Agricultural Water Management 180 (2017) 172–177

Contents lists available at ScienceDirect

Agricultural Water Management

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

Water pillow irrigation versus drip irrigation with regard to growth and yield of tomato grown under greenhouse conditions in a semi-arid region

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ARTICLE INFO

Article history:
Received 12 May 2016
Received in revised form 18 October 2016
Accepted 11 November 2016

Keywords:
Water pillow irrigation method
Tomato
Greenhouse
Weeds

ABSTRACT

Increasing world population entails an increase in agricultural productions. Climate change and resultant global warming points out more efficient use of soil and water resources. Irrigation is the most significant input in agriculture to increase yield levels. Therefore, efficient water use is a critical issue in irrigation practices to have 'more crop per drop'. Water pillow is a new irrigation method with quite high irrigation water efficiency. In this study, efficiency of water pillows irrigation method was investigated in tomato irrigation under greenhouse conditions and results were compared with drip irrigation. Amount of applied irrigation water was measured as 416.3 mm in water pillows and 798.7 mm in drip irrigation. The value in water pillows was 52% less than drip irrigation. The total yield was 360.11 t ha^{-1} in water pillows and 306.62 t ha^{-1} in drip irrigation method. Average yield per plant was 11.31 kg in water pillows and 9.63 kg in drip irrigation. The differences in yields of treatments were found to be significant ($P < 0.05$). Weed development was observed in drip irrigation, but not observed in water pillows. Physico-chemical analyses on tomatoes from water pillows and drip irrigation revealed that tomatoes irrigated with water pillows had better pH, titration acidity, brix, total dry matter and color values than the tomatoes irrigated with drip irrigation.

1. Introduction

Together with rapid increase in world population, there is an urgent need to increase crop yields to feed this ever-increasing population. Climate change and resultant global warming pose significant threats on agricultural productions. Irrigation is the primary factor in improving crop yields. Therefore, efficient water use is the greatest concern especially in arid and semi-arid climate zones.

Drip irrigation is the leading irrigation method with the most efficient water use in irrigated agriculture. Several researchers carried out studies about superiorities of drip irrigation over the other methods in cotton (Aujla et al., 2005, Hussein et al., 2011), tomato (Zhai et al., 2010), pepper (Gupta et al., 2010; Edossa and Emana, 2011), cucumber (Şimşek et al., 2005; Kirnak and Demirtas, 2006) and sugarbeet (Topak et al., 2011). Mulching significantly improves efficiency in drip irrigation. Mulch reduces evaporation from soil surface and improve water use efficiency (Li et al., 1999, 2004), prevents weed growth (Billeaud and Zajicek, 1989), keeps soil cool in summer and warm in winter (Romic et al., 2003), balances soil temperature (Farias-Larios et al., 1994), prevents soil erosion and regulates water flow within soil profile (Farias-Larios and Orozco, 1997). Besides, mulching has significant impacts on plant yield and quality. Mulching also stimulates root development (Diaz-Perez and Batal, 2002). Raina et al. (1999) investigated the effects of drip irrigation together with polyethylene mulching on tomato yield and compared the mulching treatments with furrow irrigation. While the yield was 11.95 ton ha^{-1} in furrow irrigation, the value reached to 16.63 ton ha^{-1} in drip irrigation with mulching. Similarly, while water use efficiency was 0.16 tons ha^{-1} cm^{-1} in drip irrigation, the value was observed as 0.48 tons ha^{-1} cm^{-1} in drip irrigation with polyethylene mulching. Several other previous researchers also reported that drip irrigation together with mulching improved yields and water use efficiencies in different plants (Bhella, 1988; Salman et al., 1992; Seyfi and Rashidi, 2007;

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http://dx.doi.org/10.1016/j.agwat.2016.11.012
0378-3774/

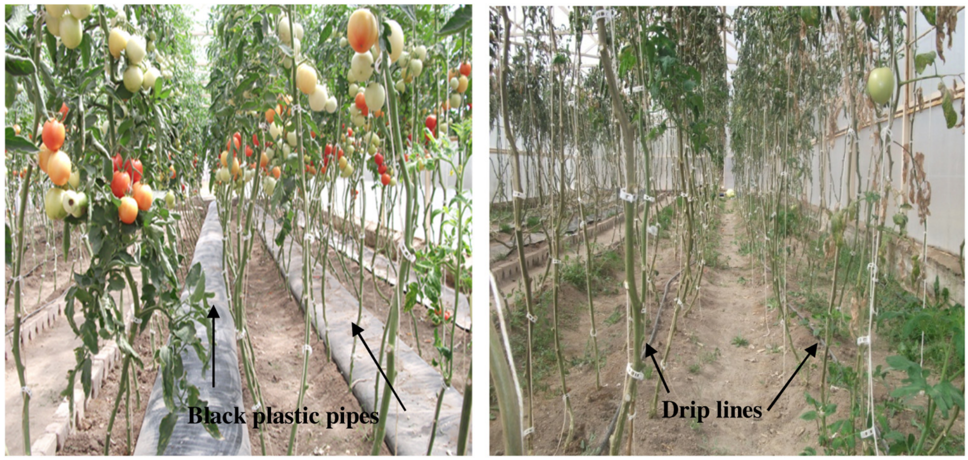

Fig. 1. Views from the experiments, the WP method on the left and the DI method on the right.

Table 1
Mean relative humidity and temperature data of the greenhouse in 2011.

Values	Months						
Climate data	April	May	June	July	August	September	November
Relative humidity, %	48.0	49.0	50.0	50.0	50.1	61.2	49.7
Mean temperature, °C	18.6	21.1	23.4	25.7	23.0	20.0	20.6

Table 2
Chemical properties of the experimental soils in 2011.

Soil depth (cm)	pH	Soil saturation (%)	EC (dS m^{-1})	Organic matter (%)	Lime $CaCO_3$ (%)	P_2O_5 (kg ha^{-1})	K_2O (kg ha^{-1})
0–30	7.46	50	0.55	3.86	8.21	6.60	28.94
30-60	7.55	58	0.33	6.41	25.79	8.60	22.90

Berihun, 2011). There are still ongoing efforts in searching for better or more efficient methods. Water pillow irrigation method with quite high water use efficiency and improved plant yield and quality is among such methods (Gerçek, 2006).

Water pillow irrigation method is a kind of combination of drip irrigation and mulching techniques. Durable and flexible plastic pipes (water pillows) are the only component of the method. Diameters of plastic pipes vary based on plant row spacing (Fig. 1). Plastic pipes, also called as water pillows, are laid between plant rows. Drip holes (1 mm in diameter) are opened along the center line of the bottom surface of the pipes in touch with soil surface. Hole spacing varies between 50 and 100 cm based on plant species. Water is filled into plastic pipes, then head and end sections are knotted tightly. Water infiltrates from the holes into the soil profile with gravity. There is no need for an extra pressure supply as it was in drip irrigation. A descending flow regime is demonstrated based on the amount of water in pillow. Since irrigation water is filled into plastic water pillows, there is no direct contact of water with soil, thus soil erosion is not experienced in this method as it was in surface irrigation methods. Although this novel irrigation method is quite similar to drip irrigation, there is no need for extra pressure for the operation of the system. Therefore, the method is quite a hybrid of pressurized irrigation and surface irrigation methods. The method bears the entire advantages of drip irrigation and mulching. Quite high yields and water use efficiencies were obtained with this method in soybean (Gerçek et al., 2009a), chili pepper (Gerçek et al., 2009b) and maize (Gerçek and Okant, 2010). Effects of the method on weeds (Bükün et al., 2005) and fungi (Urkmez, 2008) were quite satisfactory. Researches indicated that water pillow method provided improved yield and quality, better moisture and temperature values within root zone and the method was more economic than the other methods (Gerçek et al., 2009a, 2009b; Gerçek and Okant, 2010). Such findings were all obtained from field experiments and through comparisons with furrow irrigation.

The present study was conducted to investigate yield, quality and water use efficiency of tomato plants irrigated with drip and water pillow irrigation methods under greenhouse conditions and to compare water pillows method with drip irrigation.

2. Materials and methods

2.1. Experimental site

Experiments were conducted in a plastic greenhouse (20 m long, 8 m wide, polycarbonate covered) constructed over experiment fields of Erciyes University. The greenhouse is located at 38° 42′ 33″ N latitude and 35° 38′ 34″ E longitude and has an altitude of 1109 m. Experimental site (Kayseri province) has a semi-arid climate with cold and snowy winters and hot and dry summers. Summer nights are quite cool. The province has low annual total precipitation, mostly occurring in spring and autumn. According to 35-years climate data, annual average temperature is 10.4 °C, average maximum temperature is 40.7 °C in July, average minimum temperature is −31.4 °C in January and annual average total precipitation is 396 mm.

Greenhouse indoor temperature and relative humidity values were measured with a data logger (Testo Inc.) placed at mid-section of the greenhouse and 1 m above the soil surface in every half an hour (Table 1). Average temperature throughout the experiments was measured as 22.39 °C and relative humidity as 55.56%. Experimental soil had sandy-loam texture with 60.72% sand, 23.86% silt and 15.42% clay within 0–60 cm soil profile. Soil bulk density was 1.59 g cm^{-3}, field capacity was 31.11% and permanent wilting point was 17.82% (USSL, 1954). The other soil characteristics are provided