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Full Length Research Paper

The effects of different irrigation levels on flowering and flower quality of carnation (*Dianthus caryophllus* L.) irrigated by drip irrigation

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Water usage is a vital issue for all agricultural crops as well as for ornamental crops. To obtain high quality flowers, it is essential to supply water when it is required. A problem which is common with cut flower growers are determining when to irrigate and the amount of water to apply. The effect of two irrigation intervals (I_1: 10 mm pan evaporation and I_2: 20 mm pan evaporation) and four pan coefficients (Pc_1 = 0.60 Epan, Pc_2 = 0.90 Epan, Pc_3 = 1.20 Epan and Pc_4 = 1.50 Epan) based on the amount of evaporation measured by a Class A Pan (CAP) on flower yield and flower quality of carnation (*Dianthus caryophyllus L.* cv. "Judith") plant grown in a plastic greenhouse and irrigated by a drip irrigation system under Mediterranean conditions was investigated. Irrigation intervals varied from 1 to 6 days in I_1 and 4 to12 days in I_2 treatments. Both irrigation intervals (I) and pan coefficient (Pc) significantly influenced carnation yield. Maximum yields were obtained from the I_1Pc_3 treatment as 6.7 and 6.8 flowers per plant and minimum yields from the I_2Pc_1 treatment as 5.6 flowers per plant in the first and second year of the experiment, respectively. Similarly, irrigation intervals and pan coefficient had significant different effects on quality parameters such as flower stem length, flower stem diameter, stem weight, flower diameter, and vase life. Better flower quality was obtained from the treatments of higher frequency irrigations with high pan coefficients compared to lower frequency irrigations with lower pan coefficients. In conclusion, I_1Pc_3 irrigation regime is recommended for growing cut flower carnation in order to obtain higher yield with improved quality.

Key words: Carnation, irrigation, Class A Pan, pan coefficient.

INTRODUCTION

The cut flower grew in the world presently begun in the beginning of the 20th century and it has become an important commercial activity in many developed and developing countries, especially after the end of World War II. The total production land for ornamental plants reached about 610.000 ha. It is known that there are more than 50 countries in the world performing cut flower growing. The most important producers of the European Union are Italy, the Netherland and Spain. The countries of European Union produce 47 % of the total cut flower production of the world. Carnations are among the most extensively grown cut flower in the world (AIPH, 2007).

Although it is indigenous to the Mediterranean region, the carnation can be grown in almost every climate; in temperate zones, mostly in glasshouses, in sub-tropic areas, in plastic houses and glasshouses, as well as in open field and in tropic areas more or less shaded. Carnations may be planted at any time of the year, but planning peak production for times of peak demand is important.

The carnation has been commercially grown in Turkey as a cut flower crop since 1945. It can be grown easily in simple greenhouses under Mediterranean climate and soils having high pH and carbonate content. Because its transportation and marketing are relatively easy and it

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requires low initial investment costs, carnations are among the most extensively grown cut flowers not only in the world but also in Turkey. The cut flower production area in Turkey mostly includes carnation (43%), followed by rose (12.5%) and gladiolus (12%). In Turkey, the most important export production in cut flower is carnation and it consists of 89% of cut flower export. The number of carnation exported in 2009 were 296 218 547 stems and the amount of money obtained was 21 828 260 USD (AIB, 2010).

An ideal soil for carnation growth is loamy sand or sandy loam soils well drained to a depth of 0.75 to 1.0 m and slightly alkaline. Agricultural use of water is an important issue for cut flower growers. Water use in greenhouse cut flower production is frequently at excessive levels. To obtain better flower yield and flower quality, irrigation under arid climates and greenhouses conditions is essential. The amount of irrigation water and frequency in carnation depends on soil texture, photo-period, relative humidity, temperature, air convection, growing period and variety. As a general rule, it is required that the soil cultivated with carnation should be always moist. When the soil moisture level drops below the wilting point, the flowering and flower quality are affected negatively. One of the consequences of exposing plant to deficit irrigation regimes in terms of plant growth is the production of smaller leaves and shorter internodes sections and reductions in flower number, size and quality (Cameron et al., 1999; Sanchez-Blanco et al., 2004).

At present and most probably also in the future, as a result of global warming, irrigated agriculture will take place under water scarcity. Hence, sustainable methods to increase crop water productivity are gaining importance in arid and semi-arid regions. In other words, irrigation management in arid and semi-arid regions will shift from emphasizing production per unit area towards maximizing the production per unit of water consumed (Fereres and Soriano, 2007).

There are a few studies related to the effect of irrigation on yield and quality of carnation. Jasper (1966) reported that the maximum yield and the best quality could be obtained when the soil water tension is kept at -0.04 bars. Hanan (1969) pointed out that, when the solar radiation is about 600 cal m^{-2}, water use of carnation grown in greenhouse covered with glass is 12.28 mm whereas it is 8.19 mm for carnation grown in greenhouse covered with plastic. Khristov and Parlov (1977) reported that the carnation should be irrigated when 40% of the available soil moisture is depleted. Taylor et al. (2008) reported that the maximum flower yield and the best quality were obtained when the soil moisture tension was kept at -45 kPa.

In cut flower sector, more irrigation water is applied than crops need. A common irrigation practice among carnation growers, at least in Turkish growers, is to apply a large amount of irrigation water every day without any estimates of soil water contents in the plant root zone. Their rationale for doing so is the assumption that more irrigation water means more yields. On the contrary, eliminating unnecessary irrigation water could help in conserving irrigation water and preventing pollutants such as pesticides and fertilizers leaching to groundwater, provided that it can be done with low yield losses. The estimation of soil water content in the root zone is essential for a better irrigation management. In cut flower production, some researchers, although they did not mention a specific value, reported that carnation growers commonly irrigate too infrequently and that too much irrigation water is applied when irrigations are performed (Menguc and Eris, 1987; Ozkan et al., 1998; Ozzambak, 2003). The aim of this study was to determine the effects of different irrigation intervals and levels on yield and flower quality characteristics of drip irrigated *Dianthus caryophyllus L.* cv. "Judith" under protected conditions.

MATERIALS AND METHODS

The study was conducted in a plastic greenhouse located at the Bati Akdeniz Agricultural Research Institute, Antalya, Turkey between 2005 to 2007. The plastic covered greenhouse having size of 12 m x 40 m was divided into two rooms and oriented in the North-South direction. The research area was located at a latitude of 36 56' N and a longitude of 30 53' E, and an altitude of 28 m. The climate of the region is typically Mediterranean that is mild and rainy in winter and dry and hot in summer. The soil of the research area has a clay-loam texture, is unsalted and rich in calcium carbonate and alkali. Its weight based field capacity, permanent wilting point and bulk density are 27.5 %, 17.1 % and 1.35 g cm^{-3}, respectively. Some physical and chemical properties of greenhouse soil and irrigation water determined *in situ* and in the laboratory are given in Tables 1 and 2.

Two irrigation intervals (I_1: 10 mm pan evaporation and I_2: 20 mm pan evaporation) and four pan coefficient levels (Pc_1 = 0.60 Epan, Pc_2 = 0.90 Epan, Pc_3 = 1.20 Epan and Pc_4 = 1.50 Epan) were examined in the study. Irrigation treatments were based on evaporation data (Epan, mm) obtained from a Class A Pan (CAP) located inside the greenhouse. The pan was located on a wooden support at a height of 15 cm above the soil surface and readings were recorded daily. Judith standard carnation seedlings were used as plant material. Irrigation intervals were designed according to randomized blocks whereas CAP coefficients were designed as sub-plots. Thus, 2 x 4 split plots were applied and each treatment was replicated four times. As a result, 32 plots, each plot having 0.80 x 4.5 m in size and containing 80 carnation seedlings, were formed.

Seedlings were planted on 20 x 20 cm intervals on the ridge of furrows having a length of 20 m, a width of 0.80 m and a height of 0.20 m from 12 July 2005 to 13 June, 2006. To carry out cultural practices, 0.50 m wide walking spaces was left between the plots. During the experiment, the necessary cultivation practices such as maintenance, fertilization, pinching, and agricultural protection were carried out.

The experimental plots were irrigated by drip irrigation. The drippers having a discharge of 4 l h^{-1} at a pressure of 0.1 MPa on laterals were located 20 cm apart. The laterals were arranged in such a way that every ridge had three laterals with 20 cm intervals. The amount of irrigation water applied in the treatments was controlled by using a gauge on the main pipeline and valves located on each lateral. The irrigation water to be applied was calculated by

Table 1. Some physical and chemical properties of the experimental soil.

Soil property	Value
Soil depth (cm)	0-20
Texture	Clay-loam
Field capacity (%)	27.5
Permanent wilting point (%)	17.1
Bulk density (g cm^{-3})	1.35
pH	8.0
Organic matter (%)	2.9
EC (dS m^{-1})	0.81
$CaCO_3$ (%)	27.6

Table 2. Quality parameters of irrigation water.

Parameter	Value
pH	7.7
ECdS m^{-1}	0.462
Na (me l^{-1})	0.60
K (me l^{-1})	0.106
Ca (me l^{-1})	4.18
Mg (me l^{-1})	1.90
CO_3 (me l^{-1})	-
HCO_3 (me l^{-1})	4.24
Cl (me l^{-1})	0.30
SO_4 (me l^{-1})	2.23
SAR	0.34

the equation given below.

$$I = Pc \times Epan \times A \times P \quad (1)$$

Where, I is the irrigation water (mm), Pc is the pan coefficient, Epan is the cumulative evaporation (mm), A is the plot area (m^2) and P is the wetted area percentage (%). The wetted area was taken as 100% assuming that lateral interval is equal to the spaces between drippers.

Water use of carnation under plastic greenhouse conditions is computed using water balance equation, neglecting surface runoff, given below.

$$WU = I - Dp \pm \Delta SW \quad (2)$$

Where, WU is the water use (mm), I is the total irrigation water (mm), Dp is the deep percolation and ΔSW is the change in soil water storage between the planting and harvest time (mm). The moisture content in the upper 20 cm depth of the soil was taken into consideration. The moisture content at this depth was monitored daily by tensiometers and gravimetrically in ten day intervals. In the case that the soil moisture, which was determined using the measured tensiometers values together with the soil water characteristic curve was above the field capacity after irrigation applications, this surplus was considered as deep percolation. Water use efficiency (WUE) was calculated as flowers per plant yield divided by seasonal ET (Howell et al., 1990).

Irrigation water used in the experiment is classified as C_2S_1, which can be used safely in carnation, and has no sodium hazard. Electrical conductivity and sodium adsorption ratio (SAR) value of irrigation water were 0.462 dS m^{-1} and 0.34, respectively. When the carnation seedling was planted, rooted cuttings wilt easily. To prevent this, an amount of 100 mm irrigation water was applied in all treatments by using mist irrigation systems during the first three weeks of production period for rooting.

In the study, flower stem length (cm), flower stem diameter (cm), flower diameter (cm), stem weight (g), vase life (day) and yield (flowers $plant^{-1}$) in the experimental plots were determined. A variance analyses was applied to the data obtained and the Duncan's multiple range test was used to compare the means (Gomez and Gomez, 1984).

RESULTS

Amount of irrigation water and water use

Irrigations based on the measured CAP evaporation values started on 1 October 2005 in the first year and ended 20 April 2006, while it started on 1 August, 2006 in the second year and ended on 30 April, 2007. The measured cumulative evaporation and water use of the treatments during the first and second year are presented in Figures 1 and 2. While the total and average daily evaporation in the 200 days period were 366.3 mm and 1.8 mm day^{-1}, respectively in 2006, the total and daily evaporation in the 273 days period were 833.5 mm and 3.1 mm day^{-1}, respectively in 2007. Higher total pan evaporation recorded in the second year of the experiment stems from the fact that the experiment started two months earlier and ended 10 days later compared to the first year. Higher daily evaporation rate as a result of higher temperature recorded in the months of August and September increased average evaporation rate in the second year. The total evaporation in the first two months of the second year, August and September 2006, was measured as 343.3 mm. Additionally, higher temperature recorded between October 2006 May 2007 in the second year of the experiment, as seen in Figure 3, caused the evaporation of 124 mm of more water compared to the same period in the first year of the experiment.

The change in soil water content measured gravimetrically at 10 day intervals is depicted in Figures 4 and 5 for the first and second year of the experiment, respectively. The soil water content in the treatments of higher pan coefficients (I_1Pc_3, I_1Pc_4, I_2Pc_3 and I_2Pc_4) were maintained at about the field capacity, while the soil water content in the treatments of lower pan coefficient (I_1Pc_1 and I_2Pc_1) dropped below the permanent wilting point towards the end of the experiment. Also, the soil water tension was monitored by tensiometers, sometimes after the irrigations, it was observed that the soil water content exceeded field capacity. Deep percolation was computed using the measured tensiometers values and after converting tension to soil water content using the soil pF-curve. pF curve was obtained using standard methods (desiccation).

The yield, applied water, deep percolation, change in

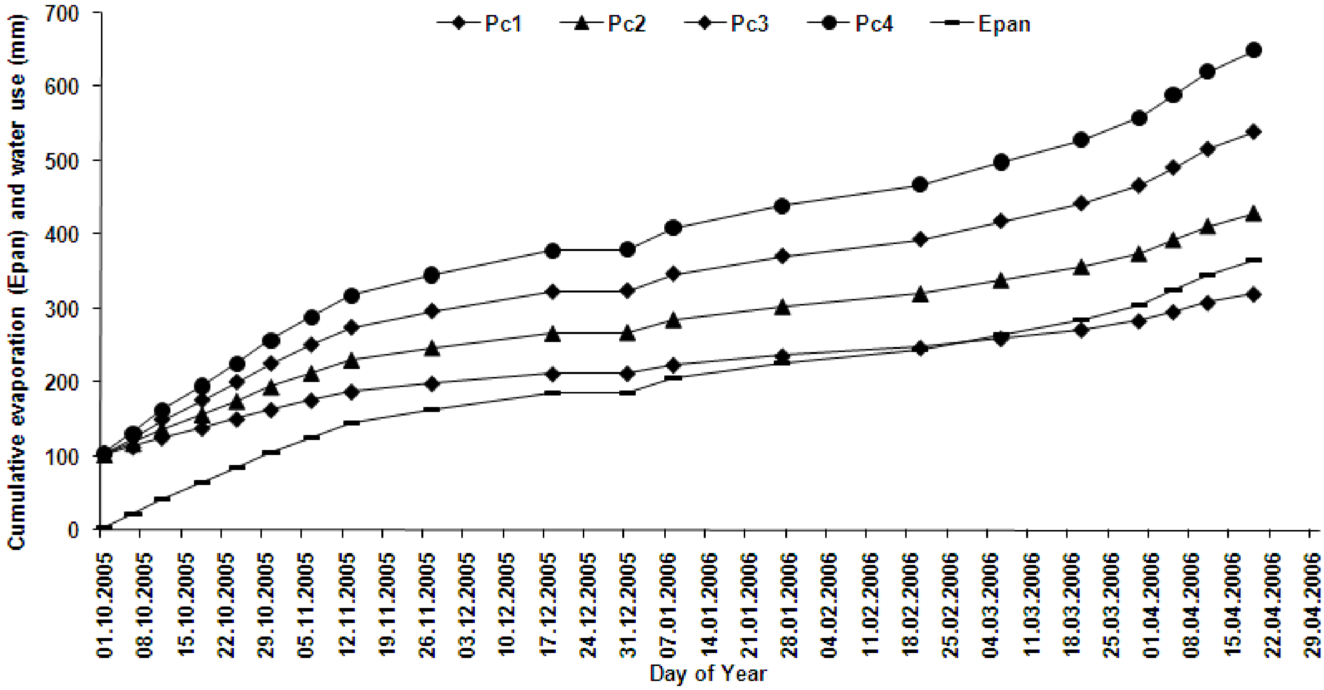

Figure1. Cumulative CAP evaporation and water use in the first year of the experiment.

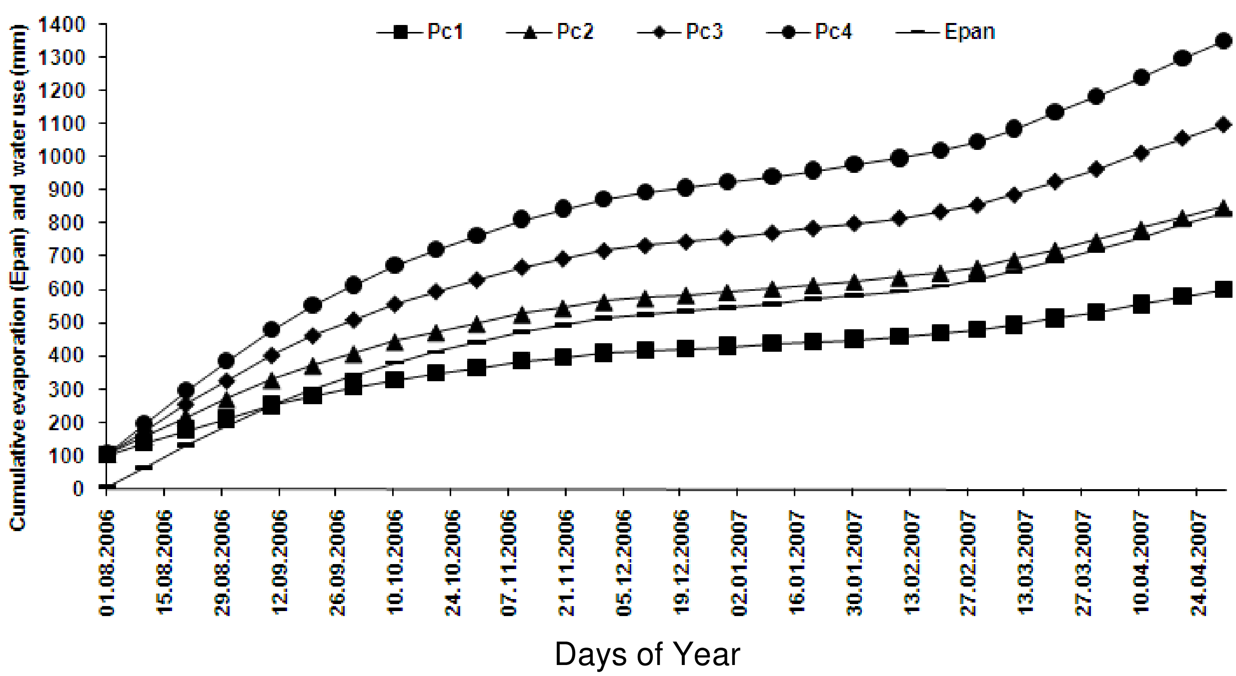

Figure 2. Cumulative CAP evaporation and water use in the second year of the experiment.

soil water content, water use, and water use efficiency during the first and second growing period in all the treatments are presented in Table 3. As mentioned in the material and method section, the irrigation water (I) in Table 3 includes also the amount of 100 mm water applied equally in all the treatments for rooting. In the first year, the amount of water applied to Pc_1, Pc_2, Pc_3 and Pc_4 treatments were 319.8, 429.7, 539.5 and 649.4 mm,

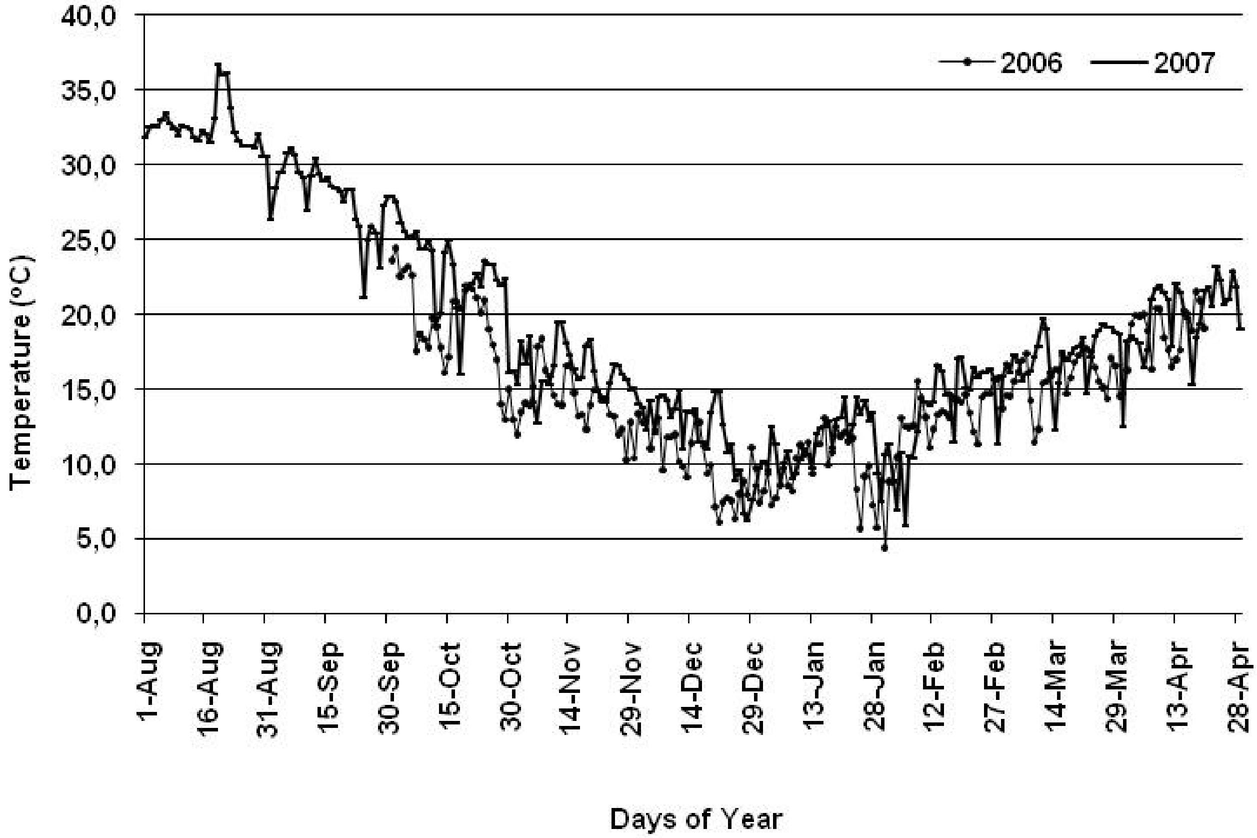

Figure 3. Greenhouse temperature in the first and second year of the experiment.

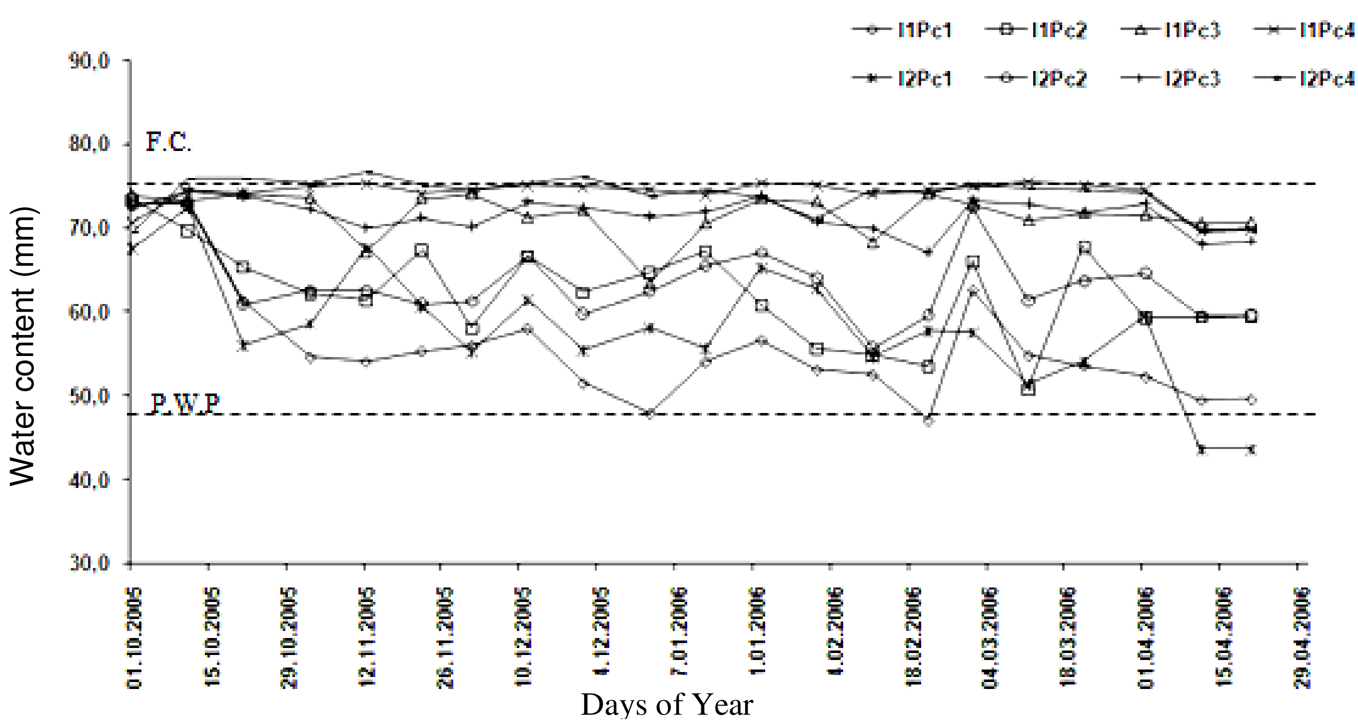

Figure 4. Change in soil water content in the first year of the experiment.

Table 3. The components of water balance and WUE in the first and second year of the experiment.

Year	Treatment	Yield number (m^{-2})	I (mm)	Dp (mm)	ΔSW (mm)	WU (mm)	WUE number(m^{-2} mm^{-1})
2006	I_1Pc_1	147.5	319.8	51.4	21.8	290.2	0.51
	I_1Pc_2	160.0	429.7	72.9	19.9	376.9	0.42
	I_1Pc_3	167.5	539.5	97.1	18.8	461.2	0.36
	I_1Pc_4	162.5	649.4	110.3	13.2	552.3	0.29
	I_2Pc_1	140.0	319.8	19.1	23.5	324.2	0.43
	I_2Pc_2	150.0	429.7	21.5	24.8	433.0	0.35
	I_2Pc_3	157.5	539.5	29.7	19.0	528.8	0.30
	I_2Pc_4	147.5	649.4	38.9	14.4	624.9	0.24
2007	I_1Pc_1	150.0	600.1	122.2	23.2	501.1	0.30
	I_1Pc_2	162.5	850.2	157.1	9.2	702.3	0.23
	I_1Pc_3	170.0	1100.2	199.0	4.2	905.4	0.19
	I_1Pc_4	165.0	1350.3	229.6	3.0	1123.7	0.15
	I_2Pc_1	140.0	600.1	36.0	13.7	577.8	0.24
	I_2Pc_2	155.0	850.2	49.6	9.8	810.4	0.19
	I_2Pc_3	157.5	1100.2	60.9	5.8	1045.1	0.15
	I_2Pc_4	150.0	1350.3	99.8	3.9	1254.4	0.12

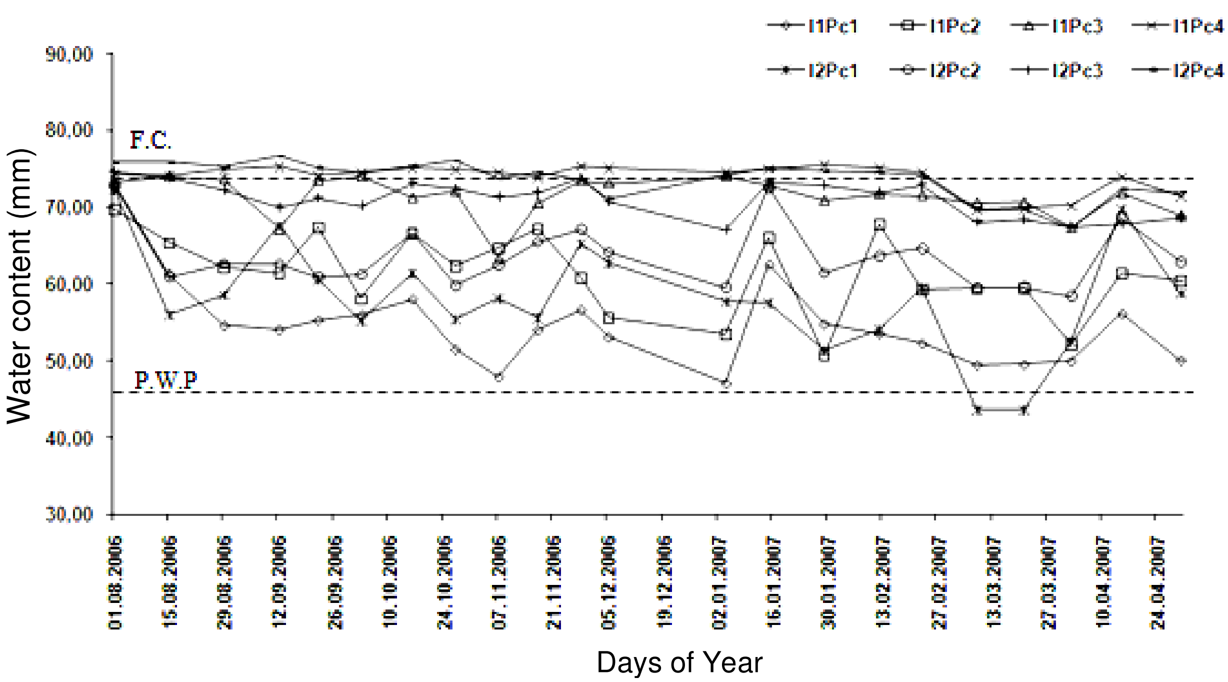

Figure 5. Change in soil water content in the second year of the experiment.

respectively. In the second year, the amount of water applied to Pc_1, Pc_2, Pc_3 and Pc_4 treatments were 600.1, 850.2, 1100.2 and 1350.3 mm, respectively. Deep percolation from the root zone was also one of the important components in soil water balance. The difference of drainage amount between treatments depended on the amount of total irrigation. As the amount of water applied in each treatments increased, depending on CAP coefficients, deep percolations increased also.

On the other hand, when the irrigation intervals increased, a decrease in deep percolation was observed because of the increased deficiency in soil water storage as a result of transpiration by carnation plants and evaporation over soil surface. I_1Pc_4 irrigation application had

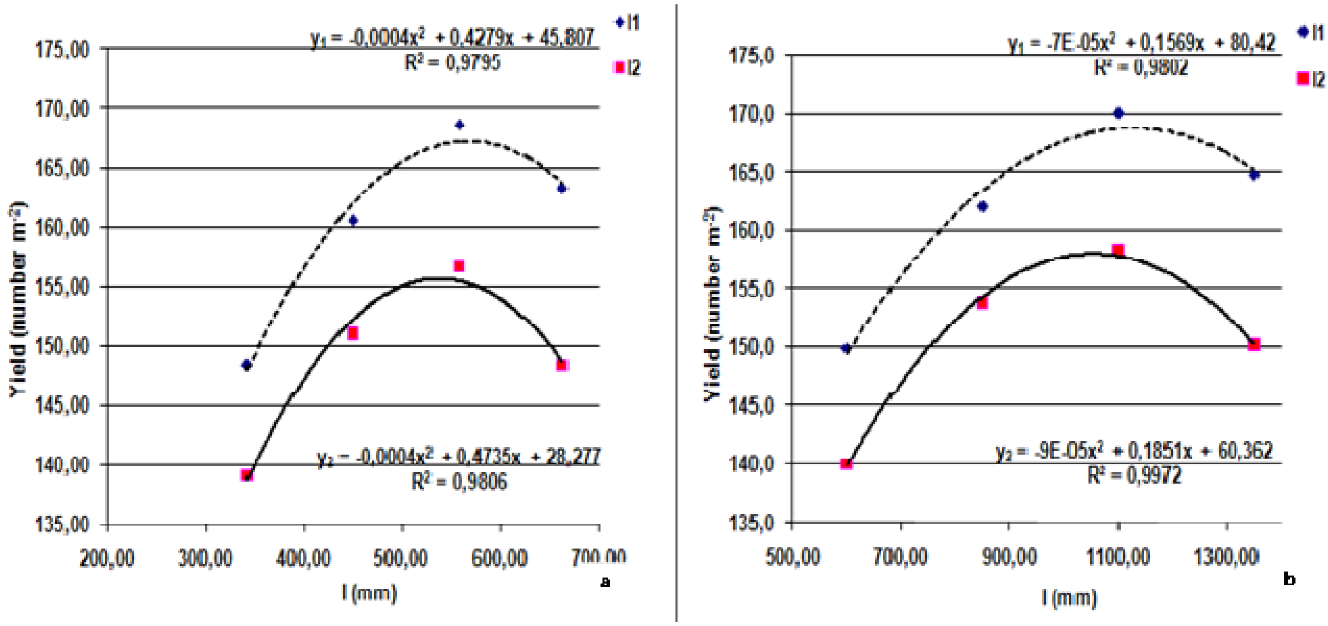

Figure 6. Relationships between flower yield and amount of irrigation in the first (a) and second year of the experiment (b).

the largest deep percolation amount and treatment I_2Pc_1 had the least amount of deep percolation (Table 3). Seasonal water use (WU) varied from 290.2 to 624.9 mm in the first year and 501.1 to 1254.4 mm in the second year of the experiment. As seen in Table 3, water use increased with increasing pan coefficient in each irrigation intervals. For a given pan coefficient, although the same irrigation water was applied, as irrigation interval increased, water use also increased as a result of decreasing deep percolation and increasing amount of water taken from the soil water storage (Table 3).

WUE values decreased when the amount of water use increased (Table 3). The highest WUE was obtained from I_1Pc1 treatment as 0.51 and 0.30 number m^{-2} mm^{-1} in the first and second year of the experiment, respectively. Halepyati et al. (1995) also obtained similar WUE values for *Polianthes tuberose* crop. The authors reported the highest value of WUE in the treatment, where applied irrigation water was 40% of pan evaporation while the highest flower yield was obtained from treatment where irrigation water was 120% of pan evaporation. Similar to their results, in both years of this study, the highest flower yield was obtained from the treatment where pan coefficient was 120% while the highest WUE value was obtained from the treatment, where pan coefficient was 60.

Water-yield relations

The relationship for carnation flower yield per unit area and the amount of irrigation in the first and second year of the experiment is illustrated in Figure 6. A second-degree polynomial equation is fitted to the data of flower yield and amount of irrigation. Coefficient of determination (r^2) values were found to be 0.98 in the first year for both of the irrigation intervals while in the second year, it was found to be 0.98 and 0.99 for I_1 and I_2 irrigation intervals, respectively.

In the first year, flower yield reached a maximum of at about 550 mm with a yield of 156 and 167 flower m^{-2} for I_1 and I_2 irrigation treatments, respectively. In the second year, flower yield reached a maximum at about 1100 mm with a yield of 157 and 168 flower m^{-2} for I_1 and I_2 irrigation treatments, respectively. The amount of applied water increased two fold compared to the first year, but the flower yield was about the same as the first year. This result reveals an interesting point from irrigation management point of view. Although it was planted two months earlier in the second year, the yield per unit area did not change noticeably. This shows that although carnations can be planted at any time of the year, the most effective result in terms of water-yield relations can be obtained with late September plantings that also come into production at Christmas.

Flower yield and quality

It was found that except for flower stem diameter, flower stem length, flower diameter, internode length, stem weight, vase life and yield in pan coefficients were statistically different (P≤0.001) (Table 4). As the irrigation intervals were examined, it was seen that flower stem diameter, flower stem length, flower diameter, stem weight and yield were found statistically different (P≤0.05, 0.01 and 0.001) except forninternodes length and vase life. The average values with respect to yield and flower quality are given in Table 5.

The longest flower stem length was obtained from I_1Pc_3

Table 4. Variance analyzes results with respect to yield and flower quality of carnation.

Source of variation	d.f.	Characteristic (variable)													
		Flower stem length (cm)		Flower stem diameter (cm)		Flower diameter (cm)		Internode length (cm)		Stem weight (g)		Vase life (days)		Yield (number plant^{-1})	
		2006	2007	2006	2007	2006	2007	2006	2007	2006	2007	2006	2007	2006	2007
Replication	3														
Irrigation intervals (I)	1	***	***	**	*	***	***	NS	NS	NS	*	NS	NS	***	***
Pan coefficient (Pc)	3	***	***	NS	NS	***	***	**	***	***	***	***	***	***	***
IxPc	3	***	***	NS	NS	NS	NS	NS	NS	**	***	NS	NS	NS	*
Error(IxPc)	21														
Total	31														

NS, Not significant; * Significant at P<0.05; ** Significant at P<0.01; *** Significant at P<0.001.

Table 5. The average values of yield and flower quality in irrigation treatments.

Characteristic	Year	I_1				I_2			
		Pc_1	Pc_2	Pc_3	Pc_4	Pc_1	Pc_2	Pc_3	Pc_4
Flower stem length (cm)	2006	62.8 f	70.9 c	81.8 a	79.2 b	60.3 g	65.7 e	71.7 c	68.1 d
	2007	65.0 f	73.1c	84.0a	81.4b	62.5g	67.9e	73.9c	70.3d
Flower stem diameter (cm)	2006	0.61	0.63	0.65	0.61	0.56	0.56	0.58	0.58
	2007	0.63	0.65	0.67	0.63	0.58	0.58	0.60	0.60
Flower diameter (cm)	2006	2.84	2.90	2.98	2.96	2.74	2.82	2.91	2.90
	2007	2.87	2.93	3.00	2.99	2.77	2.85	2.94	2.93
Internode length (cm)	2006	6.6	7.3	8.2	7.3	6.5	6.9	7.8	6.8
	2007	6.7	7.9	8.2	7.4	6.4	7.1	7.8	7.6
Stem weight (g)	2006	29.4 d	32.5 c	39.6 a	39.9a	35.9 b	38.6ab	38.9 ab	38.7ab
	2007	30.7d	33.9c	40.9a	41.2a	37.3b	39.9ab	40.2ab	40.0ab
Vase life (days)	2006	18.3	19.5	22.8	22.8	18.5	20.5	23.3	22.8
	2007	19.0	20.5	23.7	23.7	19.2	21.5	24.2	23.7
Yield (flowers plant^{-1})	2006	5.9	6.4	6.7	6.5	5.6	6.0	6.3	5.9
	2007	6.0e	6.5b	6.8a	6.6b	5.6f	6.2d	6.3c	6.0e

Different letters show different means according to Duncan's test.

treatments in 2006 and 2007 (81.8 and 84.0 cm, respectively), while the shortest flower stem length was observed in I_1Pc_1 treatments (62.8 and 65.0 cm) as seen in Table 5. As the total water use increased, flower stem length was also increased. The results obtained from the study are in accordance with already published studies (Khristov and Parlov, 1977; Kageyama et al., 1985; Masequera et al., 1989; Baas et al., 1995; Bastug et al., 2006). Low frequency irrigations with low CAP coefficients cause a decrease in flower stem length. Safi et al. (2005), in their study where they used saline water (2.5 to 3.0 dS m^{-1}), reported also that as the irrigation intervals increased, the yield and flower quality decreased. Since the plant nutrients and enzymes are transported with water, the total water use is essential in plants such as carnation whose vegetative period lasts 11 months.

While the thickest flower stem diameter was obtained from I_1Pc_3 treatments (0.65 cm) in the first year and I_1Pc_3 treatments (0.67 cm) in the second year, the thinnest flower stem diameter was observed in I_2Pc_1 and I_2Pc_2 treatments (0.56 cm) in the first year and I_2Pc_1 and I_2Pc_2 treatments (0.58 cm) in the second year, (Table 5). As the CAP coefficients increased, flower stem diameter was also increased. It is also possible to state that low CAP coefficients cause's water stress resulting in thinner flower stem diameter (Korkmaz, 1995; Cameron et al., 1999; Safi et al., 2005).

The thickest flower diameter was obtained from I_1Pc_3 treatment (2.98 cm) in the first year and I_1Pc_3 treatment (3.00 cm) in the second year while the shortest flower diameter was observed in I_2Pc_1 treatment (2.74 cm) in the first year and I_2Pc_1 treatment (2.77 cm) in the second year (Table 5). When the soil water content is kept around the field capacity, flower diameter increased. Results obtained in this study are in accordance with already published studies (Hanan, 1969; Khristov and Parlov, 1977; Reid, 2000; Safi et al., 2005).

The heaviest stem weight was observed in I_1Pc_4 treatment (39.9 g) in the first year and I_1Pc_4 treatment (41.2 g) in the second year of the experiment, while the lightest stem weight was obtained from I_1Pc_1 treatment (29.4 g) in the first year and I_1Pc_1 treatment (30.7 g) in the second year. In Table 5, a moderate restriction of water available in the soil slightly reduced total dry stem weight (Cameron et al., 1999; Alvarez et al., 2009).

The longest internodes length was obtained from I_1PC_3 treatment both in the first and second year (8.2 cm), while the shortest internodes length was observed in I_1Pc_1 treatments (6.6 and 6.7 cm) (Table 5). It was seen that when the CAP coefficient increased and irrigation intervals decreased, internodes length was increased. Our results agree with Safi et al. (2005), who stated that higher CAP coefficient could improve stem length and its positive effects on internodes lengths.

The longest vase life was determined in I_2Pc_3 treatment (23.3 days) in the first year and I_2Pc_3 treatment (24.2 days) in the second year of the experiment. The shortest vase life was obtained from I_1Pc_1 treatment (18.3 days) in the first and I_1Pc_1 treatment (19.0 days) in the second year. The length of the vase life is related to shorter flower stem length and thinner flower stem diameter, which was determined to be a function of decreasing soil water content. Flowers grown under the low frequency irrigation treatments had a significant shorter vase life compared to the other treatments (Farina and Carvelli, 1994; Korkmaz, 1995; Taylor et al., 2008). These vase life data demonstrate that irrigation intervals and CAP coefficients can have a substantial effect on the longevity of carnation flowers during the vase life.

The highest yield on the average per plant was obtained from I_1Pc_3 treatment in the first and in the second year of the experiment (6.7 and 6.8 flowers plant^{-1}), and the lowest yield on the average per plant was observed in I_2Pc_1 treatment in the first and second year (5.6 flowers plant^{-1}) (Table 5.) Increasing irrigation intervals causes lower yield per plant. Higher frequency irrigation with high Pc values created favorable soil water environment for carnation growth and resulted in higher yield. It may be stated that the yield increased as a result of keeping the soil water content at required level (Khristov and Parlov, 1977; Allera et al., 2002; Safi et al., 2005).

Pugnaire et al. (1994) reported that water deficiency in the crop root zone affected not only vegetative growth of the plant but also the quality and quantity of the crop yield. The authors also stated that similar effects occur at high soil water content in the root zone. In both cases, as a result of negative effects on cell growth, the cells were smaller. A decrease in cell growth, whether because of higher or lower water content, causes a decrease in cell wall. This will cause small sizes in plant leaves resulting to stomatal closure and lower photosynthetic activity (Davies et al., 2002; Sanchez-Blanco et al., 2004). Almost all the best parameters in this study were obtained in the I_1Pc_3 treatment where lower irrigation intervals and relatively higher CAP coefficients were applied.

Conclusions

The results obtained in this study demonstrate that the effects of irrigation water amount and irrigation frequency are significantly important in order to obtain higher yield of carnation grown in unheated plastic greenhouses under the Mediterranean climatic conditions. Irrigation intervals and different pan coefficients applied had significant effects on all the characteristics of yield and flower quality of *D. caryophyllus* L. cv. Judith except for flower stem diameter. The highest yield and quality characteristics were obtained from I_1Pc_3 treatment (cumulative CAP evaporation reached 10 mm and CAP coefficient of 1.20). The total water use of Pc_1, Pc_2, Pc_3

and Pc_4 treatments were found to be 341.6, 449.5, 558.3 and 662.7 in the first year and 501.1, 702.3, 905.4 and 1123.7 in the second year, respectively.

Based on the results obtained from the experiment, when the irrigation intervals and pan coefficients were evaluated together, it is concluded that flower stem length, flower stem diameter, flower diameter, stem weight, vase life, and yield were increased depending on higher irrigation intervals and pan coefficients compared to lower ones. It is concluded that low frequency irrigation water regimes may improve water use efficiency by reducing water consumption, not only low regimes but also high irrigation water regimes reduced plant size and decreased its ornamental quality. Under the conditions that water resources are scarce, it can be recommended that lower Pc values like Pc_2 treatment should be used instead of Pc_3 in order to save water.

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