Agricultural Water Management 182 (2016) 94–102

Contents lists available at ScienceDirect

Agricultural Water Management

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

Effects of different irrigation water and nitrogen levels on the water use, rose flower yield and oil yield of Rosa *damascena*

Yusuf Ucar[a,*], Soner Kazaz[b], Figen Eraslan[c], Hasan Baydar[d]

[a] Department of Agricultural Structure and Irrigation, Faculty of Agriculture, Süleyman Demirel University, 32260 Isparta, Turkey
[b] Department of Horticulture, Faculty of Agriculture, Ankara University, 06110 Dışkapı, Ankara, Turkey
[c] Department of Soil Science and Plant Nutrition, Faculty of Agriculture, Süleyman Demirel University, 32260 Isparta, Turkey
[d] Department of Field Crops, Faculty of Agriculture, Süleyman Demirel University, 32260 Isparta, Turkey

ARTICLE INFO

Article history:
Received 22 June 2016
Received in revised form
21 November 2016
Accepted 8 December 2016

Keywords:
Oil rose
Rosa *damascena*
Evapotranspiration
Water use efficiency
Yield response factor

ABSTRACT

This study aimed to determine the effects of different irrigation water amounts and nitrogen doses on flower and oil yields and water use in Rosa *damascena* in Isparta which is located in the Mediterranean Region of Turkey. Different water and nitrogen doses were applied to the Rosa *damascena* plant, and the drip irrigation method was used at 10-day intervals. The treatments included four different irrigation water amounts [T_0 (k_{cp0}: 0.00), T_1 (k_{cp1}: 0.40), T_2 (k_{cp2}: 0.80), and T_3 (k_{cp3}: 1.20) as crop-pan coefficients] and four different nitrogen doses (N_0:0 kg ha^{-1}, N_1: 80 kg ha^{-1}, N_2: 160 kg ha^{-1}, N_3: 240 kg ha^{-1}, and pure substance). The experiment was conducted in a randomized block factorial design with 3 replicates. The seasonal evapotranspiration, water use efficiency, irrigation water use efficiency and yield response factor (k_y) varied between 346.2 and 614.7 mm, between 4.87 and 13.86 kg m^{-3}, between 8.05 and 32.18 kg m^{-3}, and between 0.92 and 1.59, respectively. The different irrigation water amounts and nitrogen doses did not have a significant effect on flower yield in 2010, but had a significant effect ($P < 0.01$) in 2011 and 2012. The flower yield ranged from 2339 to 3046 kg ha^{-1}, 2215 to 6373 kg ha^{-1}, 2104 to 6616 kg ha^{-1} in 2010, 2011 and 2012, respectively. Similarly, the effects of different irrigation amounts and nitrogen doses on the rose oil yield were significant in 2011 and 2012 ($P < 0.01$) but not in 2010. The rose oil yield was 1.10–1.66 kg ha^{-1}, 1.13–3.42 kg ha^{-1}, 0.72–2.89 kg ha^{-1} in 2010, 2011, and 2012, respectively. The results of this study showed that the increasing irrigation water amounts and nitrogen doses significantly increased the flower yield. Considering yield and water use efficiency, it was concluded that the most efficient irrigation scheduling was T_1 and that the most efficient nitrogen doses were N_2 and N_3.

1. Introduction

Roses have significant potential in the food, perfumery, and cosmetics industries as well as the ornamental plant sector (Guterman et al., 2002; Jabbarzadeh and Khosh-Khui, 2005; Senapati and Rout, 2008). The genus Rosa comprises more than 200 species; nevertheless, only a few of them have been utilized as essential oil crops (Kovacheva et al., 2010). The most important of the four main rose species (Rosa *damascena* Mill., Rosa *gallica* L., Rosa *moshata* Herrm, and Rosa *centifolia* L.) used in essential oil production worldwide is Rosa *damascena* (Tucker and Maciarello, 1988; Kovacheva et al., 2010).

Although Rosa *damascena* is cultivated in Iran, India, Morocco, Southern France, China, Southern Italy, Libya, Southern Russia, and the Ukraine, its main producers are Turkey and Bulgaria (Rusanov et al., 2009). The cultivation of Rosa *damascena* is considerably higher in the Turkish Lakes District (Isparta and Burdur Provinces) and in the Bulgarian Kazanlak District. Rosa *damascena* has been cultivated as 'Isparta Rose' in Turkey since 1888 (for 120 years) but as 'Kazanlak Rose' in Bulgaria since 1664 (for 340 years), and the oils obtained from this rose species are known as 'the Turkish rose oil' and 'the Bulgarian rose oil' in the global markets (Baydar, 2006). Rose oil is one of the most valuable raw materials of the perfumery, cosmetics, and pharmaceutical industries. Rose oil and rose concrete are mainly utilized by large perfumery and cosmetic firms. The annual production of oil rose is 15,000 kg worldwide, and the

* Corresponding author.
E-mail addresses: yusufucar@sdu.edu.tr (Y. Ucar), Soner.Kazaz@ankara.edu.tr (S. Kazaz), figeneraslan@sdu.edu.tr (F. Eraslan), hasanbaydar@sdu.edu.tr (H. Baydar).

http://dx.doi.org/10.1016/j.agwat.2016.12.004

main producers of oil rose are Bulgaria and Turkey, which account for 85% (6750 kg) of the global oil rose demand (Anonymous, 2015).

Numerous studies have investigated the physical and chemical properties of rose oil have been conducted (Staikov et al., 1975; Garnero et al., 1976; Lawrence, 1992). However, these studies have particularly focused on the harvesting hours and retention time (Kazaz, 1997) as well as on the physical and chemical properties of rose oil (Anaç, 1984; Başer et al., 1990; Başer, 1992; Bayrak and Akgül, 1994; Usta et al., 1994; Kürkçüoğlu, 1995; Kazaz, 1997; Baydar and Baydar, 2005; Tabaei-Aghdaei et al., 2007; Kumar et al., 2013; Rusanov et al., 2013). Many studies have also investigated the composition of the rose oil. However, studies related to irrigation and fertilization of Rosa *damascena* are limited. Popov et al. (1968) in Bulgaria, Tajuddin et al. (1995) in India, Şengün (1998) in Turkey and Joshi et al. (2002) and Daneshkhah et al. (2007) in Iran have studied about the effects of fertilization on Rosa *damascena*. However, to our knowledge, no studies have focused on irrigation, except for the studies by Ganchev (1976) and Nedkov et al. (2014) that investigated the effects of irrigation water amounts and sprinkler and furrow irrigation methods on oil rose plant.

In Turkey, Rosa *damascena* plantations are generally established on sloping areas far from water resources. This prevents the irrigation of earlier oil rose plantations. However, in the recent years, the majority of the Rosa *damascena* plantations have been established in irrigable lands, and these plantations are irrigated (Baydar and Kazaz, 2008). In recent years, global warming and irregular rainfall are reported to have caused an increase in the use of drip irrigation for oil rose cultivation in Bulgaria (Kovacheva et al., 2010).

The application of irrigation in the cultivation of Rosa *damascena* has gradually increased, however, scientific research on this subject is limited, rendering it difficult for farmers to reach decisions regarding cultivation. In addition, despite the availability of studies on the effect of nitrogen application, no researchers have investigated the combined effects of irrigation and nitrogen. This study aimed to determine the effects of different irrigation water amounts and nitrogen doses on the flower and oil yields, water-yield functions, water use efficiency (WUE), and seasonal evapotranspiration of Rosa *damascena*.

2. Material and method

2.1. Features of the study area

The research was conducted on the oil rose plantation located at the Agricultural Research and Application Center at the Süleyman Demirel University. The research area is located at latitude 37.83° N, longitude 30.53° E, and an altitude of 1020 m and has a semi-arid climate characteristic. The long-term and the growing season climatic data (2010–2012) of the experimental area are shown in Table 1.

The soil of the experimental area is classified as clay-loam texture, and its available soil water content in the upper 150 cm of the soil depth is 233.54 mm (Table 2). The bulk density was determined to be between 1.30 g cm^{-3} and 1.42 g cm^{-3}. Furthermore, the infiltration rate of the soils is 15.5 mm h^{-1}.

The experimental plots had an area of 10 m^2 with dimensions of 1 × 10 m and a 2-m space (non-irrigated and unfertilized) between the plots. Irrigation water was provided using the drip irrigation method. The in-line type lateral with diameter 16 mm was used, and each plant row was irrigated by two lateral tubes (Fig. 1). According to the infiltration rate of the soil (15.5 mm h^{-1}), the emitter spacing was selected as 0.50 m and the emitter discharge as 4 l h^{-1} above 1 atmospheric pressure. Thus, the ratio of the wetted area was determined as 33% according to Keller and Bliesner (1990).

2.2. Irrigation water and nitrogen applications

The experiment was performed in a the randomized block factorial experimental design with 3 replicates. The experiments consisted of four irrigation water amounts and four nitrogen doses.

Irrigation water with a sodium absorption ratio (SAR) of 0.055 and the electrical conductivity (EC) of 0.73 dS m^{-1} is classified as C_2S_1 (Richards, 1954). The evaporation was measured using a Class A Pan (CAP) located within a weather station about 200 m away from the experimental area. The irrigation water amounts were estimated in millimeters by using Equation (1). The irrigation water amounts applied were 0.00 (T_0:k_{cp0}), 0.40 (T_1:k_{cp1}), 0.80 (T_2:k_{cp2}),

Table 1
Some climatic parameters of the vegetation periods in the study area.

CP	Long term					2010					2011					2012	
	Month																
	5	6	7	8	9	5	6	7	8	9	5	6	7	8	9	5	6
T	15.5	20.1	23.4	22.9	18.3	17.1	19.2	24.7	27.1	20.6	14.4	19.8	25.0	24.5	20.3	14.7	22.9
RH	58	52	48	50	55	55	63	50	38	52	65	57	42	38	41	64	44
WS	1.9	1.9	1.8	1.6	1.6	2.0	2.0	1.8	1.8	1.8	2.1	2.0	2.0	2.0	1.6	1.9	1.9
E	153	201	245	226	169	65	100	205	258	148	95	122	259	251	181	61	141
P	46.0	27.5	12.8	12.9	15.4	32.4	64.5	40.1	0.2	29.7	43.1	62.2	1.8	0.6	13.2	107.4	18.1

CP: Climatic parameters, T: Mean temperature, °C; RH: Average relative humidity, %; WS: Wind speed, m h^{-1}; Evaporation from Class A Pan, mm; Precipitation, mm.

Table 2
Some physical and chemical properties of the soils in the experimental area.

Layer cm	T	BD	FC*		WP*		AWHC		EC*	pH*	Lime	OM
		g cm^{-3}	%	mm	%	mm	%	mm			%	%
0–30	CL	1.30	26.39	102.79	15.76	61.39	10.63	41.40	106	7.86	30.65	1.62
30–60	CL	1.42	25.74	109.30	14.50	61.57	11.24	47.73	110	8.25	31.18	1.98
60–90	CL	1.33	27.09	108.35	16.65	66.61	10.43	41.74	122	8.19	31.56	1.53
90–120	CL	1.36	26.67	108.59	15.66	63.77	11.01	44.82	170	8.43	32.71	2.02
120–150	CL	1.33	27.30	108.93	12.80	51.07	14.50	57.86	135	8.20	32.44	1.47
Total (0–120 cm) (Root zone)				**429.03**		**253.35**		**175.68**				
Total (0–150 cm)				**537.96**		**304.42**		**233.54**				

T: Texture; BD: Bulk density; FC: Field capacity; WP: Wilting point; AWHC: Available water holding capacity, OM: Organic material; *EC and pH were determined in 1:2.5 soil/water mixtures by means of glass electrode EC and pH meters; *Field capacity and wilting point were determined as a gravimetric method.