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Empirical Models Likely to Be Used to Estimate the Evapotranspiration of Oil Rose (Rosa *damascena* Mill.)

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Abstract: This study was carried out to determine the most suitable evapotranspiration estimate method of oil rose (Rosa *damascena* Mill.) at the Agricultural Research and Application Center at Süleyman Demirel University in 2010 and 2011. Irrigation was performed every 10 days, and irrigation water as much as 1.2 times of evaporation measured from the Class A Pan in the ten-day period was applied. Evapotranspiration was measured for ten-day periods through controlling the decrease in the soil moisture. The measured evapotranspirations were compared with Penman-Monteith, Original Penman, FAO-modified Penman, Priestly-Taylor, FAO-modified Radiation, FAO-modified Blaney-Criddle, SCS Blaney-Criddle, Hargreaves, FAO-modified Pan Evaporation, and Net Radiation methods out of the evapotranspiration estimation methods. The correlation coefficient (r), root mean square error (RMSE) and seasonal average crop coefficient (Kc) of the correlation between the measured evapotranspiration and estimated evapotranspiration values were taken into consideration in the comparison. As a result of the research, the closest evapotranspiration estimation for the experimental conditions was made with the Priestly-Taylor method.

Key words: Crop coefficient, evapotranspiration, Priestly-Taylor, Rosa *damascena* Mill.

Yağ Gülünün (Rosa *damascena* Mill.) Bitki Su Tüketimi Tahmininde Kullanılabilecek Amprik Modeller

Özet: Bu çalışma yağ gülünün (Rosa *damascena* Mill.) bitki su tüketimi tahmininde kullanılabilecek en uygun tahmin eşitliğini belirlemek amacıyla Süleyman Demirel Üniversitesi Tarımsal araştırma ve uygulama merkezinde 2010 ve 2011 yıllarında yürütülmüştür. A sınıfı buharlaşma kabından 10'ar günlük periyotta gerçekleşen buharlaşma toplamının 1.2 katı kadar sulama suyu uygulanmıştır. Bitki su tüketimi 10'ar günlük periyotlarda toprak nemi izlenerek belirlenmiştir. Ölçülen bitki su tüketimi, bitki su tüketimi tahmin yöntemlerinden Penman-Monteith, orjinal Penman, modifiye FAO-Penman, Priestly-Taylor, modifiye FAO-Radiation, FAO-modified Blaney-Criddle, SCS Blaney-Criddle, Hargreaves, modifiye FAO-Pan Evaporation, ve net radyasyon yöntemleri ile karşılaştırılmıştır. Ölçülen bitki su tüketimi ile bitki su tüketimi tahmin yöntemleri arasındaki ilişkinin karşılaştırmada korelasyon katsayısı (r), hata kareler ortalaması, (RMSE), sezonluk ortalama bitki katsayısı (Kc) göz önüne alınmıştır. Araştırma sonucunda deneme koşullarında Rosa *damascena* Mill. İçin en uygun bitki su tüketimi tahmin eşitliğinin Priestly Taylor yöntemi olduğu belirlenmiştir.

Anahtar kelimeler: Bitki katsayısı, bitki su tüketimi, Priestly Taylor, Rosa *damascena* Mill.

Introduction

As a cut flower, an outdoor plant, and a pot plant, rose is essential in the sector of ornamental plants; furthermore, it is important in the food, perfumery, and cosmetic industries as a medicinal and an aromatic plant (Guterman et al., 2002; Jabbarzadeh and Khosh-Khui, 2005; Senapati and Rout, 2008). Genus Rosa is comprised of more than 200 species; however, only a few of these species have been used as essential oil crops (Kovacheva et al., 2010). Rosa *damascena* Mill., Rosa *gallica* L., Rosa *moshata* Herrm and Rosa *centifolia* L. are the most crucial essential oil crops (Tucker and Maciarello, 1988). Rosa *damascena* Mill. plantations are commonly on sloping areas which are distant from water resources in Turkey, which is an obstacle to irrigating earlier oil rose farms. In recent years, most *Rosa damascena* Mill. plantations have been established over irrigable lands and the plantations concerned have been irrigated (Anonymous, 2008).

Water availability is generally the most important natural limiting factor flourishing and development of agriculture in an arid and semi-arid region (Kadayıfcı et al., 2004). Meeting food and other needs of the increasing population is possible through obtaining a higher yield from the available agricultural lands. To achieve this, water use efficiency should be increased especially in arid and semi-arid regions besides the use of appropriate agricultural techniques. Optimization of water use efficiency and preservation of adequate levels of crop productivity and quality will entail elaborate irrigation water management under such conditions. Estimation of actual evapotranspiration (ET) constitutes a key factor to attain those targets. Determining the ET accurately can act as a viable tool to benefit from water resources better by means of well-designed irrigation management programs. In addition, reliable estimates of ET are of extreme importance to form criteria for in-season irrigation management, water resource allocation, long-term estimates of water supply, demand and use, design and management of water resources infrastructure, and assessment of the impact of land use and management changes on the water balance (Ortega-Farias et al., 2009). Reference evapotranspiration (ETo) refers to the ET from a hypothetical reference surface; moreover, it was introduced to represent the evaporative demand of the atmosphere independent of management practices, crop type, and development. Knowing the spatiotemporal distribution of ETo allows calculating the required amount of crop water by making use of the established crop coefficients (Kc) (Marti and Zarzo, 2012). The Kc is basically the ratio of ET to ETo, where ET can be measured by using a lysimeter, a soil water balance approach, the eddy covariance method, Bowen ratio energy balance system, or the surface renewal method (Ortega-Farias et al., 2009).

Now due to that such method of lysimeter, soil water budget, eddy covariance, and Bowen ratio energy balance system employing to determine evapotranspiration values are expensive and time-consuming, the methods of estimating from the climatic data are used in practice. Unless locally calibrated, the methods of estimating evapotranspiration generally do not yield any sound results in the regions with climatic conditions that are different from those of the region in which they were developed (Christiansen, 1968; Jensen et al., 1990). Furthermore, the method to be utilized may also be different when the plant genus is changed in the same region. On the other hand, in case no research result is available, the estimated values obtained as a result of the calculations performed by using the empirical equations developed by utilizing meteorological parameters are used. The equation used in estimation must be parallel with, or the closest to, actual water consumption. There are numerous empirical equations developed for estimation nowadays. Some of the equations concerned are quite simple and the meteorological data they require comprise easily measurable or obtainable parameters, whereas some of them require very detailed data sets (Taş and Kırnak, 2011).

This study was, therefore, carried out to determine the optimum crop evapotranspiration estimation method(s) of Rosa *damascena* Mill. for a fixed irrigation interval of 10 days under Isparta conditions of Turkey.

Material and Methods

This research was conducted on the Rosa *damascena* Mill. plantation located at the Agricultural Research and Application Center at Süleyman Demirel University. The experimental area is situated between latitude 37.83° and longitude 30.53°, and it is 1,020 m above sea level on average. According to the perennial long-term data, study area is characterized as mean temperature of 11.97°C; average relative humidity of 61%; average wind speed of 1.97 m/h; annual average sunshine duration of 7.4 h, and annual total precipitation of 505.7 mm (Anonymous, 2010). The ten-day average values of some climatic parameters were measured at the meteorological station (DAVIS, Model “Vantage Pro-2”, Davis Devices, USA) located in the experimental area for research periods of May-September and they are presented in Table 1. These data were used in the calculations of ET_0 according to the reference evapotranspiration equations. The soils in the experimental site have been classified as Calcaric fulivisol according to the FAO/UNESCO classification system. Accordingly, the soils in the study area are moderately and slightly textured, deep, and salt-free soils (Akgül and Başayiğit, 2005). Some physical properties of the soils in the experimental area are presented in Table 2. In order to determine optimal empirical model, the average of the evapotranspiration values measured in the k_{cp3} treatment (Tübitak-Tovag: 109O369), which the highest yield was obtained in both years, was used.

In the experiment, each experimental plot had an area of 10 m^2 with dimensions of 1×10 m and a 2-m space between the plots. Drip irrigation system was used in irrigation. The diameter of the lateral tube is 16 mm, and each plant row was irrigated by two lateral tubes (Keller and Bliesner, 1990). Irrigation was applied once every 10 days, and irrigation water as much as 1.2 times the amount of evaporation measured from the Class A Pan evaporation in the ten-day period was applied. The irrigation water amount was calculated by Equation 1.

$$I = A \times k_{cp} \times E_p \times P \qquad (1)$$

Where;

I is irrigation water (l); A is plot area (m^2); k_{cp} is crop-pan coefficient (1.2); E_p is cumulative evaporation amount at the irrigation interval (mm); and P is percentage of wetted area (%).

In the experiment, soil moisture was measured up to 0-120 cm by means of Profile-Probe1 (DELTA-T, Model Profile Probe1, England), whereas the soil moisture at the layer of 120-150 cm was determined with the gravimetric method. Evapotranspiration was computed for 10-day periods by using Equation 2 (Allen *et al.*, 1998);

$$ET= I+P-RO-DP+CR \pm \Delta SF \pm \Delta SW \qquad (2)$$

Where;

ET is evapotranspiration (mm); I is irrigation water applied (mm); P is precipitation (mm); RO is surface runoff (mm); DP is deep percolation (mm); CR is capillary rise (mm); ΔSF is subsurface runoff (mm); and ΔSW is change in soil moisture content in root zone (mm).

The crop coefficient (Kc) was calculated using following Equation 3 as suggested by Allen *et al.*, (1998).

$$Kc=ETc/ET_0 \qquad (3)$$

Where;

Kc is crop coefficient; ETc is evapotranspiration measured (mm); and ET_0 is reference evapotranspiration (mm).

Penman-Monteith (PM), Original Penman (PEN), FAO-modified Penman (FAOP), Priestly-Taylor (PT), FAO-modified Radiation (FAOR), FAO-modified Blaney-Criddle (FAOB), SCS Blaney-Criddle (SCSB), Hargreaves (HARG), FAO-modified Pan Evaporation (Epan) and Net Radiation (NETR) methods were considered

Table 1. Some climatic data about the experimental area in 2010 and 2011
Tablo 1. Deneme alanına ait 2010 ve 2011 yıllarına ilişkin bazı iklim verileri

Climatic Parameters *İklim Parametreleri*	Months/*Aylar*														
	May/*Mayıs*			June/*Haziran*			July/*Temmuz*			August/*Ağustos*			September/*Eylül*		
	1*	2	3	1	2	3	1	2	3	1	2	3	1	2	3
	2010														
Maximum temperature (ºC) *En yüksek sıcaklık*	24	24.1	23.2	23.3	29.1	24.4	30.4	31.8	32.5	35.3	36.2	32.7	28.2	29.6	27.3
Minimum temperature (ºC) *En düşük sıcaklık*	8	10.7	9.5	11.8	14	11.5	15.9	17.2	17.3	19	18.4	16	13.5	11	12.1
Average temperature (ºC) *Ortalama sıcaklık*	17	18	16.3	17.5	22	18	23.5	24.9	25.8	27.9	28.2	25.2	21.3	20.3	20.3
Pressure (mb) *Basınç*	900	901	902	900	900	898	900	899	898	899	901	899	901	902	903
Relative humidity (%) *Bağıl nem*	52	48	65	71	54	62	56	47	46	44	36	35	50	52	54
Average wind speed (m/h) *Ortalama rüzgar hızı*	1.8	2.5	1.7	2.4	1.7	1.9	1.8	1.7	2	2.1	1.5	1.9	1.5	1.7	2.3
Class A pan evaporation (mm) *A sınıfı buharlaşma kabı buh.*	18	21	26	18	52	30	58	75	72	85	84	89	57	44	47
Precipitation (mm) *Yağış*	0.2	0.8	31.4	41.4	4.4	18.7	30.7	4.6	4.8	0.2	-	-	20.6	5.4	3.7
Sunshine duration (h) *Güneşlenme süresi*	9.9	8.4	6.8	6.4	9.3	7.3	9.4	10.3	11.4	9.7	10.9	11.3	10.8	9.8	8.1
	2011														
Maximum temperature (ºC) *En yüksek sıcaklık*	-	18.5	23.1	27.6	24.7	27.1	30.3	31.8	33.8	33.2	29.8	30.1	29.5	30	23.9
Minimum temperature (ºC) *En düşük sıcaklık*	7.3	7.1	10.7	12.1	11.5	13.3	14.8	17.6	16.8	17.7	16	15	12.9	12	10.4
Average temperature (ºC) *Ortalama sıcaklık*	13	13	17.1	20.1	18.2	21.1	23.7	25.5	25.9	26.5	23.6	23.5	22.2	21.5	17.1
Pressure (mb) *Basınç*	900	901	903	901	901	899	901	898	898	898	898	901	900	901	902
Relative humidity (%) *Bağıl nem*	65	67	63	59	69	42	46	37	44	37	41	36	38	34	52
Average wind speed (m/h) *Ortalama rüzgar hızı*	2.6	1.9	1.9	1.7	1.7	2.5	1.7	2.2	2.1	1.9	2.1	2	1.6	1.5	1.7
Class A pan evaporation (mm) *A sınıfı buharlaşma kabı buh.*	22	23	50	38	12	72	72	85	102	97	80	74	75	72	34
Precipitation (mm) *Yağış*	5.4	21.9	15.8	10.6	51.6	0	1.8	-	-	0.6	-	-	-	-	13.2
Sunshine duration (h) *Güneşlenme süresi*	6.7	5.6	7.6	9.2	6.9	10.3	10.4	11.4	11.2	10.6	9.9	10.9	11.5	11.1	8.1

*The 10-day cumulative total/ 10 günlük periyot toplamı

Table 2. Some physical properties of the soils in the experimental area
Tablo 2. Deneme alanı topraklarının bazı fiziksel özellikleri

Layer *Tabaka* (cm)	Texture *Tekstür*	Bulk density *Hacim ağırlığı* (g/cm^3)	Field capacity *Tarla kapasitesi*		Wilting point *Solma noktası*		Available water holding capacity *Kullanılabilir su tutma kapasitesi*	
			%	mm	%	mm	%	mm
0-30	CL	1.30	26.39	102.79	15.76	61.39	10.63	41.40
30-60	CL	1.42	25.74	109.30	14.50	61.57	11.24	47.73
60-90	CL	1.33	27.09	108.35	16.65	66.61	10.43	41.74
90-120	CL	1.36	26.67	108.59	15.66	63.77	11.01	44.82
120-150	CL	1.33	27.30	108.93	12.80	51.07	14.50	57.86
Total/Toplam (0-120 cm)				**429.03**		**253.35**		**175.68**
Total/Toplam (0-150 cm)				**537.96**		**304.42**		**233.54**

*EC and pH were determined in 1:2,5 soil/water mixtures by means of glass electrode EC and pH meters.
*EC ve pH, 1:2,5 toprak karışımında cam elektrotlu EC ve pH metrelerle belirlenmiştir.

to determine the optimum reference evapotranspiration equation for Rosa *damascena* Mill. The reference evapotranspiration values calculated with these methods were compared with the evapotranspiration values measured. The climatic data about the evapotranspiration measurement period were used to compute the reference evapotranspiration values.

Four parameters were taken into consideration to determine the optimum evapotranspiration estimation equation for the experimental conditions, namely; a) The correlation coefficient (r) of the correlation between the measured evapotranspiration and the estimated reference evapotranspiration values, b) The seasonal ratio of the equation whereby the reference evapotranspiration value computed with the estimation methods was obtained to the actual evapotranspiration value, c) Root mean square error (RMSE). This value was calculated with Equation 4 below.

$$RMSE = \left[\frac{\Sigma D^2}{n}\right]^2 \qquad (4)$$

Where; ΣD^2 is the sum of squares of the differences between the evapotranspiration values measured and the reference evapotranspiration estimated; and n is the number of observations. d) The seasonal average crop coefficient (Kc).

In evaluation, it was assumed that the estimation method(s) with the minimum root mean square error (RMSE), the highest correlation coefficient (r), the seasonal ratio of evapotranspiration closest to 100, and the seasonal average crop coefficient closest to 1 yielded sounder results for the experimental conditions.

Results and Discussion

The irrigation water amounts applied, the evapotranspiration values measured in ten-day periods and the reference or potential evapotranspiration values calculated in the same periods according to the estimation methods in the experiment in 2010 and 2011 are presented in Table 3. The irrigation water amounts applied in 2010 and 2011 were 307.3 mm and 359.6 mm, respectively. It is supposed that the difference in the irrigation water applied was due to the variations in the climatic factors. The evapotranspiration values were 88.9, 111.9, 146.5, 142.7, and 98.6 mm in May, June, July, August, and September 2010, respectively, while these values were 91.8, 111.9, 141.6, 141.4, and 90.1 mm in 2011, respectively. The highest evapotranspiration in both years was measured in July. The evapotranspiration values measured on a monthly basis resembled in both years. The total evapotranspiration was measured as 588.6 mm in 2010 and as 576.8 mm in 2011. The lowest reference evapotranspiration /potential evapotranspiration in both experimental years was recorded with the Epan method (2010: 454.5 mm; 2011: 525.8 mm) but the highest reference evapotranspiration / potential evapotranspiration with the FAO-modified Blaney-Criddle method in both experimental years (2010: 1,002.7 mm; 2011: 1,002.6 mm). The crop coefficient (Kc) values are provided in Table 4; and the values of the parameters considered to determine the optimum evapotranspiration method are seen in Table 5. The crop coefficient (Kc) values calculated regarding the methods of estimating evapotranspiration ranged from 0.43 to 3.08 in 2010 but from 0.50 to 2.87 in 2011. Generally in all methods, the Kc values were low at the beginning of the growing season, high in the middle of the vegetation period and again low at the end of the vegetation period (Table 4). When the equations considered were evaluated in terms of the root mean square error, the minimum root mean square error was obtained with the PT (8.01) method, followed by Epan (10.91) and SCSB (11.93) methods. Given the cumulative evapotranspiration values, the closest estimations were made with the PT, SCSB, and Epan methods. Whilst PT and SCSB methods estimated values were 15% and 28% higher than the actual evapotranspiration value, respectively, the Epan method estimated a value which was 16% lower than the actual evapotranspiration value. The most important reason for the differences between actual evapotranspiration and the estimated water consumption values may be resulted from climatic parameters. Any climatic parameter used in calculation has a different effect in each method. Therefore, different results may be obtained in each method with the same parameter (Taş and Kırnak, 2011)

Table 3. The irrigation water amounts applied, the evapotranspiration measured and the reference evapotranspiration values calculated by means of some estimation equations

Tablo 3. Uygulanan sulama suyu miktarı, ölçülen bitki su tüketimi ve bazı bitki su tüketimi tahmin eşitlikleri ile hesaplanan referans bitki su tüketimi değerleri

	May/*Mayıs*			Total *Toplam* (May/ *Mayıs*)	June/*Haziran*			Total *Toplam* (June/ *Haziran*)	July/Temmuz			Total *Toplam* (July/ *Temmuz*)	August			Total *Toplam* (August/ *Ağustos*)	September/Eylül			Total *Toplam* (Sept./ *Eylül*)	Total *Toplam*
	1	2	3		1	2	3		1	2	3		1	2	3		1	2	3		
										2010											
ET	25.0	31.8	32.1	88.9	32.7	40.8	38.4	111.9	45.5	50.7	50.3	146.5	51.5	48.9	42.3	142.7	35.1	34.3	29.2	98.6	588.6
I	7.1	8.3	10.3	25.7	7.1	20.6	11.9	39.6	23.0	29.7	28.5	81.2	33.7	33.3	35.2	102.2	22.6	17.4	18.6	58.6	307.3
PM	47.5	48.9	41.6	138.0	36.3	55.4	45.4	137.1	44.4	51.5	59.1	155.0	66.9	60.0	60.9	187.8	52.3	45.5	45.7	143.5	761.4
PEN	50.7	52.8	44.5	148.0	39.2	58.0	48.3	145.5	45.6	53.5	61.8	160.9	67.7	64.1	63.5	195.3	54.8	47.0	45.5	147.3	797.0
FAOP	58.5	59.1	51.3	168.9	45.3	66.7	56.1	168.1	54.1	61.3	71.8	187.2	76.7	70.5	68.9	216.1	61.8	54.5	52.3	168.6	908.9
PT	44.7	41.0	42.1	127.8	36.7	51.5	44.3	132.5	38.1	41.7	50.1	129.9	52.8	51.3	46.7	150.8	42.6	38.5	33.5	114.6	655.6
FAOR	61.6	56.5	48.8	166.9	40.0	66.3	51.9	158.2	50.6	61.0	72.4	184.0	76.1	77.2	77.0	230.3	67.7	52.2	52.4	172.3	911.7
FAOB	57.4	56.2	48.9	162.5	41.3	69.8	53.3	164.4	64.6	80.0	83.9	228.5	87.8	86.5	83.9	258.2	70.1	61.3	57.7	189.1	1,002.7
SCSB	37.2	39.2	39.6	116.0	37.9	54.2	43.3	135.4	59.2	63.3	62.6	185.1	70.2	68.8	59.6	198.6	47.7	43.0	40.2	130.9	766.0
HARG	50.1	46.2	49.4	145.7	41.4	59.9	50.1	151.4	60.7	61.8	60.9	183.4	66.6	66.3	58.0	190.9	50.1	46.2	42.4	138.7	810.1
Epan	10.9	12.2	16.9	40.0	10.6	32.2	19.4	62.2	32.2	44.5	42.3	119.0	48.6	48.1	49.0	145.7	32.7	27.0	27.9	87.6	454.5
NETR	53.0	48.3	49.7	151.0	42.7	56.5	51.2	150.4	40.4	43.5	52.7	136.6	54.1	52.3	48.9	155.3	46.8	43.1	37.7	127.6	720.9
										2011											
ET	27.1	30.0	34.7	91.8	37.8	33.0	41.1	111.9	48.4	49.3	43.9	141.6	52.5	45.7	43.2	141.4	35.6	30.5	24.0	90.1	576.8
I	8.7	9.1	19.8	37.6	15.0	4.8	28.5	48.3	28.5	33.7	40.4	102.6	38.4	31.7	29.3	99.4	29.7	28.5	13.5	71.7	359.6
PM	34.1	38.0	41.1	113.2	51.5	43.9	60.9	156.3	61.6	67.6	66.4	195.6	64.1	57.9	58.4	180.4	52.1	48.2	38.4	138.7	784.2
PEN	38.1	41.8	44.3	124.2	54.2	46.9	64.5	165.6	65.0	70.5	68.2	203.7	67.2	61.0	61.1	189.3	55.1	51.4	40.0	146.5	829.3
FAOP	43.4	48.1	50.6	142.1	63.9	54.3	72.5	190.7	73.4	79.4	77.8	230.6	73.9	68.0	66.9	208.8	60.9	55.9	45.2	162	934.2
PT	34.1	38.9	41.3	114.3	50.4	45.4	50.7	146.5	54.3	55.9	55.9	166.1	51.6	46.7	44.4	142.7	42.0	37.5	30.3	109.8	679.4
FAOR	40.5	46.6	48.1	135.2	62.1	51.0	73.9	187.0	76.5	83.4	80.2	240.1	78.5	69.9	73.4	221.8	70.0	66.0	48.1	184.1	968.2
FAOB	36.1	42.4	47.9	126.4	63.4	52.8	75.0	191.2	80.5	89.1	87.9	257.5	86.0	74.1	77.6	237.7	71.2	69.1	49.5	189.8	1,002.6
SCSB	27.1	30.9	40.0	98.0	48.4	45.7	49.1	143.2	59.2	63.1	65.5	187.8	64.1	54.5	52.6	171.2	46.0	45.3	34.8	126.1	726.3
HARG	35.1	41.6	47.2	123.9	57.5	52.2	54.6	164.3	61.4	61.9	66.5	189.8	61.6	52.8	52.1	166.5	50.0	49.1	36.5	135.6	780.1
Epan	14.1	16.4	31.5	62.0	22.3	11.5	40.5	74.3	42.6	48.3	58.4	149.3	53.0	45.0	40.7	138.7	42.4	38.4	20.7	101.5	525.8
NETR	44.1	48.4	48.6	141.1	56.7	51.8	56.8	165.3	58.4	58.8	58.3	175.5	53.5	50.2	47.9	151.6	46.4	41.1	35.2	122.7	756.2

ET: Evapotranspiration measured/*Ölçülen bitki su tüketimi* (mm); I: Irrigation water amount/*Sulama suyu miktarı* (mm); PM: Penman-Monteith/*Penman Monteith*; PEN: Original Penman/*Orjinal Penman*; FAOP: FAO-modified Penman/*Modifiye FAO-Penman*; PT: Priestly-Taylor/*Priestly-Taylor*; FAOR: FAO-modified Radiation/*Modifiye FAO-Radyasyon*; FAOB: FAO-modified Blaney-Criddle/*Modifiye FAO-Blaney Criddle*; SCSB: SCS Blaney-Criddle/ *SCS Blaney-Criddle*; HARG: Hargreaves/*Hargreaves*; EPAN: FAO-modified Pan Evaporation method/*Modifiye Pan Evaporasyon method*; and NETR: Net Radiation/*Net Radyasyon*. 1: The 1st-10th days of the month/*Ayın 1. ve 10. günleri arası*; 2: The 11th-20th days of the month/*Ayın 11. ve 20. günleri arası*; and 3: The 21st-30th/31st days of the month/*Ayın 21. ile 30/31. günleri arası.*

Table 4. Kc values calculated for oil rose according to different methods
Tablo 4. Yağ gülü için farklı yöntemlere göre hesaplanan Kc değerleri

Months *Aylar*	Period *Periyot*	PM	PEN	FAOP	PT	FAOR	FAOB	SCSB	HARG	Epan	NETR
		2010									
May *Mayıs*	1	0.53	0.49	0.43	0.56	0.41	0.44	0.67	0.50	2.29	0.47
	2	0.65	0.60	0.54	0.78	0.56	0.57	0.81	0.69	2.61	0.66
	3	0.77	0.72	0.63	0.76	0.66	0.66	0.81	0.65	1.90	0.65
June *Haziran*	1	0.90	0.83	0.72	0.89	0.82	0.79	0.86	0.79	3.08	0.77
	2	0.74	0.70	0.61	0.79	0.62	0.58	0.75	0.68	1.27	0.72
	3	0.85	0.80	0.68	0.87	0.74	0.72	0.89	0.77	1.98	0.75
July *Temmuz*	1	1.02	1.00	0.84	1.19	0.90	0.70	0.77	0.75	1.41	1.13
	2	0.98	0.95	0.83	1.22	0.83	0.63	0.80	0.82	1.14	1.17
	3	0.85	0.81	0.70	1.00	0.69	0.60	0.80	0.83	1.19	0.95
August *Ağustos*	1	0.77	0.76	0.67	0.98	0.68	0.59	0.73	0.77	1.06	0.95
	2	0.82	0.76	0.69	0.95	0.63	0.57	0.71	0.74	1.02	0.93
	3	0.69	0.67	0.61	0.91	0.55	0.50	0.71	0.73	0.86	0.87
September *Eylül*	1	0.67	0.64	0.57	0.82	0.52	0.50	0.74	0.70	1.07	0.75
	2	0.75	0.73	0.63	0.89	0.66	0.56	0.80	0.74	1.27	0.80
	3	0.64	0.64	0.56	0.87	0.56	0.51	0.73	0.69	1.05	0.77
		2011									
May *Mayıs*	1	0.79	0.71	0.62	0.79	0.67	0.75	1.00	0.77	1.92	0.61
	2	0.79	0.72	0.62	0.77	0.64	0.71	0.97	0.72	1.83	0.62
	3	0.84	0.78	0.69	0.84	0.72	0.72	0.87	0.74	1.10	0.71
June *Haziran*	1	0.73	0.70	0.59	0.75	0.61	0.60	0.78	0.66	1.70	0.67
	2	0.75	0.70	0.61	0.73	0.65	0.63	0.72	0.63	2.87	0.64
	3	0.67	0.64	0.57	0.81	0.56	0.55	0.84	0.75	1.01	0.72
July *Temmuz*	1	0.79	0.74	0.66	0.89	0.63	0.60	0.82	0.79	1.14	0.83
	2	0.73	0.70	0.62	0.88	0.59	0.55	0.78	0.80	1.02	0.84
	3	0.66	0.64	0.56	0.79	0.55	0.50	0.67	0.66	0.75	0.75
August *Ağustos*	1	0.82	0.78	0.71	1.02	0.67	0.61	0.82	0.85	0.99	0.98
	2	0.79	0.75	0.67	0.98	0.65	0.62	0.84	0.87	1.02	0.91
	3	0.74	0.71	0.65	0.97	0.59	0.56	0.82	0.83	1.06	0.90
September *Eylül*	1	0.68	0.65	0.58	0.85	0.51	0.50	0.77	0.71	0.84	0.77
	2	0.63	0.59	0.55	0.81	0.46	0.44	0.67	0.62	0.79	0.74
	3	0.63	0.60	0.53	0.79	0.50	0.48	0.69	0.66	1.16	0.68

PM: Penman-Monteith/*Penman Monteith*; PEN: Original Penman/*Orjinal Penman*; FAOP: FAO-modified Penman/*Modifiye FAO-Penman*; PT: Priestly-Taylor/*Priestly-Taylor*; FAOR: FAO-modified Radiation/*Modifiye FAO-Radyasyon*; FAOB: FAO-modified Blaney-Criddle/*Modifiye FAO-Blaney Criddle*; SCSB: SCS Blaney-Criddle/*SCS Blaney-Criddle*; HARG: Hargreaves/*Hargreaves*; EPAN: FAO-modified Pan Evaporation method/*Modifiye Pan Evaporasyon method*; and NETR: Net Radiation/*Net Radyasyon*. 1: The 1st-10th days of the month/*Ayın 1. ve 10. günleri arası*; 2: The 11th-20th days of the month/*Ayın 11. ve 20. günleri arası*; and 3: The 21st-30th/31st days of the month/*Ayın 21. ile 30/31. günleri arası.*

The highest correlation between evapotranspiration and the reference or potential evapotranspiration was obtained with SCSB (r=0.94), HARG (r=0.88), and FAOB (0.85) respectively (Table 5). In examine the results in terms of seasonal Kc, it was seen that the value closest to 1 was detected with PT (Kc=0.87), followed by SCSB (Kc=0.79) and NETR (Kc:0.79) methods (Table 5).

When the parameters of root mean square error, correlation coefficient, the ratio of evapotranspiration and seasonal Kc coefficient – used to determine the optimum evapotranspiration estimation equation – are evaluated collectively, it might be stated that PT (Priestly-Taylor) is the optimum evapotranspiration estimation equation for Rosa *damascena* Mill. under the experimental conditions. Kırnak and Taş (2011) reported that crop coefficients reflect the physiology of a plant, its cover ratio, the locality where the data are compiled, and the method with which the potential evapotranspiration value is calculated. Many curves or tables showing the crop coefficients give the values of fully irrigated plants (USDA-SCS, 1967; Burman and Pochop, 1994). The crop coefficient calculated according to the PT method first increased and then decreased depending on the growing stages of the plant. The crop coefficient ranged from 0.56 to 1.22 in 2010 but from 0.72 to 1.02 in 2011. It is thought that this difference between the years might have been resulted from difference in the climates between both years. Considering the average kc values, the kc value was 0.75 at the beginning of the vegetation period, while it reached its highest value (1.00) in July but began to fall towards the end of the vegetation period and decreased to 0.84 (Figure 1).

Table 5. The criteria considered for determination optimum evapotranspiration equation
Tablo 5. Optimum bitki su tüketimi eşitliğinin belirlenmesinde göz önüne alınan kriterler

ET estimation method *ET tahmin yöntemi*	Root mean square error *Hata kareler ortalaması* (RMSE)	Regression equation and correlation coefficient between ET and ET_0 *ET ile ET_0 arasında regresyon eşitliği ve korelasyon katsayısı*	Seasonal average kc coefficient *Mevsimlik ortalama Kc katsayısı*	Seasonal ratio of ET *Ölçülen ET'yi karşılama oranı* (ET %)
PM	13.93	$ET=0.0003ET_0^4-0.0414ET_0^3+2.4868 ET_0^2-63.669ET_0+627.11$ r=0.82	0.76	133
PEN	16.44	$ET= 0.000ET_0^4 - 0.036ET_0^3 + 2.175 ET_0^2 - 55.887ET_0 + 558.33$ r = 0.81	0.72	140
FAOP	23.37	$ET=0.0002ET_0^4-0.0397ET_0^3+2.4013 ET_0^2 - 61.664ET_0 + 617.31$ r= 0.83	0.63	158
PT	8.01	$ET=0.0002ET_04-0.0309ET_0^3+ 1.7935ET_0^2-44.154ET_0+425.9$ r=0.76	0.87	115
FAOR	25.40	$ET=0.0003ET_0^4 -0.0501ET_0^3+3.0933 ET_0^2 - 81.295ET_0 + 818.1$ r= 0.75	0.63	161
FAOB	29.62	$ET=0.0002ET_0^4-0.0398ET_0^3+2.5136 ET_0^2 - 66.93ET_0 + 684.83$ r= 0.85	0.59	172
SCSB	11.93	$ET=6E-05ET_0^4-0.0121ET_0^3+0.8098 ET_0^2 - 21.943ET_0 + 239.97$ r= 0.94	0.79	128
HARG	14.78	$ET=9E-05ET_0^4-0.015ET_0^3+0.929 ET_0^2- 23.67ET_0 + 252.6$ r= 0.88	0.73	136
Epan	10.91	$ET=0.0001ET_0^4-0.0222ET_0^3+1.4652 ET_0^2 - 39.891ET_0 + 397.94$ r= 0.81	1.41	84
NETR	12.76	$ET=0.0002ET_0^4-0.0268ET_0^3+1.5308 ET_0^2 - 37.101ET_0 + 365.42$ r= 0.56	0.79	127

PM: Penman-Monteith/*Penman Monteith*; PEN: Original Penman/*Orjinal Penman*; FAOP: FAO-modified Penman/*Modifiye FAO-Penman*; PT: Priestly-Taylor/*Priestly-Taylor*; FAOR: FAO-modified Radiation/*Modifiye FAO-Radyasyon*; FAOB: FAO-modified Blaney-Criddle/*Modifiye FAO-Blaney Criddle*; SCSB: SCS Blaney-Criddle/*SCS Blaney-Criddle*; HARG: Hargreaves/*Hargreaves*; EPAN: FAO-modified Pan Evaporation method/*Modifiye Pan Evaporasyon method*; and NETR: Net Radiation/*Net Radyasyon*. 1: The 1st-10th days of the month/*Ayın 1. ve 10. günleri arası*; 2: The 11th-20th days of the month/*Ayın 11. ve 20. günleri arası*; and 3: The 21st-30th/31st days of the month/*Ayın 21. ile 30/31. günleri arası.*

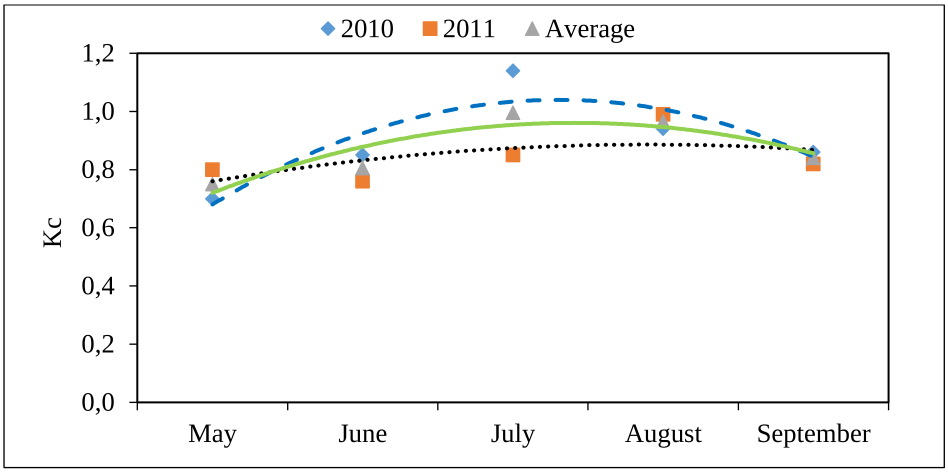

Figure 1. Crop coefficient curves for the evapotranspiration estimation method proposed for the experimental conditions

Şekil 1. Deneme koşulları için önerilen evapotranspirasyon tahmin eşitliği için bitki katsayısı eğrisi

Conclusion

In this study, it was aimed to determine the optimum estimation method likely to be used in the estimation of the evapotranspiration of Rosa d*amascena* Mill. According to the results for the two years, the evapotranspiration of Rosa *damascena* Mill. was measured as 588.6-576.8 mm. When all evaluation criteria are considered, it may be proposed to use the Priestly-Taylor method to estimate the evapotranspiration of Rosa *damascena* Mill. under the experimental conditions or in the places which climatically resemble the experimental conditions. The Kc values obtained with the Priestly-Taylor method can be used reliably to compute evapotranspiration in the places which resemble the experimental conditions where no actual evapotranspiration data are available.

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