing to harvest (2016).

	Climate parameters*	April	May	June	July	Aug.	Sep.	Oct.
The long-term climatic fluctuation of Kutahya during 1990-2015	Mean Temperature (°C)	9.9	14.5	18.1	20.7	20.6	16.6	11.8
	Max. Temperature (°C)	28.1	30.9	33.5	36.7	36.5	33.5	28.6
	Min. Temperature (°C)	-4.6	0.84	3.7	6.0	5.5	1.6	-4.2
	R. humidity (%)	63.6	63.6	61.0	57.5	57.8	61.5	67.3
	Wind Speed (m s^{-1})	1.81	1.46	1.40	1.47	1.38	1.23	1.18
	Sunshine intensity (cal cm^{-2})	93.9	107.7	119.5	98.4	111.4	88.5	61.7
	Sunshine hours (h)	5.88	7.35	9.10	10.1	9.42	7.44	5.0
2016	Mean Temperature (°C)	21.7	21.0	27.9	30.4	29.9	25.3	19.9
	Max. Temperature (°C)	29.6	29.6	34.2	38.0	36.2	32.2	28.2
	Min. Temperature (°C)	-0.6	4.5	6.5	10.7	10.9	4.1	0.6
	R. humidity (%)	57.9	68.7	59.5	56.8	64.5	66.0	69.6
	Wind Speed (m s^{-1})	1.6	1.6	1.9	1.9	1.7	1.4	1.3
	Rainfall (mm)	28.8	55.6	53.1	2.7	20.6	38.2	3.2
	Evoporation (mm)		110.7	195.7	235.5	171.8	113.2	71.1

*data measured at 2 m.

(202.2 mm), during the crop growing period, was not enough to get an economical yield from sugar beet, that's why, irrigation is a necessity to ensure uniformity in sugar beet growth. The sowing date was in April 16 and harvest date was 20 October in 2016. Sowing pattern in drip irrigation system was 45x20 cm. Buffer strips between plots were 2 m. The distance between emitters along the drip line was 0.33 m and the discharge of an emitter was 4 l h^{-1} under the running pressure of 1.5 atm.

The experimental design was a randomized complete block design with three replicates. Each plot in all treatments took the same amount of fertilizer; 137.6 kg N ha^{-1} , 184 kg P ha^{-1} were applied and N was applied at three times, first at planting then on the 15 days later after sowing and 20 days later after second application. Foliar spray of micronutrients was applied once 40 days later and twice 75 days later after sowing. Mixture of micronutrients contained humic acid (organic matter 15%, humic and fulvic acid 15%, water soluble K_2O (0.03%) 2 l ha^{-1}, 20-20-20 TE (NPK) 2.5 kg ha^{-1}, and micronutrients (0.8% B, 1.5% Cu, %5 Fe, %3 Mn, 0.2% Mo, %4 Zn) 0.5 kg ha^{-1}. In each control treatment, there was no application of micronutrients.

Irrigation treatments: In this experiment, the amount of irrigation water by using long time climatic data for the site was used to determine reference evapotranspiration by using Penman-Monteith equation and plant properties (K_c taken from Ilbeyi (2001)) to estimate the actual evapotranspiration (ET_a), then irrigation time and amounts to be applied were estimated by using soil properties (field capacity and permanent wilting point etc.). Irrigation was commenced according to irrigation schedule determined by irrigation programme and adjusted according to the amount of rainfall if existed. Three different irrigation levels were adjusted, in the full irrigation treatment soil moisture was intended to refill the root zone up to field capacity when 40% of soil moisture was depleted by crops and full evapotranspiration (ET) was compensated in this full irrigation treatment ($D_{1.00}$). In the deficit treatments, the water applied averaged 66% of the ET ($D_{0.66}$) and 33% of the ET ($D_{0.33}$). All treatments took same amount of water for 20 days after sowing to establish root development, then irrigation water was applied according to treatments. Water Use Efficiency (WUE) (kg m^{-3}) (Hillel and Guron 1975) was estimated as

$$WUE= Y/ET$$

Where; Y is yield (kg ha^{-1}) and ET is evapotranspiration (mm).

Leaf area index (LAI): Three plant samples from each plot were selected randomly for leaf area measurement on August. The green leaves were separated and leaf area was determined using a CI-202 portable laser area meter in cm^2. The Leaf Area Index (LAI) was determined by the following equation (Kar and Kumar 2007).

$$LAI = \frac{Measured\ \ leaf\ \ area\ \ of\ 3\ plants}{Ground\ area\ covered\ \ by\ 3\ plants}$$

Sugar yield: Sugar analysis was done in Kutahya Sugar Factory. Sucrose content (%) was measured with a polarimeter after extraction of sugar from the pulp with lead acetate Carruthers and Oldfield (1960). Sugar yield (kg da^{-1}) (1 decare (da)= 1000 m^2) was determined according to the equation given by Suheri (2007).

$$SY = \frac{SC}{100}.Root\ yield\ (kg\ da^{-1})$$

Where; SY: Sugar yield (kg da^{-1}), SC: Sugar content (%)

Fresh and dry weights (root and leaf) were determined separately by weighing. After that, they were all oven-dried at about 70°C till reaching to a constant weight to determine the dry weight of whole plants in each treatment. Crop development parameters in each stage had been observed for the whole growing period. Representative three samples in the center rows from each plot were used to measure the quantitative and qualitative parameters, including root yield and sugar content. Sugar beet was harvested by hand on Oct. 20th (183 days old). Harvested roots for each sub-plot were weighed and adjusted to kg per da. Total soluble solids were determined on a blended composite using a portable hand-held refrectometer.

Statistical analysis: Data on yield and quality parameters were analyzed using ANOVA and means were separated by Duncan's multiple range test at the probability level of 1% and 5%.

3. Results and Discussion

Irrigation water, evapotranspiration and yield: The irrigation amounts (I), evapotranspiration (ET), water use efficiency (WUE), root yield, sugar content, sugar yield and total soluble solid parameters are given in Table 2.

Water applications commenced after sowing and continued until one month before harvest date. The total amount of water applied fluctuated from 286 mm in the severe stress treatment ($D_{0.33}$) to 867 mm in the full water application ($D_{1.00}$). Water use efficiency declined as the applied water decreased according to the irrigation treatments. In this case, the lowest WUE was obtained from the treatment to which the least water was applied ($D_{0.33}$), while the highest came from the treatment of $D_{1.00}$. if we take the full irrigation treatment as a reference, when micronutrients were applied, averagely yields were 50.3% and 71.9% less in the $D_{0.66}$, $D_{0.33}$, and also when not applied, those values were 48.6% and 67.5% less in the $D_{0.66}$, $D_{0.33}$, respectively. Therefore, it is clear that foliar application of micronutrients resulted in around 5% increase in yield when full water requirement of sugar beet was met. Therefore, the most important factor affecting sugar beet (*Beta vulgaris* L.) cv. esperanza yield is the amount of irrigation water applied during the whole growing period.

Table 2. Irrigation depth (I), Evapotranspiration (ET), Water Use Efficiency (WUE), Yield (Y), Sugar Content (SC), Sugar Yield (SY), Total Soluble Solids (TSS).

Irrigation Treatments	Micronutrients application	I (mm)	ET (mm)	WUE kg m^{-3}	Y (kg da^{-1})	SC (%)	SY (kg da^{-1})	TSS Brix (20°C)
$D_{1.00}$	With foliar spray of micronutrients	867	894	15.2	13899	16.16	2246	17.2
	Without foliar spray of micronutrients				13216	16.66	2201	16.7
$D_{0.66}$	With foliar spray of micronutrients	572	599	11.4	6913	18.23	1260	21.8
	Without foliar spray of micronutrients				6794	16.62	1129	20.2
$D_{0.33}$	With foliar spray of micronutrients	286	313	13.1	3909	19.23	751	22.3
	Without foliar spray of micronutrients				4292	18.97	814	16.7

In the full irrigation ($D_{1.00}$) treatment: The peaks of WUE, yield and sugar content were obtained from the $D_{1.00}$ treatment. The amount of irrigation water and evapotranspiration for the full irrigation treatment were 867 mm and 894 mm respectively. These values were very close to the values given in literature. Katerji and Mastrorilli (2009) reported evapotranspiration values of sugar beet as between 731 and 836 mm and Fabeiro et al. (2003) as between 690 and 897 mm. Jensen and Erie (1971) obtained the highest root yield (57360 kg ha^{-1}), sugar content (17.2%) and yield (9870 kg ha^{-1}) by applying irrigation water as 1281 mm and evapotranspiration as 1468 mm.

In the present study, the establishment period lasted 38 days and in which period the amount of water applied was 127 mm, hence this amount of water applied in this period was so important for the later development stages of sugar beet and averagely plants' root and leaf weights reached to 51.9 g and 114.9 g, respectively (Fig. 1a). The second period, the vegetative and yield formation period, lasted 92 days, in which period the applied water (553.2 mm) increased the weight of tuber rapidly, especially affected its weight increment towards the end of this development period. The fluctuations of fresh and dry weights for both root and leaf in the full irrigation

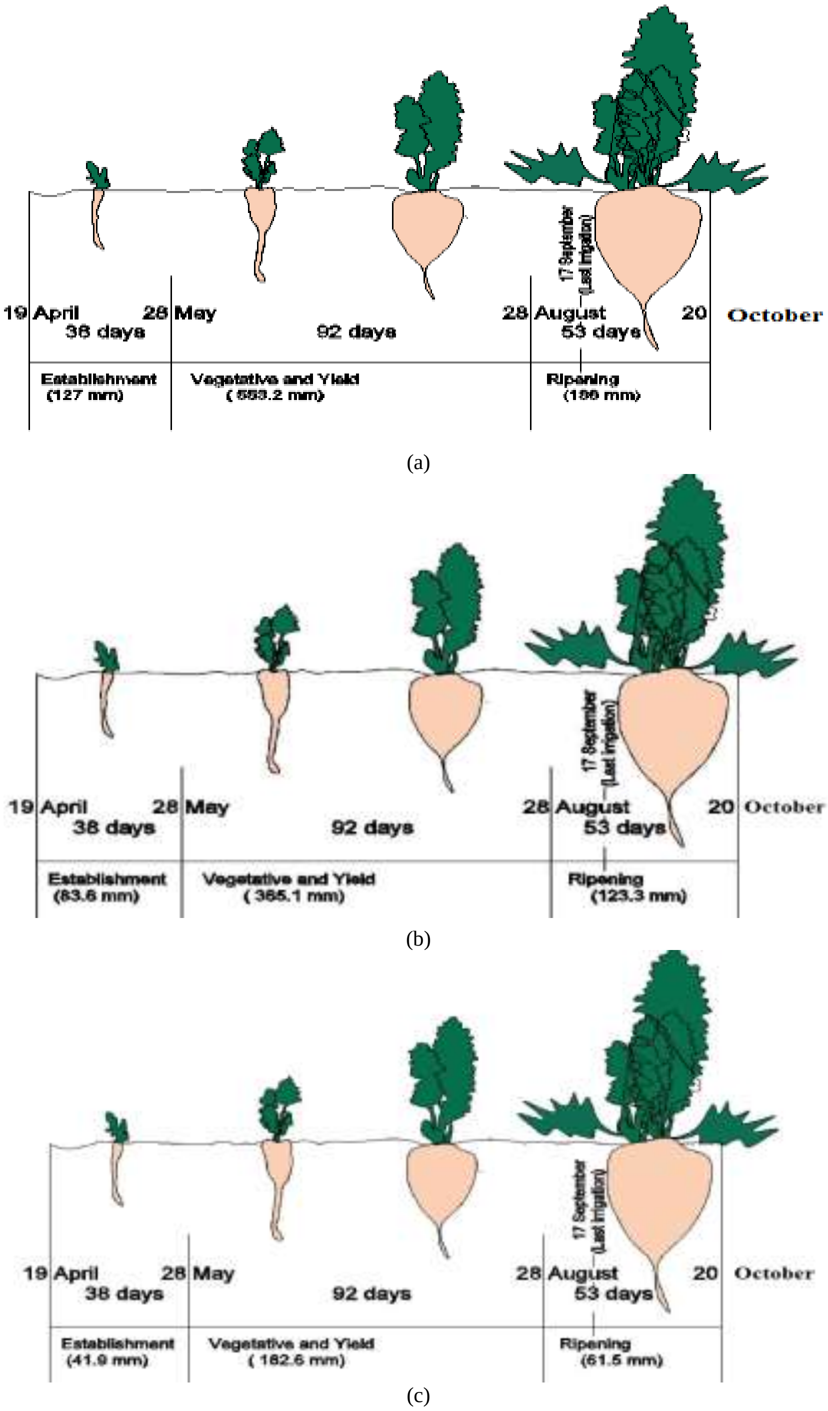

Figure 1. Growing periods of sugar beet and applied water in the treatments of (a) $D_{1.00}$, (b) $D_{0.66}$, and (c) $D_{0.33}$.

treatment ($D_{1.00}$) throughout the entire growing season were compiled and given in Figure 2a. The tuber and leaf weights reached to 1 276.4 g and 509.2 g, respectively. In the ripening period, applying irrigation water of 186.8 mm provided tuber weight reached to 1351.6 g, while leaf weight decreased to 329.8 g due to leaf senescence. Hence, the applied water of 867 mm in the whole growing period caused sugar beet to gain weight up to 1 351.6 g. It was observed that leaf and tuber development of sugar beet indicated a steady development till June 6 in the establishment period, but after June 6, a rapid growth, especially in the root development, was observed and continued to the date of August 28, and then exhibited a low increase. Meanwhile, leaf weight increased up to 509.2 g till August 28, then after that day dropped to 204.6 g at harvest time due to leaf senescence. When full water requirement of sugar beet was compensated by drip irrigation system, the tuber weight reached to 1 358.8 g, of which almost 68.5% was water and 31.5% was dry matter, at the same time leaves consisted of 88.5% water and 11.5% dry matter. Therefore, the most important factor affecting sugar beet growth and yield is the amount of irrigation water applied during the whole development period.

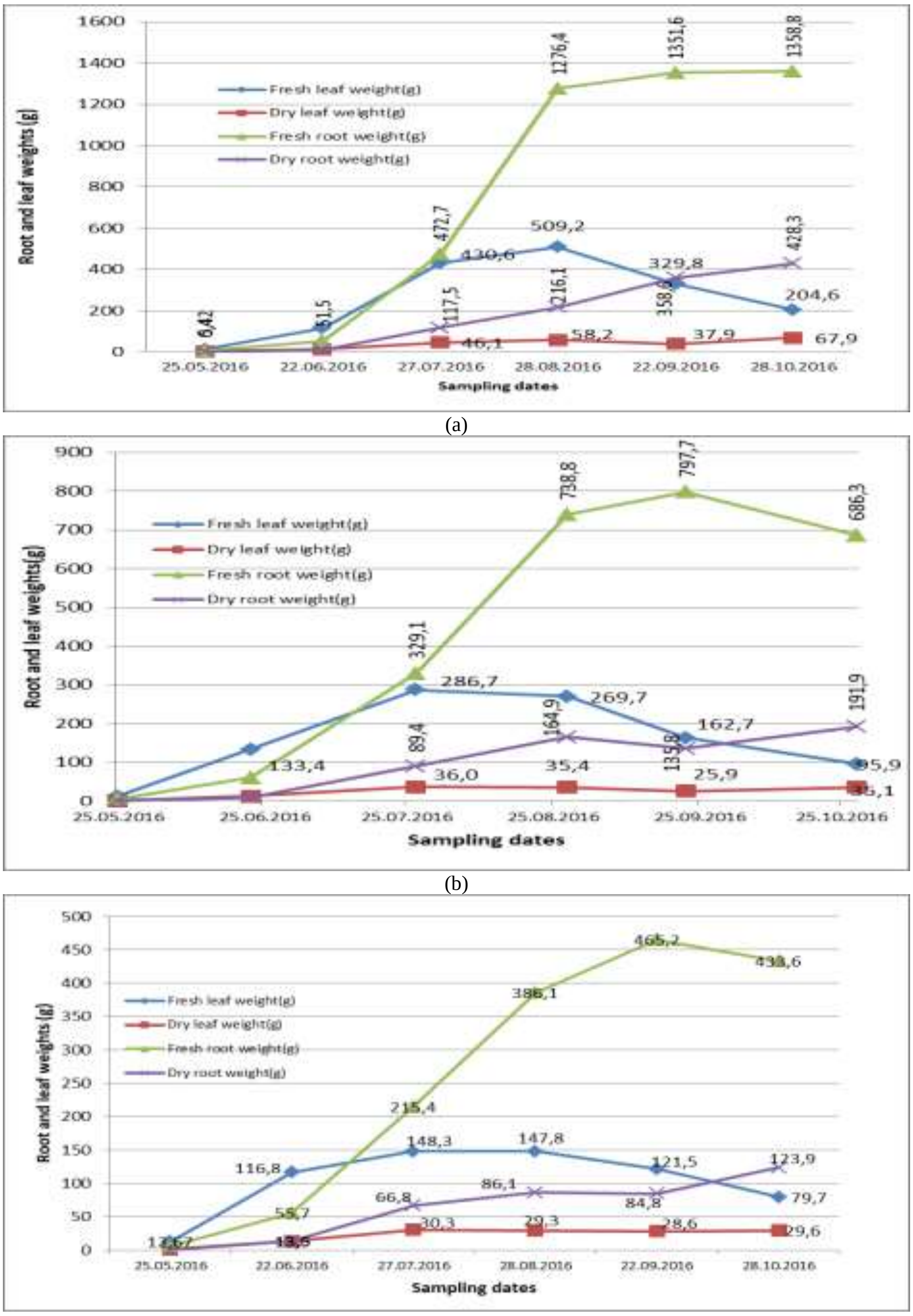

Figure 2. Changes in the weight of root and leaf of sugar beet during crop-growing season under different irrigation levels (a) $D_{1.00}$, (b) $D_{0.66}$, and (c) $D_{0.33}$.

In the moderate deficit irrigation ($D_{0.66}$) treatment: In the present experiment, a 34% reduction in irrigation water in the $D_{0.66}$ treatment reduced yield averagely by up to 6 854 kg da^{-1}. It is evident from the current results that a deficit irrigation treatment was not a suitable irrigation strategy for sugar beet since the results obtained from deficit irrigation of 30% by Şahin et al. (2014) indicating significant yield reduction when deficit irrigation was applied. The amount of water applied and evapotranspiration were 572 mm and 599 mm, respectively (Fig. 1b). In the establishment period applying irrigation water of 83.6 mm allowed the tuber and leaves to reach the weights of 60.5 g and 133.4g respectively, and totally was 193.9 g (Fig. 2b). In the vegetative and yield formation period caused these weights to reach 738.8 g and 269.7 g, respectively. In the ripening period, the applied water was 123 mm and irrigation was terminated on September 17, almost one month ago before harvest. At the harvesting time, the tuber weight decreased to 686.3 g, while there was no reduction in tuber weight in the full irrigation treatment at harvesting time. Therefore, a reduction of irrigation water as 295 mm in the moderate deficit irrigation ($D_{0.66}$) caused a serious yield reduction of 49%.

The fluctuations in fresh and dry weights in the moderate deficit irrigation treatment ($D_{0.66}$) are presented in Figure 2b. In a similar manner, the rapid growth of tuber and leaves were observed in the vegetative and yield formation period, while it was very slow in the establishment period. When the sugar beet had completed its development, the tuber and leaf weights reached to 738.8 g and 269.7 g and also the average weights of them were 65.8% and 71.6% less respectively rather than those of that obtained from the full irrigation treatment. In the present study, a 34% reduction in irrigation water in the $D_{0.66}$ treatment reduced the yield by up to 6854 kg da^{-1}. Water deficit of more than 30% had a negative effect on the root and sugar yields. Regarding quality and yield, the full water requirement of sugar beet need to be met for the whole growing period, and also foliar application of micronutrients caused a slight increase in yield. As seen in Fig. 2b, all development stages of sugar beet in all treatments indicated the similar manner, that is, a rapid growth of the tuber and leaves of sugar beet was observed after June 25. Therefore, it is extremely important to meet the full water requirement of sugar beet for getting high root and sugar yield.

In the severe stress ($D_{0.33}$) irrigation treatment: In the severe stress, a 67% reduction in irrigation water reduced the yield to 4 100 kg da^{-1}, since the amount of water applied was 286 mm. In the establishment period, the application of irrigation water as 41.9 mm caused the tuber and leaf weights to be 55.7 g and 116.8 g, respectively (Fig. 1c). In the second period, the tuber and leaf developments were so weak that they reached to 386.1 g and 147.8 g, respectively, since the amount of water applied has been very low as 182.6 mm for the development periods of 92 days in the vegetative and yield formation period. When the sugar beet completed its development, the tuber and leaf weights reached to 465.2 g and 121.5 g, respectively. These weights, respectively, were 65.8% and 71.6% less than the weights obtained from the full irrigation treatment. In the severe stress treatment ($D_{0.33}$) the yield was very low to get an economical profit. All treatments exhibited same development results on the tube and leaf until June 22, after that a rapid growth on the tuber was observed (Fig. 2c). That's why, the present study indicated that compensating full water requirement of sugar beet during the vegetative and ripening period is so important for root and sugar yield.

Therefore, evapotranspiration was high throughout the vegetative period, if water requirement does not meet at that period, plants develop stress and when the roots could not take up water at the time they need it, stress development could not be prevented. Hence, water deficit during the middle development stage seems to have a significant effect on the root and sugar yield. The present results correlated well with the findings of Doorenbos and Kassam (1979), who reported that light irrigations were preferred during the emergence period since early over-watering may retard leaf development, and water deficits in the vegetative and yield formation period tend to affect sugar yields more strongly. In the present study, the amount of water applied in the highest ($D_{1.00}$) and the lowest ($D_{0.33}$) treatments indicated that the weight of the tuber was very close to each other in the establishment period. However, the present study indicated that meeting full water demand of sugar beet, especially during the vegetative development period, is the key point of an irrigation strategy. If water scarcity exists, the amount of irrigation water may be dropped to 680 mm for the establishment and vegetative periods, however, a lesser amount will cause severe drought stress on sugar beet yield.

Changes in sugar yield with and without foliar spraying of micronutrients under different irrigation levels: The changes in sugar content against three different water levels under the foliar spraying of micronutrients and not are presented in Figure 3a-3b. In general, sugar beet is very sensitive to water deficits, especially at the time of vegetative and yield formation periods. When available water resources are limited as being in the treatment of $D_{0.33}$ and $D_{0.66}$, root yield considerably decreased and also a little bit decrement occurred in sugar yield, as seen in Figure 3b, when foliar application of micronutrients were not applied. The treatment that full water requirement was compensated and leaf fertilizer was applied caused sugar beet to give the highest sugar yield. However, sugar yield was reduced slightly when only leaf fertilizer was not applied. The rate of reduction in sugar yield was more pronounced in the water deficit of 36% ($D_{0.33}$). This clearly indicates that the efficiency of some cultural activities such as fertilization increases when full water requirement of sugar beet were compensated for the whole growing season. Therefore, the amount of water applied resulted in a significant effect on the yield. Sugar content with foliar spraying of micronutrients was 25.8 kg da^{-1} per the amount of water of 10 mm, but it decreased to 23.9 kg da^{-1} (7.4%) when leaf fertilizer was not applied. Singh et al. (2001) reported that tuber dry matter in potato plant increased from 3.8% to 25.1% when the amount of CO_2 was enriched. According to Chaves et al. (2002), stomal closure seems to be the main cause of the decrease in the photosynthetic rate under mild drought conditions. In the experiment, sugar yield significantly decreased in both two deficit irrigation treatments, even foliar spraying of micronutrients was done. It clearly indicates that severe water stress caused stomal closure, which significantly reduces root and sugar yield of sugar beet. Therefore, some cultural activities in field such as fertilization and foliar application of micronutrients in the treatments of both severe ($D_{0.33}$) and moderate water stress ($D_{0.66}$) have resulted in a little bit increment in yield but not as much as the effect of irrigation.

Measurements of plant development parameters for the whole growing season are given in Table 3. Parameters related to development, such as fresh root and leaf weights and LAI, indicated that plant development was negatively affected as the amount of water decreased from 867 mm to 286 mm. In addition to the amount of irrigation, leaf fertilization has a positive effect on the root development which makes the sugar yield high, when full water requirement of sugar beet was compensated for the

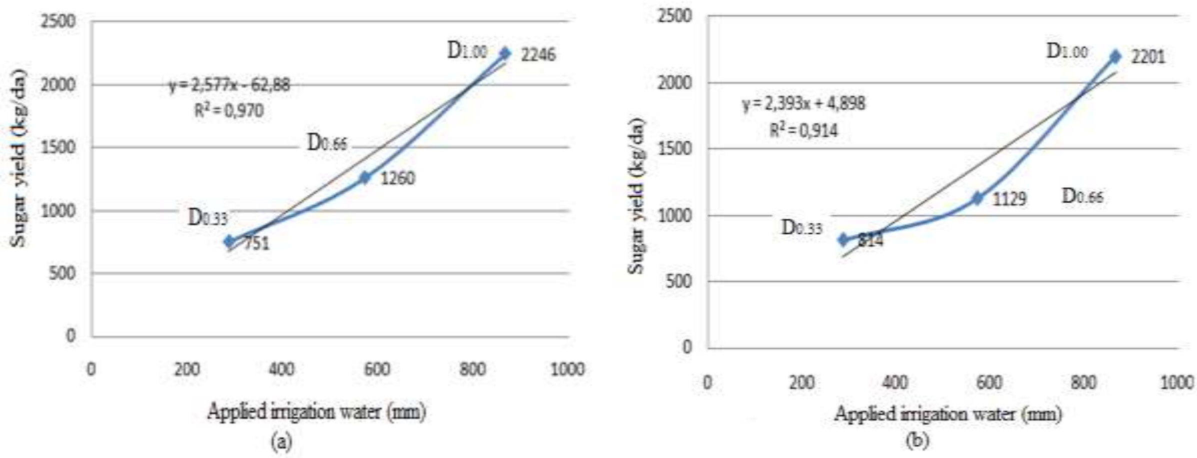

Figure 3. Changes in sugar yield (a) with foliar spraying of micronutrients(b) without foliar spraying of micronutrients.

Table 3. Effects of different water levels and the application of leaf fertilizer on sugar beet development.

Treatments		Root fresh weight (g)	Root dry weight (g)	Leaf fresh weight (g)	Leaf dry weight (g)	Root height (cm)	Root dia. (cm)	Leaf area (cm^2)	LAI
*With foliar application of micronutrient	$D_{1.00}$	1695.0^a	408.9^a	141.7^a	48.13^a	28.0	13.7^a	3089.3^a	3.40
	$D_{0.66}$	698.4^b	149.6^b	53.0^b	23.37^b	22.0	10.7^b	2014.7^b	2.22
	$D_{0.33}$	394.9^c	115.8^b	66.7^b	17.73^b	22.3	8.0^c	1797.9^b	1.98
*Without foliar application of micronutrient	$D_{1.00}$	1313.0^a	384.1^a	204.6^a	69.8^a	27.4	13.2^a	3554.6^a	3.91
	$D_{0.66}$	686.3^b	222.6^b	95.8^b	36.7^b	25.2	10.7^b	2025.3^b	2.23
	$D_{0.33}$	433.6^b	123.2^b	79.7^b	31.1^b	26.6	8.54^c	1683.7^b	1.85

Differences between values signed with the same small letters are non-significant ($p \leq 0.05$). *Duncan test was performed separately for two subjects to see the effect of the different water levels when applied and not applied of micronutrients.

whole growing season. The highest root weight and sugar yield in the $D_{1.00}$ treatment with foliar application of micronutrients were 1 695 g plant^{-1} and 2 246 kg da^{-1}, respectively. This situation may be attributed to, firstly the amount of irrigation water and secondly the application of fertilization. If the full irrigation treatment was taken as a reference, yields were 49% less in the $D_{0.66}$ and 70% less in the $D_{0.33}$ treatments when leaf fertilization was done. The weight of root and leaves decreased in the water stress treatments, even with or without foliar application of micronutrients. Rassam et al. (2015) reported that foliar application of the micronutrients increased the quantity and quality of sugar beet with three times application of micronutrients mixture as 2 l ha^{-1}. Sugar beet growth depends significantly on the amount of water and especially a water deficit of 34% marks the critical level, above which plant development is severely affected. Yield in the $D_{0.66}$ treatment was also considered low as compared with the $D_{1.00}$ treatment, which indicating that even water deficit of 34% inhibited plant development parameters in terms of root weight, diameter, LAI and so on. Therefore, compensating the full water requirement of sugar beet has a significant effect, first on the growth and root yield and also sugar content is able to be increased by the foliar application of micronutrients.

4. Conclusion

The present study indicated that meeting full water demand of sugar beet, especially during the vegetative development period is the key point of an irrigation strategy. Drip irrigation has a crucial importance on the yield of sugar beet to get an economical yield. Hence, it is clear that drip irrigation increases the efficiency of irrigation water and fertilization.

The highest yield was obtained when the full water requirement of sugar beet was compensated for the whole growing period so that foliar application of micronutrients has also a certain amount of increase in sugar yield when the full water requirement of it was compansated. Sugar beet (*Beta vulgaris* L.) cv. esperanza has not high tolerance to water deficit, especially deficit irrigation more than 34% of ET has very significant negative effects on vegetative development and sugar yield. Furthermore, water stress considerably affects the fresh and dry weights of root and leaves.

Stegmen and Bauer (1997) reported that vegetative growth was particularly sensitive to internal water deficits and the loss of turgor pressure. Therefore, sugar beet is very sensitive in the initial and crop development stages, the application of water as 680.2 mm by drip irrigation system makes sugar beet cells to become turgid in these periods, hence, this amount of irrigation water prevents the loss of root and sugar yield. If water scarcity exists, water as 186.8 mm need to be saved in the ripening period for preventing more root and sugar yield loss. Thus, it appears that crop is more sensitive to moderate water deficits. The effect of reduced water supply over the total growing period decreased the efficiency of the foliar application of micronutrients.

Present findings were well agree with Doorenbos and Kassam (1979) reported that light irrigations were preferred during emergence period and over-watering in emergence period may retard leaf development and also water restriction should be avoided in vegetative and yield formation periods since affecting sugar yields more strongly. Therefore, drip irrigation system in the experiment increased the yield of sugar beet and application of micronutrients with foliar spraying provided an increment in the root and sugar yield of sugar beet (*Beta vulgaris* L.) cv.

esperanza The highest root yield was obtained from the full irrigation treatment with foliar application of micronutrients. Hence, these results can be considered as a strategy for the management in sugar beet irrigated by drip irrigation system.

Acknowledgment

Authors are grateful to Scientific Program of Canakkale Onsekiz Mart University (BAP) for the financial support provided Research Project Reference No: FYL-2017-1226.

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