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Yield and quality response of surface and subsurface drip-irrigated eggplant and comparison of net returns

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ABSTRACT

Yield and quality response to various irrigation regimes applied with subsurface and surface drip systems on eggplant and net profit generation in the Mediterranean Region of Turkey was evaluated. Surface drip (DI) and subsurface drip systems (SDI); two irrigation frequencies (IF_3: 3-day; IF_6: 6-day) and four irrigation regimes (Full irrigation, FI; deficit irrigations, DI_{50}; DI_{75}; and Partial Root-zone Drying PRD50, which received, respectively 50, 75 and 50% of FI) were tested in a split-split plot design. In general, SDI used slightly less water than the surface drip plots due to reduced evaporation losses from the soil surface. Irrigation systems, intervals and regimes resulted in significantly different yields and quality. The results showed that surface drip resulted in higher eggplant yield than SDI by 7.3 and 11% for 3-day and 6-day irrigation frequency in 2013, but the two systems performed similarly in 2014. IF_3FI treatments under both drip systems produced significantly greater yields than other irrigation regimes. Water stress reduced eggplant yield significantly and PRD_{50} treatments resulted in the lowest yields in both growing seasons. Fruit weight, volume and number increased but fruit dry matter, total soluble solids and water productivity decreased with increasing irrigation. The highest water productivity (WP) was found in DI_{50} under subsurface drip 6-day interval (SDI IF_6 DI_{50}) and the lowest in PRD_{50} under subsurface drip 6-day interval (SDI IF_6 PRD_{50}). IF_3FI in the surface drip system generated the highest net income followed by IF_3FI in SDI. In case of water scarcity, IF_3DI_{75} is recommended for high yields and higher net income in the Mediterranean region.

1. Introduction

Water is fast becoming an economically scarce resource in many areas of the world, especially in arid and semi-arid regions such as the Mediterranean. The increased competition for water between agricultural, industrial and urban consumers creates the need for continuous improvements of irrigation practices in commercial agricultural production (Todorovic, 2016). Effective irrigation management strategies can aid in improving crop water productivity through proper timing and application of irrigation water. Therefore the efficient utilization of limited available fresh water resources in irrigated agriculture necessitates the use pressurized irrigation systems such as surface and subsurface drip systems for increasing yield and quality.

Eggplant is an economically important vegetable crop, produced as 35.3 million tons from 1.9 million ha worldwide. Turkey is in the third place among the eggplant producing countries and produces 3% of the world production. Although eggplant production is realized in all the geographical regions in Turkey, the Mediterranean region provides 42% of total production (TUIK, 2015).

Crop growth and yield are mainly dependent on irrigation. Thus, irrigation methods and management are of importance to soil and plant water status. Drip irrigation is the most efficient method of irrigation for vegetable cultivation (Fereres and Soriano, 2007). The delivery of low amounts of water at a high frequency usually limits water evaporation and drainage, thus represents high water productivity (Sharmasarkar et al., 2001; Sun et al., 2013). Subsurface drip (SDI) has proven to be an efficient irrigation method with potential advantages of high water use efficiency, fewer weed and disease problems, less soil erosion, efficient fertilizer application, maintenance of dry areas for tractor movement at any time, flexibility in design, and lower labour costs than in a conventional drip irrigation system (Lamm and Camp, 2007; Irmak et al., 2016). There has been an increasing usage of SDI for vegetable production in the World especially in arid and semi-arid regions due to advantages mentioned above. The yield and quality response of the eggplant to irrigation with SDI is needed to be able to evaluate the economic feasibility of using SDI under local conditions and provide scientifically based practical information to the farmers. In our country, the usage of the SDI is very limited and there is not

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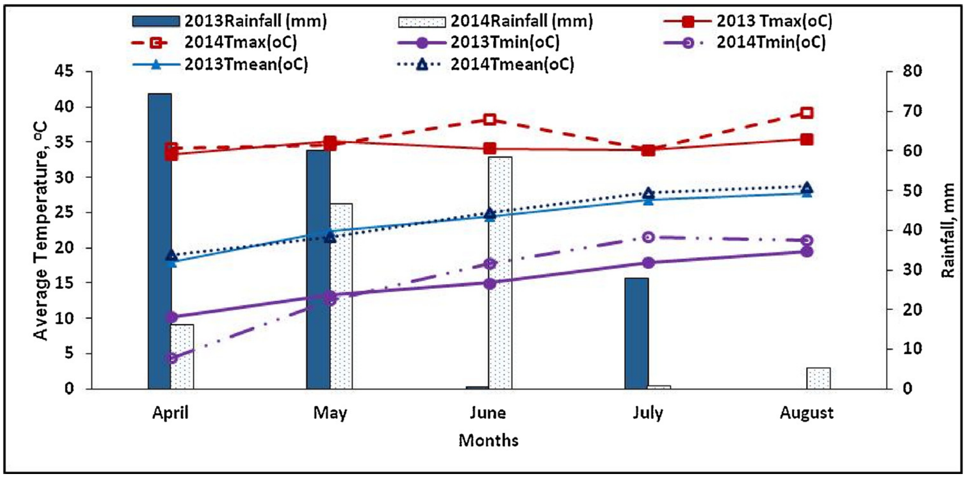

Fig. 1. Monthly mean maximum, minimum and average temperature and rainfall in the experimental years.

sufficient information about the effectiveness of this system over the surface drip irrigation system.

Deficit irrigation and partial root-zone drying (PRD) are the water management techniques in which applying less irrigation water than required allows larger irrigation areas with the available water resources. PRD, simulating drip irrigation, using same quantity of water produced greater biomass yield compared with conventional uniform watering (Wang et al., 2005). However, PRD might results in increased root-zone salinity as compared with conventional deficit irrigation due to moving salts towards the roots in alternating drip-line operation during irrigations on both sides of the crop row. Many investigations have been carried out worldwide regarding the effects of deficit irrigation on yield of mainly horticultural crops (Fereres and Soriano, 2007; Nagaz et al., 2012; Sezen et al., 2014; Bozkurt Çolak et al., 2017). There are several studies on eggplant irrigation carried out in different countries (Chartzoulakis and Drosos, 1995; Aujla et al., 2007; Gaveh et al., 2011; Karam et al., 2011) showing that eggplant can be produced at moderate levels of drought stress without major impact on fruit yield. Kırnak et al., (2002) and Chaves et al., (2003) reported decrease in eggplant yield in response to increased soil water stress levels. Lovelli et al. (2007) demonstrated that the sensitivity to water stress of eggplants was expressed in high marketable yield decrements and a drop in water productivity. In eggplant, the most critical periods for irrigation are during flowering and fruit formation (Blum, 2005). Fruit size and yield as well as biomass yield are reduced by moisture stress. Eggplant needs uniform soil moisture conditions for high fruit production and dry periods may cause shedding of flowers and young fruits (Burt, 2000; Díaz-Pérez and Eaton, 2015). Many researchers reported greater yields and water productivity values of drip irrigation system over the surface irrigation methods throughout the world in different vegetable crops including eggplant (Chartzoulakis and Drosos, 1995; Wang et al., 2006; Yuan et al., 2006; Aujla et al., 2007).

Irrigation frequency is one of the important factors in drip irrigation management, especially in coarse-textured soils. Proper irrigation frequency can establish a balance between soil moisture and oxygen conditions in the crop root zone throughout the growing season (Wan and Kang, 2006). High irrigation frequency is associated with constantly elevated moisture levels in the crop root zone and consequently, the hydraulic conductivity and water availability are maintained for longer times at high levels (Raviv et al., 1999).

Eggplant is an important summer vegetable in the Mediterranean region of Turkey. Farmers' practice for raising the crop with 6–8 irrigations by surface method leads to high water demand. However, availability of irrigation water in drier months is the main limiting factor to enhance crop productivity in the region. Hence, the efficient use of water should be prioritized to increase crop-water productivity in the region. Drip system may be an alternative of conventional irrigation due to its precise and direct application of water in root zone. The dependence of crop yield on water supply is a critical issue because of the increasing limited water resources for irrigation. The objectives of the present study were to: (i) evaluate and compare the interactive effects of full and conventional deficit irrigation regimes and partial root-zone drying, and irrigation frequencies on yield, quality and water productivity of field grown eggplant (*Solanum melongema* L.) under surface drip and subsurface drip systems; and (ii) compare net income generated by different irrigation regimes for surface and subsurface irrigated eggplant grown in the Mediterranean region of Turkey.

2. Materials and methods

2.1. Experimental site

The field experiment was conducted at the Tarsus Soil and Water Resources Unit of Horticultural Research Institute (36°53′ N and 34°57′ E, altitude 60 m above sea level), in Tarsus, Turkey. Typical Mediterranean climate prevails in the study area. Mean monthly maximum and minimum air temperatures, rainfalls in 2013 and 2014 growing seasons in the experimental area are presented in Fig. 1. The eggplant-growing period, April to August, was characterized by a dry summer. The mean monthly minimum (Tmin) and maximum (Tmax) temperatures within the crop season varied between 4.4–21.6 °C, and 33.2–39.2 °C, respectively. Tmin values in April and May were lower but in June through August higher in the first growing season than those in the second season. Tmax values in June and August in the second growing season were much higher than those in the first season. The rainfall received during the growing seasons (April through August) was 163 mm in 2013, and 126.3 mm in 2014. Rainfalls in April and May in the first growing season delayed the transplanting as compared to second season.

The soil of the experimental site is classified as clayey-silt. In the root zone depth (60 cm), soil water contents at the field capacity and permanent wilting point are 245 and 157 mm, respectively. Mean bulk density varies from 1.30 to 1.45 g cm^{-3}; the average electrical conductivity (ECe) values range between 0.91 and 1.03 dS m^{-1}.Water is obtained from a deep well in the experimental area, with a pH value of 7.31 and EC of 1.47 dS m^{-1}.

2.2. Irrigation design and treatments

In this study two irrigation systems, namely surface drip (DI) and subsurface drip systems (SDI); two irrigation intervals (IF_3: 3-day; IF_6: 6-day) and four irrigation regimes (Full irrigation, FI; deficit irrigation,