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WATER CONSUMPTION OF OIL ROSE (ROSA DAMASCENA MILL.) IN ISPARTA CONDITIONS

Abdullah Kadayifci, Ulas Senyigit, Kahraman Kepenek
Suleyman Demirel University in Isparta

Summary

This study was carried out at the rose garden established in the Deregumu region of Isparta province in Turkey in 2014. In the experiment, the effects of deficit irrigation applications with different techniques (Traditional deficit irrigation; TS: Full irrigation; GKS-75, GKS-50, GKS-25, GKS-0 and partial root zone drying; YIS:) and protection nets with different shading ratios (A: Non-covered, A-1: Shading ratio 75% and A-2: Shading ratio 35%) on the seasonal water consumption of the Isparta oil rose were determined and crop coefficient values (k_c) were acquired according to the reference plant water consumption estimation method (Radiation FAO modification) that can be used in the region conditions. The highest irrigation water amount and the highest plant water consumption values were determined in the TS treatments during the experiment. Approximately % 20 and % 24.4 less irrigation water was applied to A-1: and A-2 treatments in comparison with the A treatment and similarly an average of 16 % and 17% decrease in plant water consumption was realized.

Key words*:* Oil rose, deficit irrigation, plant water consumption, crop coefficient

INTRODUCTION

Requirement for essential oils in the world gradually increases. Rose oil has an important place within these kinds of oils as one of the basic raw materials of perfume and cosmetics industry. The most important type of rose which has been cultivated in order to extract oil and which has an economical value is the *Rosa damascena Mill.* which is also known as "oil rose". Turkey is the top producer of the odorous rose type and the obtained rose oil worldwide. Turkey meets approximately 70% of the rose oil production of the world. Almost all production areas are available in Isparta, Afyon, Burdur and Denizli. Especially Isparta and its surrounding has achieved the condition of the most important oil rose production center of not only Turkey but also the world (Timor, 2011). Rose oil obtained from Isparta region which is known as the rose garden of Turkey and its surrounding is recently in competition with the price of gold with its 7 thousand euro price per kilogram.

The annual average rainfall of Isparta is 520 mm and only 162 mm (% 31) of this amount falls during the months of May and October. Accordingly, the region has a semi-arid climate and irrigation is vital for an effective plant cultivation in the region. However, the number of producers who make conscious irrigation for rose cultivation in the region is very low. The rose producers in the region generally start irrigation following the rains in April. They complete the harvest within 5-6 weeks in mid-May and after the harvest irrigation is done another 1-2 time more and irrigation is terminated. In addition, irrigation practices are still performed using primitive methods in the region and generally flood irrigation methods which have a very low efficiency were preferred. A small number of producers use furrow and drip irrigation methods.

Pollution of water sources as a result of rapidly increasing population, industrialization and urbanization and aridness that occurs due to the global warming are among the most important factors that limit the water amount spared for irrigation as well as the plant growth in agricultural areas along with plant production. This situation has forced irrigation engineers for research to direct to seek new irrigation techniques that use water more efficiently and to determine the criterion for these techniques.

Plant water consumption is used as a fundamental data related with studies on hydrology, meteorology, plant physiology and soil science, in the determination of the irrigation water requirement for plants, preparation of the irrigation schedule, determine the requirement of supplementary irrigation as well as the surveying and feasibility studies of irrigation projects and their planning, execution, management and maintenance (Kodal, 1982). Even though direct measurement methods are the best methods for determining plant water consumption values, estimation methods based on climate data are used since the aforementioned methods are costly and time consuming. Whereas direct measurement methods are mostly used for the calibration or modification of empirical equations in regional conditions (Burman et al., 1983). The way generally followed in the plant water consumption estimation methods based on climate parameters is to estimate the reference or potential water consumption for alfalfa or grass plants reflected specific conditions and to calculate the plant water consumption correcting the values obtained from the estimation method used with plant–specific crop coefficient (Doorenbos and Pruitt, 1984; Jensen et al., 1989). Plant water consumption estimation methods generally do not give reliable results in the regions with different climatic condition in where they were made, if regional calibrations have not been made (Christiansen, 1968, Jensen et al., 1989). Moreover, the method to be used may also be different when the plant variety changes in the same region. Although many studies have been researched both in the world and in Turkey on seasonal water consumption and irrigation scheduling for many different plants and rose has been cultivated in Isparta for over 100 years, there is almost no research on this topic in Isparta rose.

The objective of this study was to determine the effects of deficit irrigation applications with different techniques (partial root zone drying and traditional deficit irrigation) and excessive rain and hail protection nets with different shading ratios on the seasonal water consumption of Isparta rose and to obtain the crop coefficient values (k_c) related with the reference plant water consumption estimation method that can be used for irrigation scheduling in the region conditions.

MATERIAL AND METHODS

The study was carried out at the rose garden established at the Deregümü region of the city of Isparta in Turkey at an altitude of 1095 m between latitude $37^{o}\ 47^{I}\ 17^{II}$ N and longitude $30^{o}\ 30^{I}\ 32^{II}$ E. The garden that was established in 2005 has dimensions of 4860 m^2 (45 m x 108 m). Some soil properties related to irrigation of the experimental area were determined in accordance with Tuzuner (1990) and the results were given in Table 1. Accordingly, soil of experimental area was loamy-sand and the soil that was deep with no drainage and salinity issue. The infiltration rate of the experiment area soil was measured using double cylinder infiltrometer according to Gungor and Yildirim (1989) and the stable infiltration rate was determined as 21 mm/h.

Table 1. Some physical properties of the soil in the experimental area

Soil Depth (cm)	Structure	Bulk density (gr cm^{-3})	Field capacity (%)	Wilting point (%)	Available soil water content (mm)
0-30	LS	1,4	16,45	7,72	36,7
30-60	LS	1,4	16,79	7,74	38,0
60-90	LS	1,4	16,72	6,42	43,3

Since the experiment area is located inside the Lakes Region, there is a transition between the continental climate of Central Anatolia and the Mediterranean climate. In terms of rainfall regime, it is similar to the Mediterranean climate, however in terms of temperature regime summers are dry and hot whereas winters are cold and harsh as the climate of Central Anatolia. The average temperature of the region is 12.1 ^{0}C, the average relative humidity is 62% and the average rainfall amount is 524 mm (TSMS, 2012).

The Isparta rose (*Rosa damascena*) in the experiment garden is a cross-breed of Rosa gallica and Rosa moschata species. It has a pink color, semi-layered with a strong scent, perennial, thorny plant with strong winter resistance (Kazaz, 1997).

The experiment plot was divided into three blocks and 1/3 had relatively higher shading ratio (75%, dense), 1/3 had relatively low shading ratio (35%, sparse) nets and 1/3 was left non-covered. Treatments were arranged on the field by the strip plot design in random blocks with three replications. The protection net plots were setup overlap with the main parcels and the irrigation plots were setup overlap with the submain parcels. 3 m space was left between the plots. Details of an irrigation plot were given in Figure 1. A treatment plot was 12 x 6 m and a harvest parcel was 9 x 6 m.

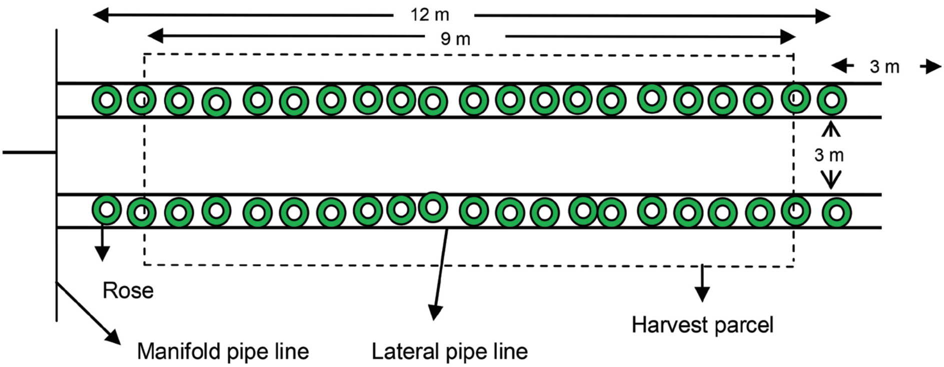

Figure 1. Details of an irrigation plot

Irrigation treatments: TS: Irrigation water was applied as required amount that made available moisture reach to field capacity when about 50% of available soil water was depleted at the effective root depth (full irrigation); GKS-75: 75% of the applied irrigation water amount in TS; GKS-50: 50% of the applied irrigation water amount in TS; GKS-25: 25% of the applied irrigation water amount in TS; (Traditional deficit irrigation), GKS-0: non-irrigated and YIS-50: 50% of the applied irrigation water amount in TS was applied consecutively on one side of the rows with leaving the other side unirrigated and the irrigated side was changed every irrigation (Partial root zone drying).

Net treatments: A: Plot was no covered with excessive rain and hail protection nets (Control), A-1: Plot was covered with excessive rain and hail protection nets which had khaki colored and relatively high shading ratio (shading ratio 75%) and A-2: Plot was covered with excessive rain and hail protection nets which had khaki colored and relatively low shading ratio (shading ratio 35%).

Profile-Probe device was used in the experiment to measure the soil moisture. Access tubes were placed to all experiment plots for readings. Calibration was made via gravimetric moisture measurements for experiment soil conditions in order to determine the current moisture in m^3/m^3 at different depths (10, 20, 30, 40, 60 and 100 cm) using the Profile-Probe device. The m^3/m^3 values read from the device and the volumetric moisture values obtained from the field with sampling (m^3/m^3) were graphed (Figure 2) and the equation related to linear relationship (R^2=0,902, p<0,01, Sx=0,0068, RMSE=0,0438) between them were obtained (Equation 1).

$$P_v = 0{,}464\,\Delta T + 13{,}94 \quad (1)$$

Where, Pv is the soil moisture ($m^3\ m^{-3}$) and ΔT is the measured value from profile-probe device ($m^3\ m^{-3}$).

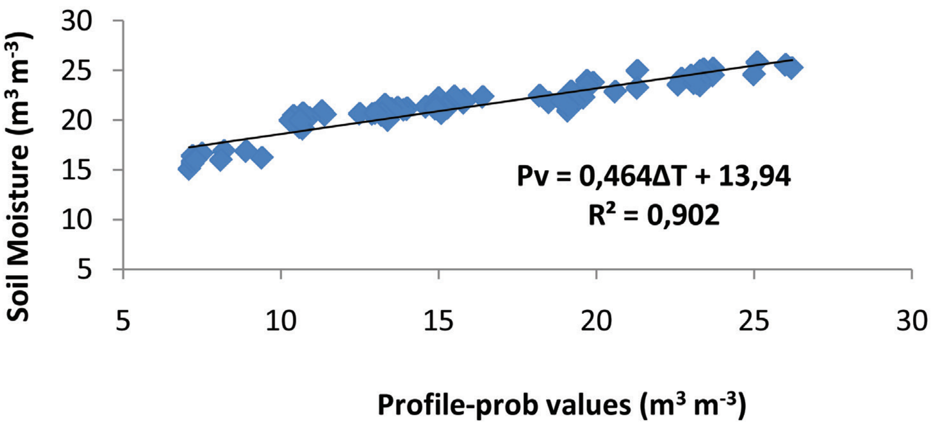

Figure 2. Calibration curve of profile-probe device

In the experiment, irrigation water was delivered from a pool close to the field that belongs to the farmer by a pump and the irrigation was applied with drip irrigation system. The engineering properties and operating principles of the system were arranged according to Kanber (2010). Accordingly, the water that was taken to the main pipe line (Φ75 PE) was sent to the plants within the plots by manifold (Φ50 PE) and lateral pipes (Φ16 soft PE). Laterals were placed on the plots with 4 L/h dripper flow rate and 50 cm dripper interval as two laterals for each plant row. In addition, small valves were installed in each plot for control of applied water. Irrigation started on June 10, 2014 and the final irrigation was done on September 10, 2014. Irrigation was not done in the first 10 days of May and June due to the fact that rain was sufficient. Irrigation was performed according to the average moisture amount measured in the 0-60 cm effective root depth of the soil in TS treatment located in the A, A-1 and A-2 plots. Irrigation water amounts were controlled using the water meter in the system.

During the experiment, frequent measurements were made using the Profile-Probe device so as to ensure that the irrigation times would not pass the period when 50 % of the available water capacity was consumed. Applied irrigation water amount was calculated using equation 2 (Gungor and Yildirim, 2004).

$$I=(FC-AW)/100)x\gamma_t xDxP \qquad (2)$$

In the equation; *I,* irrigation water (mm),*TK*, field capacity (%), *AW, available moisture* (%), γ_t, bulk density (g cm^{-3}), *D*, root depth (mm) and *P,* percentage of wetted area (33%). Plant water consumption for the treatments were calculated using the water balance method (Equation 3) given below according to the soil moisture values measured by Profile-Probe at soil depths 0-10, 10-20, 20-30, 30-40, 40-60 and 60-100 cm before and after each irrigation (James 1988).

$$ETc=I+P-D_p+C_p\pm R_f\pm\Delta S \qquad (3)$$

Where, *ETc* is the plant water consumption (mm), *I* is the irrigation water (mm), *P* is the precipitation (mm), *Cp* is the capillary rise (mm), *Dp* is the water loss by deep percolation (mm), *Rf* is runoff loss (mm) and *ΔS* is the change in the soil water content (mm). In the experiment area, since there was no capillary water entrance from the water table and runoff loss due to the drip irrigation method, Cp and Rf values were neglected in the calculations. The increase in the soil water below the effective root depths (60-100 cm) was accepted as drained water. The plant water consumption values obtained using the equation 3 for the wetted area inside the plots were transformed into plant water consumption values that represent the total area by Equations 4, 5 and 6 described by Allen et al. (1998).

$$ETc\ adj = ks\ x\ kc\ x\ ETo \qquad (4)$$

$$ks = (TAW-Dr)/(TAW-RAW)\ for\ Dr>RAW \qquad (5)$$

$$ks = 1\ for\ Dr<RAW \qquad (6)$$

Where, *ETc adj* is the adjusted plant water consumption (mm), *ks* is the water stress coefficient, *kc* is the crop coefficient, *ETo* is the reference plant water consumption (mm), *Dr* is the root zone depletion (mm), *RAW* is the readily available water (mm) and *TAW* is the total available water (mm).

Reference plant water consumptions were calculated with Penman Monteith (P-M), Original Penman (P-O), Penman FAO modification (P-FAO), Priestley Taylor (PT), Radiation FAO modification (R-FAO), Blaney-Criddle FAO modification (BC-FAO), SCS Blaney-Criddle (BC-SCS), Hargreaves (H), FAO modification of the Pan Evaporation (CAP) and Net Radiation (Net-R) methods described by Doorenbos and Pruitt (1977), Jensen et al (1989), Smith (1991) and Jensen (1973) using the CROPWAT and IAM.ETo computer software according to 2014 year climate data.

Relationships between the calculated plant water consumption values and the estimated reference plant water consumption values were determined; crop coefficient (k_c) values in accordance with the reference plant water consumption estimation equation that can be used in the region conditions were obtained and in this regard curves were plotted.

Table 2. Total plant water consumption and irrigation water amount

Treatments	Irrigation water amount, mm	Plant water consumption, mm	
		ETc	ETc adj
		A	
TS	623,0	839,5	814,8
GKS-75	467,3	729,8	714,2
GKS-50	311,5	531,9	516,9
GKS-25	155,8	442,0	434,5
GKS-0	30,0	219,2	219,2
YIS-50	311,5	547,0	547,0
		A-1	
TS	469,0	688,9	660,8
GKS-75	351,8	566,4	563,7
GKS-50	234,5	447,1	447,1
GKS-25	117,3	317,2	317,2
GKS-0	28,2	218,0	218,0
YIS-50	234,5	462,9	462,9
		A-2	
TS	498,4	709,8	678,0
GKS-75	373,8	600,7	599,1
GKS-50	249,2	418,9	418,9
GKS-25	124,6	334,1	334,1
GKS-0	28,6	218,2	218,2
YIS-50	249,2	450,1	450,1

Table 3. Plant water consumption values for 10 days in the treatments (mm per day)

Date	Treatments					
	TS	**GKS-75**	**GKS-50**	**GKS_25**	**GKS-0**	**YIS-50**
			A			
1-10 May	2,2	2,2	2,2	2,2	2,2	2,2
11-20 May	3,3	3,3	3,3	3,3	3,3	3,3
21-31 May	3,8	3,8	3,8	3,8	3,8	3,8
1-10 June	4,0	4,0	4,0	4,0	4,0	4,0
11-20 June	5,0	5,1	4,8	4,0	3,1	3,5
21-30 June	7,0	5,3	3,4	3,9	0,6	3,5
1-10 July	7,2	5,8	4,8	3,7	0,3	3,7
11-20 July	6,9	6,4	3,3	2,7	0,7	4,6
21-31 July	10,4	7,9	5,2	1,9	0,3	5,5
1-10 August	7,2	7,4	4,2	4,0	0,8	4,7
11-20 August	7,4	6,6	6,5	3,0	0,6	3,8
21-31 August	5,6	3,9	3,0	2,1	0,4	3,1
1-10 September	6,7	5,4	2,4	2,5	1,5	4,1
11-20 September	5,6	4,9	1,5	2,7	0,3	4,1
			A-1			
1-10 May	2,0	2,0	2,0	2,0	2,0	2,0
11-20 May	2,7	2,7	2,7	2,7	2,7	2,7
21-31 May	3,0	3,0	3,0	3,0	3,0	3,0
1-10 June	3,9	3,9	3,9	3,9	3,9	3,9
11-20 June	5,0	3,3	3,3	2,3	2,8	3,5
21-30 June	5,9	5,4	3,7	2,3	2,7	5,2
1-10 July	6,0	5,5	3,9	3,3	0,9	3,3
11-20 July	4,9	4,5	2,6	1,4	0,2	2,6
21-31 July	7,6	6,4	4,1	1,7	0,4	4,2
1-10 August	5,3	3,1	3,0	2,3	0,4	3,3
11-20 August	8,1	6,1	4,2	1,5	0,6	4,4
21-31 August	4,0	3,8	3,0	1,7	0,6	3,2
1-10 September	4,5	2,5	1,2	0,3	0,6	1,9
11-20 September	5,1	3,9	3,9	3,0	1,0	2,6
			A-2			
1-10 May	2,2	2,2	2,2	2,2	2,2	2,2
11-20 May	3,0	3,0	3,0	3,0	3,0	3,0

Date	Treatments					
	TS	GKS-75	GKS-50	GKS_25	GKS-0	YIS-50
			A-2			
21-31 May	3,2	3,2	3,2	3,2	3,2	3,2
1-10 June	3,7	3,7	3,7	3,7	3,7	3,7
11-20 June	4,6	4,3	2,1	2,1	2,0	2,2
21-30 June	4,6	4,2	2,1	1,6	0,7	2,0
1-10 July	5,7	4,9	2,5	2,1	0,6	3,7
11-20 July	5,7	5,2	2,7	1,8	0,5	4,1
21-31 July	8,3	6,2	4,2	3,2	0,4	4,0
1-10 August	6,5	5,1	2,7	2,2	0,4	3,5
11-20 August	6,6	6,5	5,4	2,5	0,8	3,6
21-31 August	5,1	3,4	2,9	2,3	0,5	3,2
1-10 September	4,6	2,5	1,6	1,4	0,9	2,1
11-20 September	6,0	4,6	3,1	1,5	2,2	3,8

Table 4. Some climate parameters for 10 days related to 2014 experimental year

Date	Mean Temp. C°	Max. Temp. C°	Min. Temp. C°	Mean RH %	Max. RH %	Min. RH %	Mean Wind Speed $m\ s^{-1}$	Mean Sunshine duration h	Total Rain mm	Mean Evaporation mm
1-10 May	12,7	21,5	4,2	67	91	38	2,6	5,4	75,6	3,2
11-20 May	14,8	23,8	4,8	58	80	25	2,6	9,0	1,6	5,3
21-31 May	17,5	27,3	6,9	57	89	28	2,3	9,1	29,8	5,3
1-10 June	15,8	26,3	8,3	65	85	37	2,0	5,9	36,0	5,0
11-20 June	20,5	30,3	9,6	48	79	27	2,0	9,6	6,2	6,4
21-30 June	23,5	24,8	10,5	37	58	18	2,0	11,0	0,6	8,2
1-10 July	25,1	34,2	12,4	40	65	22	2,1	11,1	-	8,5
11-20 July	23,9	32,8	14,7	47	64	26	2,5	10,5	-	8,9
21-31 July	24,7	34,9	14,1	44	66	18	2,1	11,0	0,8	8,1
1-10 Aug	23,0	31,2	11,5	53	92	28	2,1	9,5	3,2	7,6
11-20 Aug	24,9	36,9	14,6	45	83	19	1,6	9,9	6,4	7,6
21-31 Aug	25,7	36,8	15,3	41	76	18	1,6	10,0	-	7,6
1-10 Sept	20,6	31,2	12,0	63	91	23	1,8	8,4	9,2	5,8
11-20 Sept	17,8	28,1	9,1	64	94	33	1,4	7,9	31,0	4,5

Table 5. Reference plant water consumption values calculating with estimation methods

Date	P-M	P-O.	P-FAO	PT	R-FAO	BC-FAO	BC-SCS	H	CAP	Net-R
1-10 May	2,2	2,7	2,9	2,8	3,0	2,6	2,6	4,0	2,3	3,5
11-20 May	2,7	3,4	3,7	3,4	4,5	3,8	2,9	4,4	3,6	4,2
21-31 May	2,9	3,7	4,0	3,7	4,7	4,2	3,5	5,0	3,7	4,4
1-10 June	2,5	3,2	3,4	3,2	3,6	3,4	3,6	4,7	3,5	3,7
11-20 June	3,1	4,1	4,4	4,1	5,3	4,9	4,3	5,5	4,4	4,6
21-30 June	3	4,2	4,3	3,9	6,0	5,1	3,7	4,3	5,2	4,6
1-10 July	3,5	4,7	4,9	4,5	6,4	6,2	5,3	6,2	5,6	4,9
11-20 July	3,5	4,7	4,9	4,5	6,2	6,0	5,4	5,7	5,9	4,8
21-31 July	3,6	4,9	5,1	4,7	6,6	6,6	5,7	6,3	5,2	4,9
1-10 Aug	3,4	4,3	4,7	4,4	5,3	5,2	4,8	5,7	5,4	4,9
11-20 Aug	3,6	4,8	5,3	4,8	6,1	6,6	6,1	6,8	5,1	5,0
21-31 Aug	3,6	4,9	5,3	4,8	6,3	6,7	6,2	6,7	5,0	4,9
1-10 Sept	3,2	4,2	4,6	4,2	5,0	5,3	4,9	5,8	4,0	4,6
11-20 Sept	3,1	3,8	4,1	4	4,5	4,2	4,1	5,3	3,2	4,5

RESULTS AND DISCUSSION

The total applied irrigation water amount for the treatments and the obtained plant water consumption values for the wetted area were given in Table 2. The average plant water consumption values for 10 days were also given in Table 3. As seen from Tables 2, the highest amount of irrigation water was applied to TS treatment and the highest plant water consumption was also determined in the same treatments. Less irrigation water was given in treatments established in the sparse covered and dense covered areas compared with the treatments established in the non-covered areas average 20% and 24,4%, respectively. Covering material affected the plant water consumption values in the treatments. A decrease of % 16 and % 17 on average occurred in the total plant water consumption in non-covered areas compared with the sparse and dense covered areas, respectively.

Some climate parameters for 10 days of the experimental area related to 2014 experimental year were given in Table 4. During the experiment period, strong rain was observed on 10th of May 2014 with 23,4 mm and 15 minute ineffective hail was observed on 5th of June 2014.

Calculated reference plant water consumption values by different estimation methods were given in Table 5. Radiation FAO modification method was common used for reference plant water consumption (ETo) calculations in the studies carried out under Ankara, Adana and Isparta condition (Koksal et al., 2000; Unlu, 2000; Senyigit, 2008). Since Isparta is located in the Lakes region and has a transition climate between the Mediterranean and the Central Anatolia continental climate conditions although it has a semi-arid climate, crop coefficients (kc) were determined according to the reference plant water consumption calculated with Radiation FAO modification method and ETc values obtained from TS treatments in non-cover, sparse covered and dense covered areas. The curves of the crop coefficients for R-FAO were shown in Figure 3.

As a result, the crop coefficients values obtained from the study for R-FAO water consumption estimation methods can be suggested to use in irrigation scheduling of oil rose which has widespread cultivation in Isparta region.

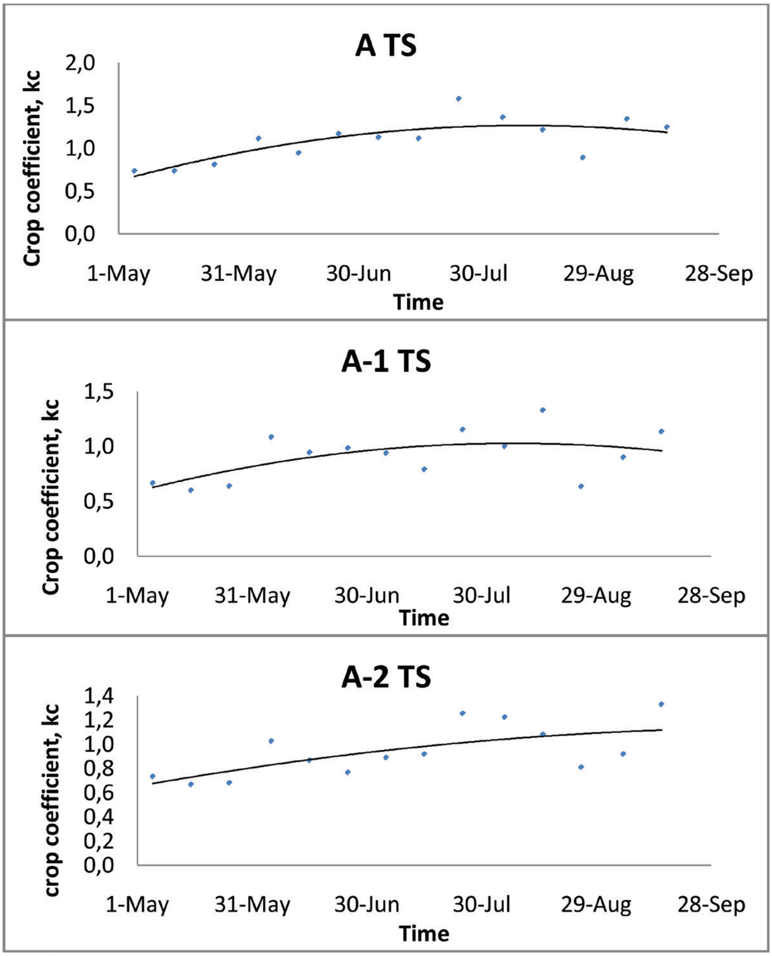

Figure 3. Crop coefficient curves for R-FAO method in different net treatments

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Assoc. Prof. Abdullah Kadayifci
Suleyman Demirel University,
Technical Education Faculty,
32260 Isparta, Turkey

Assoc. Prof. Ulas Senyigit,
Suleyman Demirel University,
Faculty of Agriculture,
Agricultural Structures and Irrigation Department,
32260 Isparta, Turkey

PhD Kahraman Kepenek
Suleyman Demirel University,
Faculty of Agriculture,
Biotechnology Department,
32260 Isparta, Turkey

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