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Water use and yield of sugar beet (*Beta vulgaris* L.) under drip irrigation at different water regimes

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ABSTRACT

This study examines the effects of different irrigation regimes on water use and root yield of sugar beet, irrigated with a drip system under field conditions in the 2012–2013 seasons at Cukurcayir in the Kırsehir Centrum of the Central Anatolian region of Turkey. Experiments were carried out in split plots in randomized blocks with three replications.

The application of irrigation water was based on cumulative class A pan evaporation within irrigation intervals. Study treatments consisted of one irrigation interval (7 days); the two sugar beet varieties (C_1: Esperanza and C_2: Calixta) and three different irrigation levels (I_1, I_2, and I_3) adjusted according to the class A pan evaporation (E_{pan}) using three different plant-pan coefficients (K_{cp1}: 0.5; K_{cp2}: 0.75; and K_{cp3}: 1.00).

The lowest and the highest values of irrigation water and plant water consumption (*Et*) were observed in the I_1 and I_3 treatments in both years, respectively. In 2012, the lowest and the highest root yields were observed in the I_3C_1 (85.38 t ha^{-1}) and I_2C_2 (75.10 t ha^{-1}) treatments. In the second experimental year, the lowest and the highest root yields were achieved with the I_3C_1 (66.13 t ha^{-1}) and I_1C_2 (47.57 t ha^{-1}) treatments, respectively.

The impact on the examined parameters of irrigation programs in the C_2 treatment had not significant. On the other hand, in the C_1 treatment of irrigation programs had a significant effect on sugar rate, sugar yield, and other parameters. If the economic yield and quality are desired, the I_1C_1 treatment can be suggested for sugar beet production under the similar soil and climatic conditions.

1. Introduction

Today, about 144 million tons of sugar is produced each year in as many as 127 countries around the world (Thelen, 2004). Worldwide, 80% of the world's sugar supply comes from sugarcane, cultivated in tropical climates in developing countries, while the remaining 20% comes from sugar beet that is mainly cultivated in industrialized countries. The largest producing countries are Brazil (25%), India (10%), China (10%) and the 27 European countries (9%), followed far behind by the United States, the Russian Federation, Turkey, Ukraine and Food and Agriculture Organization of the United Nations (FAO, 2009).

Sugar beet (*Beta vulgaris* L.), grown mostly under irrigated conditions, is a major commercial field crop in Turkey, and Turkey's share in world production of beet sugar in 2010/11 was 2.27 million tons, accounting for 8% of the world total. Sugar beet takes an important place among the field crops grown in the Kırsehir Province, given its economic importance as the raw material for the production of sugar. In the Kırsehir Province, the average sugar beet production was 58.2 t ha^{-1} in 2012 on 49,113 ha of sugar beet growing area (TSFGD, 2013).

A common irrigation method in sugar beet production in this region is sprinkler irrigation, and crop yield may increase if proper irrigation methods are followed. Drip irrigation has been shown to reduce irrigation water requirements for a variety of crops under certain circumstances when compared to sprinkler or furrow systems (Kruse et al., 1990), among which can be counted sugar beet (Tognetti et al., 2002). The cost of drip irrigation systems has been declining with the advent of new concepts and materials, and if sugar beet can be proved to be well suited to drip irrigation, farmers with established drip systems may consider including sugar beet in their crop rotations.

The appropriate management of irrigation is of vital importance for the preservation of water resources, quantitatively and qualitatively, and to maximize food production with the available water resources. Irrigation scheduling is one of the most important tools

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in the development of best management practices for irrigated areas (Al-Jamal et al., 1999), and this is especially the case in semi-arid areas that are prone to frequent droughts and with limited water resources. In short, irrigation water plays an essential role in agricultural practices, and particularly in sugar beet cultivation.

Deficit irrigation is one optimized solution for the cultivation of products under water scarcity conditions, with product reduced in unite level and its increase with develop (Sepaskhah et al., 2006). Deficit irrigation involves plants receiving less water than requested (English et al., 1990), and its effects on sugar beet yield and on yield components have been examined in relation to different water levels and irrigation methods. For example, Sharifi et al. (2002) made a study of the effect of various levels of irrigation on sugar beet. They considered white sugar yield by reducing the water consumption from 1000 to 725 and to 655 mm decreased 16.6% and 39.7%, respectively. It showed reduced in high stress condition is high. Vazifedousta et al. (2008) reported that we can get to economic yield in deficit irrigation by the limitation in water resources and they reported that it was obtained 1.1 kg dry material per 1 m^3 water for sugarbeet.

The objectives of this study are to investigate the effects of deficit irrigation on sugar beet root yield, sugar rate and the quality parameters of sugar beet, and to evaluate the water use efficiency of sugar beet (*Beta vulgaris* L.) in the Kırsehir Centrum of the Anatolian region of Turkey, and to suggest a suitable irrigation program to farmers in the region using the drip irrigation system.

2. Materials and methods

2.1. Experimental site, soil and climate

The experiment was conducted in 2012 and 2013 under the field conditions at the Cukurcayir in Kırsehir Centrum, Turkey. The experimental site is 1017 m above sea level and has a 36°42′ and 39°16′ N latitude, 31°14′ and 34° 26′ E longitude.

According to the Thornthwaite climate classification, Kırsehir has a semi-arid climate type and total annual precipitation of 384.4 mm. It has also continental climate prevails. In general, summers are warm and dry, and winters are cold. The most significant meteorological data and the long term averages were obtained from weather stations of Kırsehir's Region Meteorology Station (2014). The monthly average meteorological data of the trial years and the long years in the experimental region are shown in Table 1. The long years (1970–2012) annual mean temperature, relative humidity, total annual precipitation, wind speed and sunshine duration per day in the area were 11.4 °C, 55%, 384.4 mm, 2.7 m s^{-1} and 7.2 h, respectively. During the growing periods (from the sowing to harvesting dates) of the years 2012 and 2013, an average temperature of 20.1 and 18.2 °C, total precipitation of 53.2 and 70.5 mm, and an average relative humidity of 45.2% and 47.6% were recorded, respectively. The average temperature and relative humidity data of sugar beet growing seasons were similar to long year's meteorological data. The precipitation in the growing season of the second year was 70.5 mm, which was greater than the first growing season (53.2 mm). However, 2 years' precipitations were lower than long year's averages.

Soil at a depth of 90 cm was sampled before the experiments began and subjected to a physicochemical analysis. Some physical and chemical characteristics of soils in the experimental area are given in Table 2. As seen in Table 2, the texture is silty-clay-loam, alkaline pH, and with a high limy and potassium content. In the experimental area, water content at field capacity varied from 24.4% to 30.6% and wilting point varied from 13.4% to 15.7% on a dry weight basis. The soil contained high percentages of sand (42.6–49.2%), followed by silt (25.4–28.5%) and clay (24.6–30.3%). The bulk density ranged from 1.2 to 1.4 g cm^{-3} throughout the 90 cm deep profiles. The organic matter contents for different soil layers range from 0.73% to 2.13%.

Chemical characteristics of the applied well water are presented in Table 3. Water is obtained from a well using a pump in the experimental area, and good quality irrigation water, and the mean pH is 7.22, and the average electrical conductivity is 91.20 dS m^{-1}.

2.2. Sowing and fertilization

In the study, the two sugar beet varieties of Calixta and Esperanza were used as the plant material and the seeds that are widely used by farmers in the region. Sowing was conducted on April 14 and 2 in 2012 and 2013, respectively. There was 2.0 m separation between each plot in order to minimize water movement among treatments. Each experimental plot was a total of 18 plots, with each plot measuring 9 m in length and 2.25 m in width and had a total area of 20.25 m^2 with five rows. Sugar beet seeds were sown at 1.5–2 cm depths using a 5-row mechanic beet seeder. The experimental design was carried out in split plots in randomized blocks with three replicates. Study treatments consisted of one irrigation interval (7 days); two sugar beet varieties (C_1: Esperanza and C_2: Calixta) and three different irrigation levels or three plant-pan coefficients (K_{cp1}: 0.5; K_{cp2}: 0.75 and K_{cp3}: 1.00). Three different irrigation levels (I_1, I_2, and I_3) were adjusted according to the class A pan evaporation using three different plant-pan coefficients.

Fertilizer applications were given according to the soil analysis results. A compound fertilizer of (12–30–12% N, P_2O_5, K_2O) and nitrogen were applied at the rate of 50 kg ha^{-1} and 160 kg ha^{-1} prior to planting on April 14, 2012, and on April 2, 2013; the rest of nitrogen dose was applied to all experimental plots in the form of ammonium sulfate (21% N) at a rate of 50 kg ha^{-1} on June 28 and July 25 in 2012 and 2013.

2.3. Irrigation and evapotranspiration

Irrigation water was supplied from a well using a pump. The water was classified as C_3S_1 with a low sodium risk and a high electrical conductance (USSL, 1954). The 16 mm diameter lateral pipes carrying 4 l h^{-1} water had inline drippers with 20 cm spacing. Soil water contents were measured by the gravimetric method from the soil samples taken from soil depths at 30–60 and 90 cm increments in each plot at sowing, pre-irrigations, and at the final harvesting date. Experimental plots were irrigated by precipitation at the beginning for a uniform plant establishment. After the emergence of sugar beet seedlings, the plants were irrigated by drip irrigation for a soil profile of 0–90 cm to field capacity. Subsequent irrigations were applied according to the prescribed irrigation rates at 7 day intervals.

Irrigation scheduling methods based on pan evaporation are widely used because of their easy applications (Elliades, 1988). Cumulative evaporation between the irrigations was measured with a class A pan located near the plots. In calculating irrigation water volume, class A pan evaporation, whose fundamentals were described by Doorenbos and Pruitt (1977) and Ertek et al. (2012), was used, as follows:

$$I = E_{\text{pan}} \times K_{\text{cp}} \times A \tag{1}$$

where I: the volume of irrigation water applied (liter), E_{pan}: the cumulative evaporation at class A pan in the irrigation intervals (mm), K_{cp}: the plant-pan coefficient and A: the plot area (m^2). Thus, treatments occurred from three different irrigation levels ($I_1 = E_{\text{pan}} \times K_{\text{cp1}}$, $I_2 = E_{\text{pan}} \times K_{\text{cp2}}$ and $I_3 = E_{\text{pan}} \times K_{\text{cp3}}$).

Soil water measurements were taken throughout the crop growth season. The soil water, up to the 90 cm depth in 30 cm increments, was measured gravimetrically (oven dry basis) at sowing,