Agricultural Water Management 180 (2017) 78–87

Contents lists available at ScienceDirect

Agricultural Water Management

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

Irrigation scheduling and water use efficiency of cucumber grown as a spring-summer cycle crop in solar greenhouse

Recep Çakir[a,*], Ulviye Kanburoglu-Çebi[b], Surreya Altintas[c], Aylin Ozdemir[b]

[a] ÇanakkaleOnsekiz Mart University, Lapseki Vocational College, Lapseki, Çanakkale 17800 Turkey
[b] Ataturk Soil Water and Agricultural Meteorology Research Institut, Kirklareli, Turkey
[c] Namik Kemal University, Faculty of Agriculture, Department of Horticulture, Tekirdag, Turkey

ARTICLE INFO

Article history:
Received 10 August 2016
Received in revised form 24 October 2016
Accepted 30 October 2016

Keywords:
Mini cucumber
Unheated tunnels
Yield
Ky

ABSTRACT

This 3-year study aimed to determine the most appropriate irrigation application and water use efficiency programs based on Class A Pan evaporation for mini (Lebanese) type cucumber plants grown as a first crop under protected conditions in a solar greenhouse. Research was carried out in an unheated solar greenhouse constructed on the lands of Ataturk Soil Water and Agricultural Meteorology Research Institute in Kirklareli, Northwestern Turkey. In order to prevent excessive increase in temperature within the protective structure, the semicircular shaped unheated greenhouse with sidewall ventilation was screened with 75% green-coloured shading net. The experimental layout of the study was a split-plot design with 3 replications. Two irrigation intervals (D1–2 days and D2–4 days) and four different plant–pan coefficients (0.75, 1.00, 1.25 and 1.50) were applied to main and subplots in the experiment. It was determined that cucumber yields increased with the increase in the irrigation water amount and reached averages of 128.2 and 126.5 ton ha^{-1} with use of highest plant pan coefficients of 1.50 and 1.25 vs. 90.7 and 90.9 ton ha^{-1} under the lowest Ecp coefficient of 0.75. The highest irrigation water use efficiency (IWUE) and water use efficiency (WUE) values of about 56 kg ha^{-1} m^{-3} and 42 kg ha^{-1} m^{-3} were obtained from the conditions with least applied irrigation water amounts. The average seasonal value of the yield response factor (k_y) estimated on the basis of data from the 3-year study was determined as 0.75.

1. Introduction

Cucumber is one of the most popular vegetables grown under open field conditions and in greenhouses in Turkey. More than 62% of the total cucumber production in the country is obtained as a result of protected cultivation carried out under heated glass or unheated solar greenhouses and other facilities, on a total area of 61,776 ha during 2015 (Anonymous, 2015).

According to Tuzel and Leonardi (2009), protected cultivation has rapidly expanded in many regions all around the world, particularly starting from the early 1960's because of the introduction of plastics in agriculture and subsequently during the 1970's when the rise in oil prices resulted in increased heating costs. Greenhouse cultivation of various types is considered an expensive method to produce products in many parts of the world (Canakci and Akinci, 2003), however it provides high yields and high profits per unit. Protected agriculture also allows effective use of marginally small lands and productive use of labor resources in the region of the study during all seasons of the year. Yuan et al. (2001) reported that solar greenhouses rely on sunlight as primary energy source without heating systems in general, and have a simple structure which makes them inexpensive to build and cheap to maintain as they do not need any additional energy for heating in winter.

In general water availability is the most important factor limiting the development of agriculture in countries and regions with deficient water resources. Therefore efficient use of water by irrigation is becoming increasingly important and irrigation scheduling is very important for water saving (Mao et al., 2003). The competition for water resources is increasing dramatically nowadays, which requires improving water use efficiency that is possible under conditions of the protected structures.

Irrigation scheduling and water application programming are very effective tools for effective water use in open field and/or protected agriculture. The main methods used for the purpose can be classified as water balance method based on determining crop water requirements from climatic data; and use of soil or

* Corresponding author.
E-mail addresses: crec56b@yahoo.com, rcakir@comu.edu.tr (R. Çakir).

http://dx.doi.org/10.1016/j.agwat.2016.10.023
0378-3774/

plant sensors. Water content of soil is an important component in greenhouses, which has a direct impact on the amount of water applied to irrigate crops. Furthermore, the main goal of greenhouse development is to improve productivity and efficiency of water consumption (Hasandokht, 2005). Research carried out earlier showed that a close relationship exists between plant water consumption and pan evaporation. Elliades (1988) noted that in scheduling irrigation programs, methods based on pan evaporation have widespread usage because of its simple and easy application.

Class A Pan evaporation approximation has been successfully used for irrigation scheduling of cucumber grown under open field conditions (Simsek et al., 2005; Ertek et al., 2006; Sahin et al., 2015). However, this scheduling method is much more popular than the other approximations in greenhouses and was used for irrigation programming of cucumbers (Elliades, 1988; Blanko and Folegatti, 2003; Ayas and Demirtaş, 2009; Al-Omran and Louki, 2011; Al-Omran et al., 2013). Some authors (Mao et al., 2003; Yuan et al., 2006; Wang et al., 2009; Zhang et al., 2011) applied evaporation from standard pan with surface of 20 cm in diameter.

Several other authors (Chartzoulakis and Michelakis, 1990; Blanko and Folegatti, 2003; Tuzel et al., 2005; Tabatabaei et al., 2011; Rahil and Qanadillo, 2015; Buttaro et al., 2015) prefer to use soil moisture status in the soil monitored using tensiometers or soil moisture measurements using neutron probe (Mao et al., 2003) or TDR (Zhang et al., 2011; Douh et al., 2015) devices.

Water supply during intensive farming activities in protected structures is very limited because of different timing compared to open field agricultural activities. According to Rahil and Qanadillo (2015), scheduling water application is very critical to make the most efficient use of drip irrigation systems, as excessive irrigation water reduces yield while inadequate irrigation causes water stress and reduces production. Chartzoulakis and Michelakis (1990) studied the effect of five irrigation systems (furrow, microtubes, drip, porous clay tubes and porous plastic tubes) on yield and water use of cucumber plants grown in greenhouses, and determined that the lowest irrigation water amount of 292 mm was applied under conditions of drip irrigation. In experiments carried out on greenhouse grown cucumber in the North China Plain (Mao et al., 2003), the level of fulfilment of water requirements was used as a gauge to differentiate five border irrigation treatments and it was determined that fruit yields were highly influenced by the total volume of irrigation water at every studied growth stage. The majority of research using various scheduling approximations, techniques and tools for irrigation programming of greenhouse grown cucumber crops have been conducted under conditions of surface (Blanko and Folegatti, 2003; Yuan et al., 2006; Ayas and Demirtaş, 2009; Al-Omran and Louki, 2011; Tabatabaei et al., 2011; Buttaro et al., 2015) or subsurface (Wang et al., 2009; Zhang et al., 2011; Douh et al., 2015) drip irrigation applications providing much greater water use (WUE) and irrigation water use (IWUE) efficiencies.

The aim of our study was to determine the most appropriate irrigation application and water use efficiency programs based on Class A Pan evaporation for mini cucumber plants grown as a first crop under protected conditions in a solar greenhouse.

2. Material and methods

The study was conducted over three years at the Ataturk Soil Water and Agricultural Meteorology Research Institute in Kirklareli (41° 42′ N and 27° 12′ E). The climate o f the research area is classified as Csa according to the Köppen-Geiger system. On the whole, winter months are cold and snowy, while autumn is rainy and the summer is dry and hot in Kirklareli.The average annual daily temperature is estimated as 13.0 °C. The average yearly precipitation and evaporation values for a long-term period are determined to be 589.6 mm and 1099.2 mm, respectively. The long- term averages for air temperature and monthly evaporation values for the months of the study are estimated as 12.0 °C and 91.9 mm (April), 17.0 °C and 136.2 mm (May), 21.2 °C and 168.7 mm (June), and 23.3 °C and 206.7 mm (August), respectively.

The experimental site is covered with soils of silty loam (SL) texture, classified as Entisol soil (Udic Ustifluvent) and described as poor in organic matter and rich in potassium. Undisturbed and disturbed soil samples, collected in three replications from different layers (0–30. 30–60. 60–90 and 90–120 cm) of the greenhouse area, were analysed following procedures given by Richards (1954). The experimental soil is poor (1.35%) in organic matter and rich in potassium. Values of some soil characteristics related to irrigation are presented in Table 1.

Field experiments were conducted in a natural sidewall ventilated and unheated greenhouse with 76.0 m length and 8.0 m width, and total area of 608 m^2. The semicircular shaped greenhouse with 2.5 m height was oriented in north-south direction and covered with polythene film. In order to prevent excessive increase of the temperature within the structure, during June and July the greenhouse was screened with 75% green-coloured shading net.

Evaporation in the structure was measured using Class—A pan located in the central part of the greenhouse on a wooden floor of 15 cm height. A stainless steel circular pan of 121 cm diameter and 25.5 cm in height was used for the purposes of the study.

Greenhouse experiments were conducted with Marathon F1 mini (Lebanese) type cucumber plants, resistant to diseases and pests, characterised with seedless short fruit with thin dark-green skin, early maturation and high quality of the fruits. The used cultivar was also very popular among farmers and consumers in the region. Seedlings were produced in nursery plots located close to the experimental greenhouse, sowing one seed in each small pod (viol) filled with peat. When the cucumber plants in the nursery unit reached 3–4 leaf stage, they were transplanted into the experimental plots with 0.8 m distance between the rows and 0.4 m space between the plants in the row, on 27th, 14th and 08th of April

Table 1
Physical and Chemical Characteristics of the Experimental Soil.

Physical Properties						
Soil Depth. cm	Bulk Density gr cm^{-3}	Texture			Field Capacity. Pw	Wilting Point. Pw
		Clay.%	Loam.%	Sand.%		
0–30	1.46	16	33	51	16.5	7.4
30–60	1.49	14	18	68	14.4	7.3
60–90	1.49	26	27	47	20.5	9.9
90–120	1.48	31	23	46	24.5	14.1
Chemical Properties						
	pH	Salinity dS/m	OM%	P_2O_5 kg ha^{-1}		K_2O kg ha^{-1}
0–30	7.4	0.590	1.35	89.3		505