Agricultural Water Management 98 (2011) 1197–1206

Contents lists available at ScienceDirect

Agricultural Water Management

journal homepage: www.elsevier.com/locate/agwat

Effect of irrigation method and quantity on squash yield and quality

Kamal H. Amer*

Department of Agricultural Engineering, Menofia University, Mostafa Kamel, El-Bar El-Sharky Faculty of Agriculture, Shibin El-Kom, Menofia 32511, Egypt

ARTICLE INFO

Article history:
Received 21 December 2010
Accepted 13 March 2011
Available online 6 April 2011

Keywords:
Squash yield and quality
Furrow irrigation
Trickle irrigation
Scheduling
Crop coefficient

ABSTRACT

Squash yield and quality under furrow and trickle irrigation methods and their responses to different irrigation quantities were evaluated in 2010 spring and fall growing seasons. A field experiment was conducted using squash (*Cucurbita pepo* L.) grown in northern Egypt at Shibin El Kom, Menofia. A randomized split-plot design was used with irrigation methods as main plots and different irrigation quantities randomly distributed within either furrow or trickle irrigation methods. Irrigation quantity was a fraction of crop evapotranspiration (ET_c) as: 0.5, 0.75, 1.0, 1.25, and 1.5 ET_c. Each treatment was repeated three times, two of five rows from each replicate were left for squash seed production. In well-watered conditions (1.0 ET_c), seasonal water use by squash was 304 and 344 mm over 93 days in spring and 238 and 272 mm over 101 days in fall under trickle and furrow irrigation methods, respectively. Squash fruit yield and quality were significantly affected by season and both irrigation method and quantity. Fruit number and length were not affected by irrigation method and growing season, respectively. Interaction between season and irrigation quantity significantly affected leaf area index, total soluble solid (TSS), and fruit weight. Moreover, seed yield and quality were significantly affected by growing season and both irrigation method and quantity except harvest index, which was not affected by irrigation method. Significant differences for the interaction between season and irrigation method were only found for seed yield and 100 seeds weight. Except for harvest index, no significant difference was observed by interaction between season and irrigation quantity. Both fruit and seed yields were significantly affected in a linear relationship ($r^2 \geq 0.91$) by either deficit or surplus irrigation quantities under both irrigation methods. Adequate irrigation quantity under trickle irrigation, relative to that of furrow, enhanced squash yield and improved its quality in both growing seasons. Fall growing season was not appropriate for seed production due to obtaining many of empty seeds caused by low weather variables at the end of the season. The results from small experiment were extrapolated to large field to find out optimal irrigation scheduling under non-uniform of irrigation application.

1. Introduction

In Egypt, River Nile which floods about 55 billion m^3 water a year is the most important water resources for agricultural, industrial, and urban activities. Rainfall which is about 13 mm a year and occurs only in winter season is not sufficient even for an irrigation interval. Even though, most of ground water comes due to infiltrating and moving water from Nile or its irrigated fields. More than 85% of water consumption is due to agricultural related activities. Moreover, a large number of small scale farmers who owns dispersed plots over an area irrigate their crops from small earthen ditches where it is impossible to measure the water used by individual farmers. Farmers rationally endeavor to obtain more water during its flowing in ditches to achieve maximum crop production, but, not all of them can have the same quantity of water under the limited availability of water. Therefore, modern irrigation techniques are demanded in order to use water more efficiently and sustain the increase of both cultivated land and populations.

Squash is predominantly grown on small fields which are less than 1 ha in spring, summer, and fall seasons. Squash plants grow best on fertile, well drained soil with organic matter. Plants should be irrigated during dry weather. Trickle or furrow irrigation is better than sprinkler irrigation as any moisture on the leaves increases the incidence of leaf disease. The fresh fruits are harvested 40 days after planting when they are small and tender (3–5 cm in diameter) before the rind hardens; therefore, they should be harvested two or three times a week. But, seed yield is harvested at the end of the season. Squash is sensitive to, and may be damaged by, excessive soil water from seed sowing to maturity. Since squash rooting depth is relatively shallow, soil water has to be maintained above 50% of the available soil water in order to avoid detrimental water deficit (Hess et al., 1997). Squash roots, most of which are in the top of 40–50 cm of soil, develop rapidly. Irrigation should be scheduled to avoid excessive moisture or water stress. Lack of adequate

* Corresponding author. Tel.: +20 105753127; fax: +20 25769495.
E-mail address: kamalamer@yahoo.com

0378-3774/$ – see front matter
doi:10.1016/j.agwat.2011.03.003

soil water at harvest can result in misshapen fruits, but too much soil water can aggravate root and stem rot diseases (Richard et al., 2002).

Squash is an important commercial crop that has gained popularity for both open-field and greenhouse in the Mediterranean region (Rouphael and Colla, 2005). Squash is normally grown in soil under conditions using both trickle and furrow irrigation methods during the spring-summer and the summer–fall seasons in order to respond to the high demand of this fresh product on both national and international markets. Rouphael and Colla (2005) working on zucchini squash observed that the total and marketable yield and fruit weight and number were significantly affected by the growing season and the irrigation system and not by their interaction. Total yield, marketable yield, and fruit weight and number were significantly reduced by 35, 33, 35 and 26%, respectively in the summer–fall growing season in comparison with the spring-summer growing season. The lower yield recorded during the summer–fall growing season was related to a reduction in both fruit mean weight and fruit number. The results also indicate that the effect of the growing season on yield and fruit quality of zucchini was significant and more pronounced than the effect of irrigation system, plants grown in the summer–fall season exhibited a lower yield and growth than those grown in the spring-summer season. The higher yield of zucchini squash in the spring to summer growing season in comparison to the summer to fall season is due to better temperature conditions and solar radiation (Adams, 2002). The higher solar radiation due to the high level of natural light and long photoperiod was presumably responsible for the increased photosynthesis in the spring-summer with respect to the summer–fall growing season. The global radiation and temperature were ranged from 12.2 to 22.5 MJ m^{-2} d^{-1}, 10.8 to 28.8 8 °C, respectively, in the spring-summer versus 3.0 to 17.1 MJ m^{-2} d^{-1} and from 6.0 to 24.8 8 °C, respectively, in the summer–fall growing season.

Considering all other factors of production at their optimum level, crop response is defined as a crop yield decreased constantly by decreasing quantity of water applied into the root zone in deficit irrigation (Richard et al., 2002; Amer, 2010); nevertheless, crop yield is decreased constantly by increasing quantity of water applied in surplus irrigation. The relationship between crop yield and irrigation quantity can be found from irrigation experiments in which a large range of irrigation application is conducted. Ahmet et al. (2004) using furrow irrigation on squash found that fruit yield significantly increased in linear relationship from 22.4 to 44.7 Mg ha^{-1} as irrigation water applied increased from 279 to 475 mm in deficit irrigation where no deep percolation occurred.

Al-Omran et al. (2005) studied squash using both surface (DI) and subsurface drip irrigation (SDI) methods in sandy soils with three clay deposits found that fruit yield has a linear relationship to increased irrigation water level for each season within the same treatment. They found that fruit yields significantly increased with clay deposits compared with control. The differences between SDI and DI on fruit yields were also significant. Water use efficiency linearly increased as irrigation water applied increased for deficit irrigation level and decreased for excessive irrigation level.

Amer (2010) working with furrow irrigated corn (Zea Mays) found that maximum yield (Y_m) of 9.12 Mg ha^{-1} was achieved by 325 mm adequate irrigation quantity (d). A yield reduction ($1 - Y/Y_m$) was linearly decreased in a rate of 1.15 by increasing water deficit fraction ($1 - \mu/d$) in complete deficit irrigation in range of 0.6–1.0 ET_c, where Y is the corresponding yield achieved by irrigation quantity μ. He found that the crop yield was linearly decreased in surplus areas by increasing irrigation water quantity ranged from 1.0 to 1.4 ET_c in a rate of 0.32. Furthermore, an optimal irrigation scheduling is statistically developed based on crop response to extrapolate data from the small experiment (uniform condition) to large field (non-uniform condition) under the experiment constraints.

The purpose of the study was to assess the yield and quality of squash under both furrow and trickle irrigation systems and to assess the crop responses to different irrigation quantities in spring and fall growing seasons. Additionally, optimal irrigation scheduling in non-uniform irrigation based on crop yield maximization was utilized by extrapolating the results from the small experiment.

2. Materials and methods

2.1. Field experimental work

Squash was grown in 2010 spring and fall growing seasons in clay soil located at an arid site in northern Egypt (Shibin El-Kom area, 17.9 m above sea level, 30° 32′N, 31° 03′E). The crop was planted on 16 March and 18 August, and terminated on 17 June and 27 November in the 2010 spring and fall growing seasons, respectively. A Randomized Split Plot design with irrigation method treatments as main plots and irrigation quantities as random treatments within an irrigation method was established. Each treatment was repeated three times, two of five rows from each replicate were left for squash seed production. Plot size for an irrigation method was 18 m × 27 m with 0.5 m row width, and an about 0.5 m spacing between plants within rows. Squash seeds were sown with a seed to each hole. All treatments were separated as surrounded by 1 m non-irrigated area. Plants were adequately watered in first irrigation. Irrigation quantity treatments were initiated at the second irrigation. Furrow and trickle irrigation systems represented the irrigation method treatments. Irrigation quantity treatments rated as 0.5, 0.75, 1.0, 1.25, and 1.5 ET_c, where ET_c is crop evpotranspiration. Irrigation water was applied when volumetric soil moisture content reached in between 0.318 and 0.354 m^3 m^{-3} in the upper 0.5 m of soil profile for 1.0 ET_c treatment. The Watermark 253 soil moisture sensors working with a datalogger CR-23X (Campbell Scientific Inc., Logan, Utah) were set in each 1.0 ET_c replicate and calibrated by taken soil samples. In the beginning of each experiment, a relationship between sensor readings and sampled soil moisture content was found. Sensors were vertically installed at 0–10 cm, 10–20 cm, 20–30 cm, 30–40 cm, 40–50 cm, and 50–60 cm depths. They were horizontally installed at 0, 10, 20, 30, 40, and 50 cm for each 10 cm vertical soil depth. Sensors readings each experimental plot were monitored before and after irrigation in both methods. But, readings were taken in between two following irrigations only for furrow method. Readings were taken after 36 h from irrigation to draw soil–water redistribution under both furrow and trickle irrigations. Sensor readings were taken before irrigation to a depth of 0.6 m to determine water use by plant. But, irrigation schedule was to refill the 0.5 m depth of root zone until soil reached field capacity (0.423 m^3 m^{-3}). Irrigation scheduling for 0.5, 0.75, 1.25, and 1.5 ET_c treatments were fractioned from 1.0 ET_c for each irrigation method. In the experimental site, there was no rainfall or ground water contribution, which water table was greater than 2.8 m, during the study period.

Furrow and trickle irrigation systems were installed before planting in the experiment. The control unit of both irrigation systems consisted of a pressurized water resource, flow meter, pressure gage, and control valves. Furrow width was 1 m and planted by two rows of squash. Emitters with 4 l/h flow rate at 101 kPa pressure were spaced 0.5 m on trickle lateral. A trickle line for each plant row and an emitter for each squash plant were used in the experiment. Farmyard manure was added as 17 Mg ha^{-1} before squash sowing. Chemical fertilizer quantity added to the experiment was the recommended rate for squash production in this area,