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The deficit irrigation productivity and economy in strawberry in the different drip irrigation practices in a high plain with semi-arid climate

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ABSTRACT

Management of drought stress with productive irrigation practices can be an essential way to realize rational strawberry production in regions with water deficiency. In this study, different irrigation levels (full irrigation, 25, 50, and 75% deficit irrigation) were applied to strawberry crops with different irrigation practices (SD: surface drip, SSD: sub-surface drip, and MD: surface drip covered with black polyethylene mulch) to determine the yield and quality responses of the crops to drought stress. The experiment was conducted in a high altitude region with semi-arid climate considering a split-plot randomized complete block design with three replications. The results indicated that the MD practice was the most effective in water use productivity due to provide higher yields with lower irrigation quantities without creating a decline fruit quality. Although it could not reach to the economic benefit level determined in SD practice, MD practice provided more economic benefit compared to SSD. As considering our findings, it was concluded that MD practice can be used effectively for the aim of saving water in strawberry production due to higher irrigation water use efficiency in water shortage conditions. However, SD practice can be more applicable due to provide higher economic gain while not exceeding 50% water deficit.

1. Introduction

Many strategies aimed at saving water are practiced in horticulture. Drip irrigation method increases the efficiency of water use while decreasing water. Sub-surface drip irrigation and plastic mulching are used in commercial strawberry production as water management practices to improve water use efficiency have improved recent years (Létourneau et al., 2015). In sub-surface drip irrigation method only the targeted root zone is irrigated and prevents development of weeds. In addition, since the soil surface will be dry, the plants will more effectively utilize the existing water due to reduction evaporation from the soil surface (Boutheina and Abdelhamid, 2012). As another water saving strategy, covering plant beds with polyethylene mulch preserves the existing soil moisture by reducing evaporation from the soil surface (Kumar and Dey, 2011; Tariq et al., 2016). This polyethylene cover also are decreases the rate weed-growth caused transpiration (Pop et al., 2013). Polyethylene mulching is not only beneficial in water saving but also increased strawberry yield due to improved soil heating (Medina et al., 2011; Fan et al., 2012; Kaur and Kaur, 2017).

Strawberries are an important commercial, production and export fruit crop in Turkey, with production spread out all around the country (Serçe and Özgen, 2015). Turkey, with a strawberry production of 415150 tons in a production area of 15431 ha, was ranked fifth in 2016 year in global production according to the FAOSTAT statistics in 2016 (FAO, 2018). Strawberry production in Turkey is economically possible at altitudes up to 2000 m above sea level (Aslantaş and Karakurt, 2007). In coastal areas, the production season generally lasts until the end of June. In Eastern Anatolia Region with high altitudes and cooler summer months, the harvest season, can last from the end of June until the first frosts of autumn, if day-neutral varieties are used. Therefore, the importance of places with high altitudes has increased considerably for late season fresh strawberry production (Özbahçali and Aslantaş, 2015). Altitude and climatic factors influence on fruit yields and quality (Aslantaş and Karakurt, 2007). Temperature is an essentially vital factor effecting water use, flowering, fruit growth and quality, and ripening.

The drought in regions with limited fresh water reservoirs and arid or semi-arid climate depresses plant horticultural growth and productivity. Water stress stimulates a set of physiological and biochemical agents affecting yield and quality in plants (Khan et al., 2017).

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Strawberries have shallow roots that are mostly found into topsoil of 15 cm (Létourneau et al., 2015). Therefore, these plants require irrigation treatments at frequent intervals with less water for optimal yield (Kachwaya et al., 2016). Many researchers reported that deficit irrigation treatments result with reduction in strawberry yields (Bordonaba and Terry, 2010; Nezhadahmadi et al., 2015; Kachwaya et al., 2016; Adak et al., 2018).

A lot of studies conducted in different regions of the world show that drip irrigation method can be more useful than other methods for strawberry irrigation efficiency. However, the previous studies indicated that there were no strategies to improve effective water use in strawberry production with different drip irrigation practices combined with different irrigation levels in high altitude conditions. This study's aim is to determine the effects of different drip irrigation practices under full and various deficit irrigated conditions on strawberry yield, quality and irrigation economy in high altitude region with semi-arid climates.

2. Material and methods

2.1. Study site description, climate and soil properties

Field strawberry production experiments were carried out in a period from 2014 to 2016, in the soil and water resources research area at the East Anatolian Agricultural Research Institute in Erzurum, Turkey. The research field is located at a longitude of 41.1225 °East and latitude of 39.9369 °North, and at an elevation of 1762 m above sea level. All experimental plots were irrigated with equal irrigation quantities considering total evaporation measured from a Class A pan in the region for intervals of 3–4 days during the 2014 growing period (establishment year). The climate type in the study region is defined as the Dsc (D: severe in winter, s: dry in summer, c: mild cool in summer) according to the Köppen-Geiger classification (Öztürk et al., 2017). Long-term (1929–2017) annual mean temperature is 5.7 °C and total annual precipitation is 431.2 mm (TSMS, 2018). The coldest month is January (−9.2 °C), the warmest is August (19.5 °C). Fig. 1 shows monthly total precipitation and mean air temperature in the experimental area's growing seasons. Total precipitation values measured by a pluviometer was 142.6 mm in 2015 (from 1 June to 5 October) and 239.2 mm in 2016 (from 1 June to 3 October). The experimental field's soil in an effective rooting depth of 40 cm is classified as clay loam comprised of 30.4% sand, 41.9% silt, and 27.7% clay. The soil is slightly alkaline (pH: 7.80), has electrical conductivity of 2.08 dS m^{-1}, 1.94% organic matter content, 9.25% $CaCO_3$ content. The soil water contents retained at the field capacity and wilting point were calculated as 123 and 62.5 mm/ 40 cm, respectively. The soil water contents at the field capacity and wilting point were determined as corresponding to pressures of 0.033 MPa and 1.5 MPa, respectively from measurements in a pressure-membrane apparatus in the laboratory. Undisturbed soil samples were used for determining water retention at the field capacity.

2.2. Experimental procedures

The experimental field soil was plowed to a depth of 30 cm in autumn, 2013. In 2014 spring, fermented manure was spread on field surface homogenously at the dose of 40 t ha^{-1}. Then, field soil was treated with a disc harrow in first week of June 2014, and the final preparation was realized with a combined harrows. The raised beds for planting in the experimental field were established. The day-neutral "Sweet Ann" cultivar which was suitable for the experimental conditions was used as plant material (Özbahçali and Aslantaş, 2015). Sweet Ann bears fruit during the summer in the plateau and passage areas. The strawberry seedlings were transplanted to trapezoidal raised beds measuring 1.1 m at the base, 0.70 m at the top and a height of 0.25 m. Beds were placed 0.40 m apart in the experimental field. Two rows of plants with 35 cm spacing were established along the bed and the plants were spaced in a row 0.30 m apart.

The basal fertilizers; 80 kg ha^{-1} triple super phosphate (42% P_2O_5) and 200 kg ha^{-1} ammonium sulfate (20.5% N) were spread on the bed surface soil considering the current concentrations in the soil beginning of the trial years. Liquid fertilizer solution (8-5-10 NPK) at the dose of 15 L ha^{-1} was applied once every three weeks during the 2015 and 2016 yield periods. Iron chelate was also applied at 5 kg ha^{-1} dose to eliminate chlorosis in plants.

The experiment was carried out according to split-plot randomized complete block design with three replications. The main plots were arranged as the irrigation practices, and the sub-plots as irrigation levels. A total of 36 experimental plots were arranged considering three different irrigation practices combined with four irrigation levels (full and three deficit irrigations). Additionally, 18 tampon raised beds that included strawberry plants fully irrigated were constructed to eliminate border effects in the experimental area. Surface drip irrigation (SD), sub-surface drip irrigation (SSD) and the surface drip irrigation (MD) that the raised beds surface was covered with black polyethylene mulch were selected as irrigation practices. In the full irrigation treatments (W1), the irrigations were initiated when approximately 30% of available soil moisture in the effective rooting depth was consumed. The current water was elevated to the field capacity. Therefore, fixed 18.16 mm irrigation quantity was applied to the W1 treatments in each irrigation throughout the 2015 and 2016 growing seasons. The irrigation quantities applied in the W2, W3, and W4 deficit irrigation treatments were adjusted to equal of 75, 50 and 25% of the water amount given to the full irrigation plot, respectively.

The soil water content was monitored during growing seasons using tensiometers to determine approximate irrigation dates. In the fully-irrigated plots of all practices, tensiometers (Irrometer Co.) were

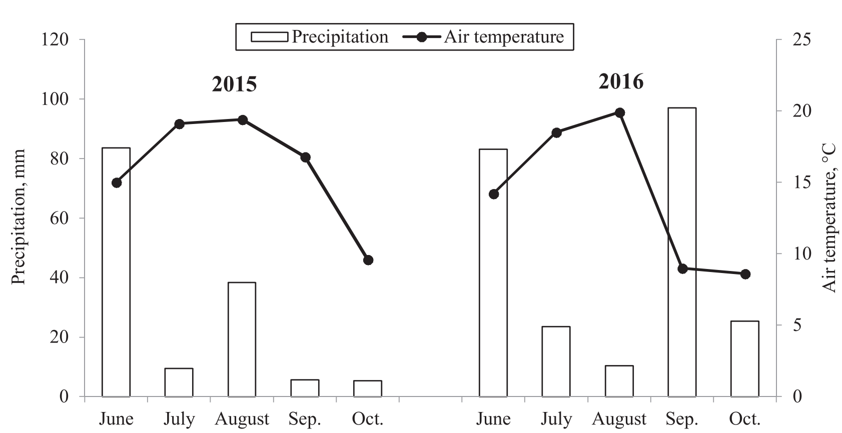

Fig. 1. Monthly total precipitation and mean air temperature values in 2015 and 2016 growing periods.