Determination of Irrigation Water Amount and Interval for Carnation (Dianthus caryophyllus L.) with Pan Evaporation Method

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Abstract. This study was carried out to determine the optimum irrigation water amount and interval for carnation plants (Dianthus caryophyllus L.) using the pan evaporation method. The values of class A pan, located inside the greenhouse, were used to determine the irrigation water amount. Irrigation treatments consisted of three irrigation intervals (I1: 1-d, I2: 2-d, and I3: 3-day) and five crop-pan coefficients (kcp1: 0.25, kcp2: 0.50, kcp3: 0.75, kcp4: 1.00, and kcp5: 1.25). Irrigation water amounts applied to the experimental treatments ranged from 218 to 786 mm; seasonal evapotranspiration ranged from 219 to 601 mm and the yield acquired from the treatments ranged from 10 to 89.82 stems/m². The highest yield was obtained from I1kcp4 (89.56 stems/m²) followed by I1kcp5 (82.89 stems/m²) and I1kcp3 (82.22 stems/m²). The seasonal yield response factor (ksc) was calculated to be 0.73, 1.00, and 1.42 in I1, I2, and I3, respectively. Significant relationships were obtained between yield and irrigation water ($R^2 = 0.998$) and evapotranspiration ($R^2 = 0.993$) in the I1 treatments, in which the highest yield was found. In carnation cultivation under greenhouse conditions, it was proposed to apply irrigation water with 1-day intervals under a crop-pan coefficient of kcp4.

The production area of ornamental plants in Turkey is 2500 ha, and cut flower production is carried out in 1199 ha (48%) of this area. Carnation is the primary cut flower crop with its production area of 514 ha (43%) among cut flower species in Turkey (T.C. Tarım ve Köy İşleri Bakanlığı, 2009). Carnation (Dianthus caryophyllus L.) is a native of the Mediterranean area, which includes Turkey (Besemer, 1980; Whealy, 1992). Both suitable climate structure and affordable labor in this region provide important advantages for Turkey in carnation cultivation. Suitable climate conditions provide an opportunity for carnation cultivation year-round in the Western Mediterranean Region of Turkey. Located in this region, Antalya in winter months and Isparta in summer months are important centers of carnation production.

In carnation cultivation, irrigation water amount and irrigation interval vary with soil texture, photoperiod, air temperature and humidity, air movement, the mass of the plants relative to loss of water by transpiration, and variety as well as growth stage of the plant. In general, soil must always be kept moist for good-quality carnations (Besemer, 1980; Laurie et al., 1969). Various researchers reported that when water deficiency was applied to carnation, the parameters of yield and quality were negatively affected (Baas et al., 1995; Farina and Cervelli, 1994; Konishi, 1978; Taylor et al., 2004).

Isparta has a semi-arid climate characteristic with its annual rainfall of 524 mm. To obtain both efficient water use and maximum products in semi-arid climate regions, research must be conducted on irrigation scheduling of the cultivated plants and water yield relationships must be determined. The data to be obtained might contribute significantly to water users in decision-making. Because it is simple and easy to apply, the pan evaporation method is a commonly used method for the irrigation scheduling of plants (Elliadès, 1988; Wang et al., 2009). Studies have shown that there is a close correlation between evapotranspiration and pan evaporation. Therefore, the pan evaporation method is reported to be practicable for farmers in irrigation scheduling (Kanber, 1984).

The aim of this study was to determine the effects of different irrigation intervals and kcp on the yield and evapotranspiration of carnation plants and to choose the most suitable irrigation schedule for carnation plants grown under the greenhouse conditions by using pan evaporation and related crop-pan coefficients.

Materials and Methods

The research was conducted in a polyethylene-covered greenhouse located at the Agricultural Research and Application Center of Agricultural Faculty at Suleyman Demirel University (lat. 37.83° N, long. 30.53° E, altitude 1.020 m) in Isparta, Turkey. Some characteristics of greenhouse soil (in 0- to 20-cm depth) were as follows: texture: clay-loam; bulk density: 1.31 g·cm⁻³; field capacity: 18.10%; permanent wilting point: 7.43%; EC: 0.11 mS·cm⁻¹; pH: 7.85; CaCO₃: 30.12%; and organic matter: 3.45%. When the average values of the climatic parameters in the research area were considered, temperature, relative humidity, wind speed, sunshine duration, and total rainfall were 11.97 °C, 61.1%, 1.97 m·s⁻¹, 7.4 h, and 524 mm, respectively (T.C. Meteoroloji Genel Müdürlüğü, 2007).

Rooted cuttings of carnation (Dianthus caryophyllus cv. Turbo, which is a standard type) were planted into plots (1.25-m length, 1.00-m width) with four rows (12.5 × 20-cm spacing, 32 plants/m²) on 1 June 2007, and each plot contained 40 plants. For 20 d after planting (DAP), the depth of water evaporating from the pan was measured by using a single pinched above the fifth leaf pair from the bottom (Kazaz et al., 2009; Whealy, 1992).

The treatments consisted of three different irrigation intervals (I1: 1-d, I2: 2-d, I3: 3-day) and five crop-pan coefficients (kcp1: 0.25, kcp2: 0.50, kcp3: 0.75, kcp4: 1.00, and kcp5: 1.25). Irrigation water amounts applied to the experimental treatments ranged from 218 to 786 mm; seasonal evapotranspiration ranged from 219 to 601 mm and the yield acquired from the treatments ranged from 10 to 89.82 stems/m². The highest yield was obtained from I1kcp4 (89.56 stems/m²) followed by I1kcp5 (82.89 stems/m²) and I1kcp3 (82.22 stems/m²). The seasonal yield response factor (ksc) was calculated to be 0.73, 1.00, and 1.42 in I1, I2, and I3, respectively. Significant relationships were obtained between yield and irrigation water ($R^2 = 0.998$) and evapotranspiration ($R^2 = 0.993$) in the I1 treatments, in which the highest yield was found. In carnation cultivation under greenhouse conditions, it was proposed to apply irrigation water with 1-day intervals under a crop-pan coefficient of kcp4.

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3-d) and five different crop-pan coefficients ($k_{cp1}: 0.25$, $k_{cp2}: 0.50$, $k_{cp3}: 0.75$, $k_{cp4}: 1.00$, and $k_{cp5}: 1.25$). They were arranged according to split-split plots experimental design with three replications. Water and nutrients were supplied using an automatically controlled fertigation computer (Spagnol Ltd., Vidor, Italy). The composition of nutrient solution (ppm) is as follows: nitrogen: 160, phosphorus: 46, potassium: 224, calcium: 140, magnesium: 18, iron: 1.95, manganese: 0.41, zinc: 0.19, boron: 0.21. The target pH and electrical conductivity (EC) values were 5.5 and 1.7 mS·cm$^{-1}$ (Kazaz et al., 2009).

Irrigation treatments were based on the evaporation data ($E_p$, mm) obtained from a CAP located inside the greenhouse (Doorenbos and Pruitt, 1977). Irrigation water amount was calculated using Eq. [1] (Kanber, 1984).

$$I = A \times E_p \times k_{cp} \times P$$  [1]

where I is the irrigation water amount (L), A the plot area ($m^2$), $E_p$ the cumulative evaporation in the irrigation intervals (CAP, mm), $k_{cp}$ the crop-pan coefficient, and P the percentage of wetted area (%).

Irrigation water was applied to the experimental plots using a drip irrigation method. Laterals with a diameter of 16 mm, a dripper spacing of 20 cm, and a discharge of 2 L·h$^{-1}$ per dripper at 0.1 Mpa were used. Arrangement was made in such a way that each lateral tube irrigated one plant row. Because plant row spacing was equal to dripper spacing (20 cm), the percentage of the area wetted (P) was taken as 100% in the application of irrigation water (Keller and Bliesner, 1990). Irrigation water with EC and sodium absorption ratio being 0.73 mS·cm$^{-1}$ and 0.05, respectively, was obtained from the groundwater.

To monitor soil moisture change in the root zone of plants, a tensiometer (Soilspec H&TS Electronics Pty. Ltd., Melbourne, Australia) was installed into 20-cm depth of each plot, and the tensiometer was read before each irrigation application. To express soil moisture in millimeters, a calibration curve was created according to the soil characteristics, and the calibration curve equation was calculated as

Table 1. Average monthly values of some climatic parameters in greenhouse inside and outside.

<table>
<thead>
<tr>
<th>Month</th>
<th>Inside</th>
<th>Outside</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>$T^\circ (\degree C)$</td>
<td>RH (%)</td>
</tr>
<tr>
<td>June</td>
<td>23</td>
<td>54</td>
</tr>
<tr>
<td>July</td>
<td>25</td>
<td>42</td>
</tr>
<tr>
<td>August</td>
<td>25</td>
<td>48</td>
</tr>
<tr>
<td>September</td>
<td>19</td>
<td>48</td>
</tr>
<tr>
<td>October</td>
<td>15</td>
<td>62</td>
</tr>
<tr>
<td>November</td>
<td>13</td>
<td>75</td>
</tr>
</tbody>
</table>

$^x$Temperature.  
$^y$Relative humidity.  
$^x$Evaporation from class A pan.  
$^w$Solar radiation.
The maximum crop yield without water stress, \( Y_m \), is given by

\[
Y_m = \frac{1}{1 - \frac{Y_a}{Y_m}}
\]

and the crop-pan coefficients, \( k_{cp1}, k_{cp2}, k_{cp3}, k_{cp4}, \) and \( k_{cp5} \), are 0.25, 0.50, 0.75, 1.00, and 1.25, respectively. These values were applied to the treatments with 1-, 2-, and 3-d intervals. The deep percolation was also high. Deep percolation of water is further enhanced by the fact that plants consume less water at the beginning of the growth period and a higher

**Result and Discussion**

**Temperature in greenhouse.** Temperature is one of the important factors that affect growth of carnation and the shapes of flower, leaf, and stem. Average monthly values of some climatic parameters in greenhouse inside and outside are presented in Table 1. Throughout the vegetation period in the greenhouse, the mean daily air temperature ranged from 10 to 29 °C, and the lowest temperature averages were in October and November. Optimum cultivation temperatures for carnation should range from 10 to 14 °C at night and from 15 to 20 °C during the day (Bunt and Cockshull, 1985; Laurie et al., 1969; Yamaguchi, 1994); thus, suitable temperatures took place in the greenhouse during the growth period.

**Evapotranspiration and irrigation water amount.** Rooted cuttings will easily immediately after planting. For successful cultivation, it is quite important to prevent the cuttings from wilting and drying out within the first 2 weeks after planting (Besemer, 1980; HilverdaKooij Plant Technology, 2010). Therefore, irrigation schedules were started 20 DAP. Within this establishment period, the whole evaporation amount (76 mm) was applied to all treatments as irrigation water.

**Fig. 2.** Relationships between I (irrigation water amount) and yield, evapotranspiration (ET), and yield (I1 = irrigation interval 1-d; I2 = irrigation interval 2-d; I3 = irrigation interval 3-d).

**Table 2.** Irrigation interval \( \times \) crop-pan coefficient for yield (stems/m²).

<table>
<thead>
<tr>
<th>Crop-pan coefficient</th>
<th>Irrigation interval</th>
<th>11</th>
<th>12</th>
<th>13</th>
</tr>
</thead>
<tbody>
<tr>
<td>( k_{cp1} )</td>
<td></td>
<td>42.89 f</td>
<td>32.67 h</td>
<td>10.00 i</td>
</tr>
<tr>
<td>( k_{cp2} )</td>
<td></td>
<td>68.00 e</td>
<td>53.56 f</td>
<td>36.00 h</td>
</tr>
<tr>
<td>( k_{cp3} )</td>
<td></td>
<td>82.22 b</td>
<td>53.56 f</td>
<td>44.67 g</td>
</tr>
<tr>
<td>( k_{cp4} )</td>
<td></td>
<td>89.56 a</td>
<td>77.57 b-d</td>
<td>71.33 de</td>
</tr>
<tr>
<td>( k_{cp5} )</td>
<td></td>
<td>82.89 b</td>
<td>75.33 cd</td>
<td>79.33 bc</td>
</tr>
</tbody>
</table>

\( ^1 \) Irrigation interval 1-d.

\( ^2 \) Irrigation interval 2-d.

\( ^3 \) Irrigation interval 3-d.

\( ^4 \) Means followed by the same letter do not differ significantly at \( P \leq 0.05. \)

\( k_{cp1} = 0.25; k_{cp2} = 0.50; k_{cp3} = 0.75; k_{cp4} = 1.00; \) and \( k_{cp5} = 1.25; \) crop-pan coefficients.

\[ \text{WUE} = \left( \frac{E_y}{ET} \right) \times 100 \]

\[ \text{IWUE} = \left( \frac{E_y}{I} \right) \times 100 \]

where WUE is the water use efficiency, IWUE the irrigation water use efficiency, ET the evapotranspiration (mm), I the irrigation water (mm), and \( E_y \) the economical yield (stems/m²). Instead of economical yield, the yield obtained directly per square meter was used in the calculations.

Carnation harvest was started 96 DAP, and flowers were harvested 12 times during the study. Harvesting was performed above the second node from the base when flowers were fully open (Kazaz et al., 2009). Data were submitted to analysis of variance using MINITAB software (Minitab Inc., State College, PA), and the mean values were compared using the least significant difference (\( P \leq 0.05 \) test).
irrigation water amount is applied because evaporation from CAP is high.

ET values differed in both irrigation interval and crop-pan coefficient. The highest ET was measured in I1kcp5 (601 mm), whereas the lowest ET was found in I3kcp1 (219 mm). Generally, the higher the values of crop-pan coefficient were, the larger the ET values became and the greater the irrigation water amount was. Likewise, in treatments with applications of the same irrigation water amount, higher ET values were obtained from those with a low irrigation interval (I1kcp5: 601 mm) than those with a high irrigation interval (I3kcp5: 554 mm). The wet soil surface in the I1 treatments resulting from irrigation everyday caused higher evaporation from the soil surface than those in the I2 and I3, which increased the total ET. These results are in agreement with Meiri et al. (1992), who reported that the more frequently irrigated plants absorbed more water from the soil.

Aydinasker et al. (2009) reported that the ET value ranged from 501 to 1254 mm in the carnation supplied with irrigation water ranging from 600.1 to 1350.3 mm according to crop-pan coefficients, whereas Konishi (1978) found that the ET value ranged from 375 to 523 mm. Our results are consistent with the mentioned studies.

Soil water content before irrigation. The root zone moisture was close to the field capacity until ~60 DAP [211 d of the year (DOY)] in all the treatments of I1, 40 DAP (190 DOY) in I2, and 30 DAP (180 DOY) in I3. Thereafter, moisture content then showed a tendency to decrease in all treatments from the field capacity to the wilting point. Values of ET positively affected the yield and caused a yield-decreasing effect. On the other hand, the results revealed that under the condition of a 3-d irrigation interval, it would be necessary to apply 1.25 times more water than the Em value to obtain the maximum yield.

Our results showed that under the conditions of 1-d and 2-d irrigation intervals (especially in kcp4), maximum yield could be achieved by irrigating as much as evaporation from CAP and that application of more water than this value would not have any effect of increasing the yield, but it would have a yield-decreasing effect. According to these data, water deficit should not be applied in the event that a 3-d irrigation interval is preferred, and if water deficit will be applied, it should be done so particularly under the condition of a 1-d irrigation interval.

Water use efficiency and irrigation water use efficiency. The water use efficiency (WUE) values ranged from 0.05 to 0.20 stems/m²/mm. The highest WUE (0.20 stems/m²/mm) was recorded in I1kcp2 followed by I1kcp1 and I1kcp3 (0.19 stems/m²/mm) and the I1kcp5 (0.17 stems/m²/mm), whereas the lowest WUE value (0.05 stems/m²/mm) was determined in I3kcp1. Likewise, the irrigation WUE (IWUE) values also ranged from 0.05 to 0.20 stems/m²/mm. The highest IWUE value was found in I1kcp1 (0.20 stems/m²/mm) followed by I1kcp2 (0.19 stems/m²/mm) and I1kcp3 (0.16 stems/m²/mm), whereas the lowest IWUE value was in I3kcp1 (0.05 stems/m²/mm) (Table 3). Higher WUE and IWUE values were obtained from the treatments with a low irrigation interval than those with a high irrigation interval. These results are in agreement with Kanber et al. (1991), who reported that higher WUEs could be obtained from the

Table 3. Water use efficiency (WUE) and irrigation water use efficiency (IWUE) (stems/m²/mm).

<table>
<thead>
<tr>
<th>Treatments</th>
<th>WUE</th>
<th>IWUE</th>
<th>WUE</th>
<th>IWUE</th>
<th>WUE</th>
<th>IWUE</th>
</tr>
</thead>
<tbody>
<tr>
<td>kcp1</td>
<td>0.19</td>
<td>0.20</td>
<td>0.14</td>
<td>0.15</td>
<td>0.05</td>
<td>0.05</td>
</tr>
<tr>
<td>kcp2</td>
<td>0.20</td>
<td>0.19</td>
<td>0.13</td>
<td>0.12</td>
<td>0.11</td>
<td>0.10</td>
</tr>
<tr>
<td>kcp3</td>
<td>0.19</td>
<td>0.16</td>
<td>0.12</td>
<td>0.11</td>
<td>0.11</td>
<td>0.09</td>
</tr>
<tr>
<td>kcp4</td>
<td>0.17</td>
<td>0.14</td>
<td>0.15</td>
<td>0.12</td>
<td>0.14</td>
<td>0.11</td>
</tr>
<tr>
<td>kcp5</td>
<td>0.14</td>
<td>0.11</td>
<td>0.13</td>
<td>0.10</td>
<td>0.14</td>
<td>0.10</td>
</tr>
</tbody>
</table>

* Irrigation interval 1-d.

** Irrigation interval 2-d.

*** Irrigation interval 3-d.

kcp1 = 0.25; kcp2 = 0.50; kcp3 = 0.75; kcp4 = 1.00; and kcp5 = 1.25; crop-pan coefficients.
treatments with low ET values and irrigation water amounts and with high yield.

Changes in evapotranspiration/evaporation. In irrigation scheduling with class A pan, particular rates of evaporation from CAP are applied as irrigation water. To determine which of these applied rates is/are the closest to ET, it is necessary to determine the relationships between $E_p$ and ET as well as the ET/$E_p$ ratios. In conjunction with the development of ET equations, it is also valuable to compare crop ET with evaporation from a class A pan (Ertek et al., 2006). With this purpose, the relationship between ET and $E_p$ in I1/kcp4 produced the highest yield (Fig. 4) and the results concerning the changes in ET/$E_p$ ratios are presented in Figure 5.

The relationship between ET and $E_p$ in I1/kcp4, where the highest yield was obtained, has an exponential function ($ET = 1.1606E_p^{0.9299}, R^2 = 0.9522$). Not to have any decrease in yield, I1/kcp4, in which the highest yield was obtained, should be used as the irrigation schedule.

With respect to ET/$E_p$ ratios, similar curves were observed in similar treatments. ET/$E_p$ value seasonally ranged from 0.25 to 1.26 in treatments with a 1-d irrigation interval, whereas this value ranged from 0.08 to 1.34 and from 0.12 to 1.24 in treatments with 2- and 3-d irrigation intervals, respectively. The less the irrigation water was applied, the lower the ET/$E_p$ values were determined in treatments. The ET/$E_p$ ratios for all treatments were lower at the beginning, tended to increase rapidly midseason (in August), and then decreased after the first harvest (in September). A significant positive linear correlation was reported between accumulated ET and $E_p$ by many researchers (Dogan et al., 2008; Ertek et al., 2006; Wang et al., 2009; Yuan et al., 2001). Irrigation water amount can be accomplished by inserting the accumulated evaporation of the intervals into the equations. The ratio of ET and $E_p$ changed seasonally during the growing season. ET/$E_p$ ratios were higher in the midseason than in the other growing periods as a result of stem elongation, leaf enlargement, and flowering (Fig. 5). Similar findings were reported by Ertek et al. (2006).

Conclusion

In our study, maximum yield was obtained from I1/kcp4. Therefore, the I1/kcp4 treatment (I1: 1-d irrigation interval, kcp:1.00) should be taken as the basis during irrigation scheduling by means of CAP in protected carnation cultivation.

Under this condition, however, deep percolation will be much (119 mm), whereas the IWUE (0.14 stems/m²/mm) value will be less. If deep percolation is intended to be reduced and increased the IWUE value and with respect to efficient water use, it might be more suitable to apply kcp2 until pinching, kcp3 between pinching, and 60 DAP and kcp4 treatments from 60 DAP to the end of the growing season under the condition of a 1-d irrigation interval. In this way, quality flowers can be obtained without any decrease in yield. Furthermore, it may be more convenient not to apply any water deficit based on the crop-pan coefficient or, if water deficit will be applied, it may be more suitable to do so in I1 (k0 = 0.73) with a low k0 value because of the higher k0 values in I2 (k0 = 1.00) and I3 (k0 = 1.42) than that of I1 (k0 = 0.73) and also considering the fact that the carnation plant is quite sensitive to water at these irrigation intervals.

Literature Cited


