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Evapotranspiration, crop coefficient and seed yield of drip irrigated pumpkin under semi-arid conditions

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ABSTRACT

Pumpkin (*Cucurbita pepo* L.) is one of the most important plants in Turkey. A 2-year experiment (2013–2014) was conducted in the Konya Plain of Turkey in order to investigate the response of confectionary pumpkin to irrigation intervals. The experiment was laid out in a randomized block design consisting of three irrigation intervals (I_7: 7-day, I_{14}: 14-day, I_{21}: 21-day) with three replications each. Actual evapotranspiration (ET_a) of irrigation treatments varied from 521.2 to 660.2 mm in 2013 and from 493.6 to 629.6 mm in 2014. On an average, the ET_a rate was 4.71 mm day^{-1} under I_7 and declined by 8% and 21% under I_{14} and I_{21}, respectively. Crop coefficients (K_c) varied similar to ET_a among the different growing stages, i.e., from a mean of 0.56 at the initial stage to 0.95 at mid-season. The mean K_c was estimated to be 0.74 for the whole season. Irrigation intervals were found to significantly affect the seed yield and the quality of pumpkin in 2013 as well as 2014. No statistically significant differences ($P \leq 0.05$) were found between the I_7 and I_{14} treatments in both the years although the I_7 treatment was observed to produce the highest seed yield (1275 kg ha^{-1}). Hence, in terms of water savings, the irrigation interval could be extended to 14 days without a significant decrease in the seed yield in case of arid and semi-arid areas such as the Konya Plain.

1. Introduction

Water for agriculture is increasingly getting a scarce commodity as the competition between industrial, municipal, and environmental water users is growing. Continuously decreasing resources resulting from climatic variability further amplifies the scarcity (Rijsberman, 2006). Regions classified as semiarid or arid constitute roughly one-third of the total global land cover and, within these regions, water scarcity is one of the main factors that limits agricultural development. The impact of water scarcity in such regions is amplified by the use of inefficient irrigation practices, especially since irrigation consumes more than 85% of the available water (Er-Raki et al., 2010). Water is the main factor that limits yield in the hot and dry summer period of arid and semiarid regions. To circumvent this, irrigation programs need to be applied to ensure maximum production per unit irrigation water (Kiziloglu et al., 2009).

In order to optimize the water requirement of crop production, a comprehensive knowledge of crop water requirement, critical crop growth stages and required irrigation schedules for maximizing production are highly desirable; knowledge of the amount of water available to meet the crop demands is also needed (Yitaew and Brown, 1990). Crop water use varies substantially during the growing period as a result of variation in crop canopy and prevailing climatic conditions (Allen et al., 1998).

The most fundamental requirement for irrigation scheduling is the determination of ET_a or total water use. Field water balance is a common parameter used to measure ET_a and it is known that ET_a increases with the increase in number of irrigation from one to adequate (Prihar and Sandhu, 1987). Under stress conditions, ET_a can also be calculated by combining effects of K_c and reference evapotranspiration (ET_o), where ET_o represents nearly all effects of weather and K_c varies predominately with specific crop characteristics and is relatively less affected by climate (Allen et al., 2005). In addition, K_c is also affected by crop and water management as well as type of soil and irrigation system. Determination of K_c under local climatic conditions is the basis of improving the planning and efficiency for irrigation management in several field crops (Kang et al., 2003; Sepaskhan and Andam, 2001).

Irrigation frequency is one of the most important factors that determine the quantum of seasonal ET_a (Wang et al., 2005). Higher irrigation frequency delays maturity (Hagan et al., 1967) probably

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because of the additional vegetative growth as well as the elimination of stress-accelerated senescence while a wide gap between two consecutive irrigation sessions dries out the root and reduces both cell division and elongation (Kramer, 1972) leading, in both cases, to a decline in productivity level.

The Konya Plain, with limited water resources, has a semi-arid climate and constitutes 10% of Turkey's arable lands (Yavuz et al., 2012). According to the long-term meteorological data (1960–2013), the average annual rainfall in the Konya Plain is 323 mm and only 28% of it is received during May–September. Rainfall is extremely irregular and is concentrated around the winter months thus reducing the choice of annual summer crops to very few. Irrigation is essential for crop production during this period and most of the water used is drawn from aquifers. This has resulted in an excessive pumping of aquifer water and the situation has become alarming because within a span of 33 years (1974–2007), the aquifer water level has been depleted by 14–15 m (WWF, 2008). In recent years, however, this depletion has been estimated to be higher as a result of excessive irrigation. Due to lack of irrigation water, only one-third of the irrigated arable land in the Konya Plain can be irrigated. Therefore, scientifically applied agricultural research programs related to water saving and conservation are essential in the Konya Plain where agricultural activities account for more than 75% of the total water consumption. In this context, in Middle Anatolian, confectionary pumpkin is one of the most important plants in terms of lower water consumption when compared to plants such as sugar beet, corn, and carrot.

Pumpkin serves as a reliable source of produce and provides the families growing them with a variety of diet that helps ensure stability in terms of household food security (Mwaura et al., 2014). Pumpkin seeds have been shown to contain the antioxidant beta-carotene which helps improve immune function and reduces the risk of cancer and heart disease. In addition, pumpkin seeds also contain many vitamins and nutrients, including calcium, iron, magnesium, potassium, zinc, selenium, and vitamins A, C, and E (Ghanbari et al., 2007; Ondigi et al., 2008).

In Turkey, the effects of irrigation interval on water use patterns have been investigated for several crops (Tuzel et al., 1993; Ertek and Kanber, 2003; Sezen et al., 2006; Sezen and Yazar, 2006; Boydak et al., 2007; Ucan et al., 2007; Kara and Biber, 2008; Dagdelen et al., 2009; Kazaz et al., 2010; Sahin et al., 2014), but confectionary pumpkin has not been received sufficient attention.

Scientific information on ET_a and K_c, as a function of growth period, for the response of the confectionary pumpkin to irrigation interval under Turkey conditions are scarce. Precise information on K_c, which is required for regional scale irrigation planning, is especially lacking for growing confectionary pumpkin in developing countries such as Turkey. Hence, the objectives of this study were to: (1) determine the ET_a and seed yield for confectionary pumpkin under different irrigation frequency; (2) derive the K_c values from water use data under actual growing and local climatic conditions for use in irrigation planning and management at a regional level.

2. Materials and methods

Field trials were conducted for 2 years (2013–2014) at the Agricultural Faculty Station of Selcuk University in the Konya Plain of Turkey (38°02′N lat., 32°30′E long., 1105 m a.s.1.).

The climatic parameters such as mean max.-min. temperature, wind speed, relative humidity, solar radiation and daily sunshine during the growing season of 2013–2014 were similar to the historical average (1960–2013; 53 years) for the region. However, the total rainfall during the season (May–September) in 2013 was slightly lower than the long-term average seasonal rainfall (Table 1). An automatic meteorological station installed within the experimental facility was used for collecting climatic data used in the study. This daily data collected included precipitation, air temperatures, relative humidity, solar radiation and wind speed at a height of 2 m. The climatic datasets were checked for quality assessment as recommended by Allen et al. (1998).

The soil of the study area is characterized by a sandy–clayey–loamy texture. The presence of organic matter is low, the field capacity is 0.29 $m^3 m^{-3}$ and the permanent wilting point is 0.15 $m^3 m^{-3}$. Average bulk density in the 0–90 cm soil profile is 1.41 g cm^{-3}, and the total available water is 126 mm in the upper 90 cm of the soil profile (Table 2).

Cucurbita pepo L. cv. local population variety was used as crop material for the study. Pumpkin seeds were sown as three seeds to

Table 1
Variations of meteorological parameters of region during experimental years.

Months		Mean max. temp. (°C)	Mean min. temp. (°C)	Mean wind speed ($m s^{-1}$)	Mean relative humidity (%)	Precipitation (mm)	Mean solar radiation ($MJ m^{-2} day^{-1}$)	Mean daily sunshine (h)
May	2013[a]	25.2	11.4	2.2	59.8	46.6	23.5	7.8
	2014[b]	24.4	8.3	2.0	57.5	7.4	24.3	8.5
	53 years	22.2	8.5	2.2	55.9	43.8	25.0	8.5
June	2013	28.4	14.4	2.9	47.8	8.8	25.8	10.6
	2014	26.4	12.5	2.6	55.9	55.6	24.9	9.3
	53 years	26.6	12.7	2.5	48.4	22.9	27.8	10.4
July	2013	29.5	17.3	3.3	40.1	0.8	27.2	11.1
	2014	32.0	16.7	3.2	44.3	9.6	27.7	11.3
	53 years	30.0	15.9	2.8	42.1	6.8	28.7	11.4
August	2013	30.0	17.1	3.0	39.4	–	26.1	11.2
	2014	32.4	17.5	3.1	43.5	2.8	24.9	11.1
	53 years	29.9	15.4	2.6	42.9	5.5	26.6	11.1
September	2013[c]	25.2	11.2	2.3	47.6	3.0	18.7	9.7
	2014[c]	27.0	12.6	2.1	58.1	8.2	18.5	9.4
	53 years	26.0	11.0	2.1	48.0	11.0	22.1	9.4
Seasonal average/total	2013	27.7	14.3	2.7	46.9	59.2	24.3	10.1
	2014	28.4	13.5	2.6	51.9	83.6	24.1	9.9
	53 years	26.9	12.7	2.4	47.5	90.0	26.0	10.2

[a] Calculated from the data between 10 and 31 May.
[b] Calculated from the data between 12 and 31 May.
[c] Calculated from the data between 1 and 24 September.