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Full Length Research Paper

Effects of different irrigation regimes on yield and some quality parameters of carnation

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This study was conducted to determine the effects of different irrigation water amounts (k_{cp}1: 0.25, k_{cp}2: 0.50, k_{cp}3: 0.75, k_{cp}4: 1.00 and k_{cp}5: 1.25) and irrigation intervals (I_1: 1-, I_2: 2- and I_3: 3-day) on the yield and some quality parameters of carnation plants (*Dianthus caryophyllus* L. cv. 'Turbo') grown in soil under greenhouse conditions. Class A Pan was used to determine irrigation water amounts. Yield and quality parameters (stem length, stem fresh weight, flower diameter and stem diameter) were significantly ($p < 0.01$) affected by the irrigation water amount and irrigation interval. While node number was affected by irrigation water amount, irrigation interval did not affect node number. The highest total flower number per m^2 was recorded in I_1k_{cp}4 (89.56 flowers m^{-2}), whereas the lowest total flower number per m^{-2} was found in I_3k_{cp}1 (10.0 flowers m^{-2}). Among the irrigation water amounts, the longest stems were determined in k_{cp}5 (71.04 cm) and k_{cp}4 (69.30 cm); however, the difference between both treatments was statistically insignificant. Among the irrigation intervals, the longest stem (67.56 cm) was obtained from the carnations irrigated with high irrigation interval (I_1) . The treatments with both the same irrigation water amount and higher irrigation intervals produced higher flowers yield and quality.

Key words: Carnation, irrigation interval, yield, quality parameters, stem length.

INTRODUCTION

Carnation has a great economic importance in the cut flower sector in Turkey due to both its production area and export potentiality. In Turkey, carnation accounts for 43% of a total cut flower production area of 1,199 ha and more than 90% of cut flower export (Anonymous, 2009). The great majority of carnation production in Turkey is performed in the Mediterranean region. The summer drought is the most characteristic property of Mediterranean ecosystems (Mooney and Parsons, 1973; Specht, 1979; Mooney, 1989). Within the Mediterranean ecosystem, Isparta province with suitable climatic conditions is an important center for summer carnation production in Turkey. Water, one of the indispensable elements of life, is the leading technological factor used to increase agricultural production. The maximization of yield per unit area particularly in arid, semi-arid and protected production is possible through supplying plants with water they require at the suitable time. Inside the greenhouse, crops require frequent irrigation in order to minimize water stress and accomplish maximum production and high quality (Sezen et al., 2010). For the efficient use of water from renewable but limited natural resources in agricultural production, the yield and quality parameters of plants under different irrigation schedules should be determined. One of the recent strategies used to control growth in plants is the application of water deficit to plants (Cerny et al., 2003; Montgomery et al.,

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2004; Cameron et al., 2006). Reductions in leaf area and internode section, flower number, size and/or quality are observed in those plants which are exposed to water deficit (Cameron et al., 1999; Sanchez-Blanco et al., 2002).

Water requirements of plants are quite different. Therefore, the effects of irrigation water amount and frequency on growth, development and yield of plants should be separately determined in each plant species. The irrigation water amount and frequency of the carnation plants vary with soil texture, photoperiod, air temperature and humidity, air movement, and the mass of the plants relative to loss of water by transpiration (Besemer, 1980). It was reported that yield and quality parameters were high in frequently irrigated carnations (Hanan and Jasper, 1969; Aydinsakir et al., 2009) and that a linear relationship was observed between the applied water amount and yield (Hanan and Jasper, 1969). However, it was emphasized that the irrigation of carnation under high soil moisture tensions reduced yield and quality (Taylor et al., 2004) and that stem length decreased under limited available soil water (Plaut et al., 1973). Similarly, Konishi (1978), Farina and Carvelli (1994) and Baas et al. (1995) pointed out that yield and quality parameters were negatively affected in carnations applied with deficient water; whereas Laurie et al. (1969) and Besemer (1980) stated that the soil must always be kept moist for good quality carnations. The aim of the study was to determine the effects of different irrigation intervals and water amounts on yield and some quality parameters in carnation plants grown in soil under greenhouse conditions in the Mediterranean ecology.

MATERIALS AND METHODS

The study was conducted in a plastic-covered greenhouse located at the Agricultural Research and Application Center of Agricultural Faculty at Suleyman Demirel University (latitude 37° 83' N, longitude 30° 53' E, altitude 1020 m) between June and November 2007 in Isparta, Turkey. Climate in this region is semi-arid with a mean annual rainfall of 524 mm. Rooted cuttings of carnation (*Dianthus caryophyllus* cv.' Turbo', which is a standard type) were planted on 01 June 2007 in plots (1.25 m long and 1.0 m wide) with a plant density of 32 plants m^{-2} (with four rows), and each plot contained 40 plants. Some characteristics of greenhouse soil (in 0 to 20 cm depth) in the study area were as follows: texture: clay loam, bulk density (g cm^{-3}): 1.31, field capacity (Pw (%): 18.10, permanent wilting point (Pw (%): 7.43, EC (dSm^{-1}): 110, pH: 7.85, $CaCO_3$ (%): 30.12, organic matter (%): 3.45. Water and nutrients were supplied through a drip irrigation system. The system was automatically controlled by a fertigation computer (Spagnol Ltd., Italy) . Lateral tubes with a diameter of 16 mm, dripper spacing of 20 cm and discharge of 2 l h^{-1} at 0.1 Mpa were used when supplying irrigation water. Each lateral tube irrigated one plant row. Since plant row spacing was equal to dripper spacing (20 cm), the percentage of the wetted area (P) was taken as 100% in the application of irrigation water (Keller and Bliesner, 1990).

The target pH and electrical conductivity values were 5.5 and 1.7 mS cm^{-1}, respectively. The composition of nutrient solution (ppm) was as follows: N: 160, P: 46, K: 224, Ca: 140, Mg: 18, Fe: 1.95, Mn: 0.41, Zn: 0.19 and B: 0.21 (Kazaz et al., 2009). Three different irrigation intervals (I_1: 1-day, I_2: 2-day and I^3: 3-day) and five different crop-pan coefficients (k_{cp}) ($k_{cp}1$: 0.25, $k_{cp}2$: 0.50, $k_{cp}3$: 0.75, $k_{cp}4$: 1.00 and $k_{cp}5$: 1.25) were applied in split plots experimental design with 3 replications. When first planted, rooted cuttings wilt easily (Besemer, 1980) . For successful cultivation, it is quite important to prevent the cuttings and/or rootballs from wilting and drying out within the first 2 weeks after planting (Besemer, 1980; Anonymous, 2010). Thus, the application of irrigation treatments was started 20 days after planting (DAP). 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 Equation (1) (Kanber, 1984).

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

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 (%).

Soil moisture change in the root zone of the plants was monitored with tensiometers. Tensiometers (Soilspec H and TS Electronics Pty. Ltd. Australia) were placed in 20 cm soil depth of each plot, and they were read before each irrigation application. In order to express soil moisture in mm, a calibration curve was created according to the soil characteristics, and the calibration curve equation was found as d (mm) = 31.38 × (kpa)$^{-0.19}$ (R^2 = 0.953) (d; soil moisture, mm, kpa; tensiometer readings). Evapotranspiration was determined using Equation (2) according to the principle of water balance (Allen et al., 1998).

$$ET= I + P \pm DSW - DP – RO \quad (2)$$

Where, ET is the evapotranspiration (mm), I the irrigation water (mm), P the precipitation (mm), DSW the change in the soil water storage (mm), DP the deep percolation (mm) and RO the amount of runoff (mm).

Runoff and precipitation were assumed to be zero. In the event that the sum of soil moisture and irrigation water was above the field capacity after irrigation applications, this surplus was considered as deep-percolation. Plants were pinched above the fifth leaf pair from the bottom (Whealy, 1992; Kazaz et al., 2009). To maintain straight stems, carnation plants were supported by four layers of mesh. Carnation harvest was started 96 DAP, and flowers were harvested 12 times in total, once every 5 days, during the study. Harvesting was performed above the second node from the base when flowers were fully open (Kazaz et al., 2009). The following data were recorded: flower number m^{-2}, stem length, fresh stem weight, flower diameter, stem diameter and node number. The program MINITAB software was used for the statistical analysis of data. Differences among averages were determined with LSD (5%) test.

RESULTS

Yield and evapotranspiration

During the study, the evaporation amount measured from Class A Pan (CAP) in the greenhouse was 644 mm. According to Equation (1), 218, 360, 502, 644 and 786 mm of irrigation water was applied to the $k_{cp}1$, $k_{cp}2$, $k_{cp}3$, $k_{cp}4$ and $k_{cp}5$ experimental treatments in the vegetation period, respectively. The highest evapotranspiration value (601 mm) was recorded in I_1 with a high irrigation interval; however, the lowest (219 mm) evapotranspira-

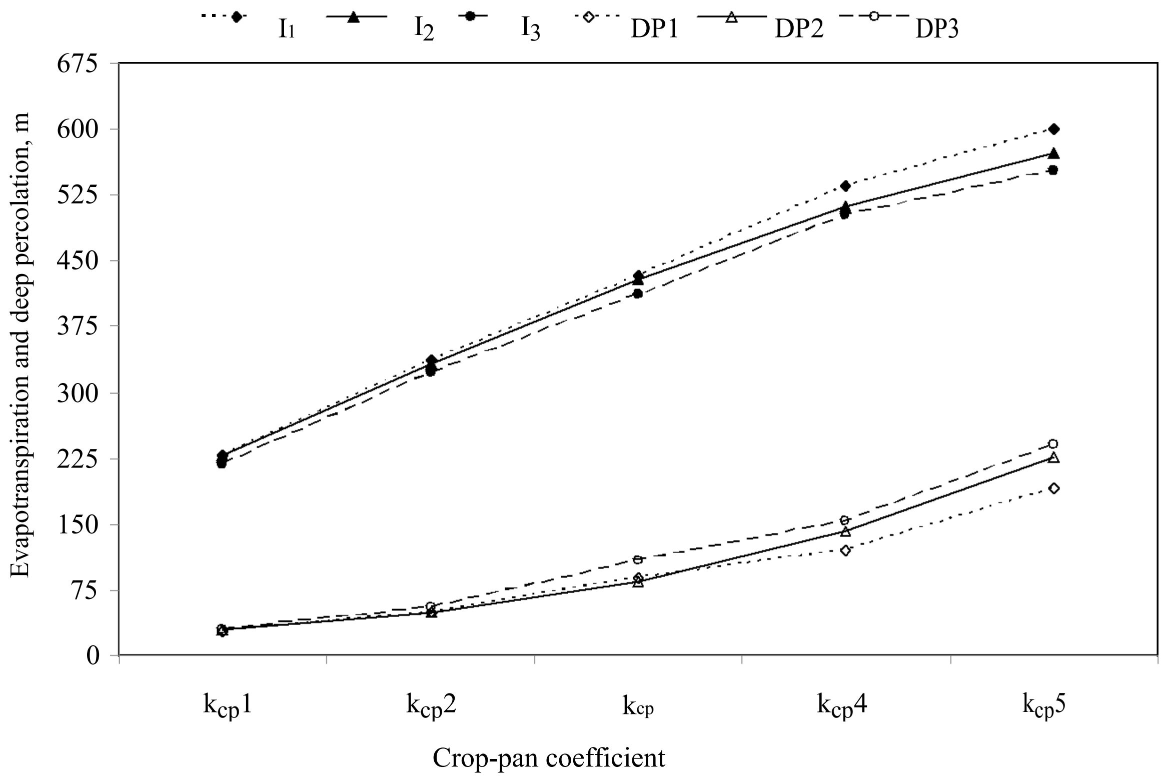

Figure 1. Evapotranspiration and deep percolation values with respect to irrigation treatments (Irrigation intervals: I_1: 1-, I_2: 2- and I_3: 3-day; DP_1, DP_2, DP_3: Deep percolations from I_1, I_2, I_3, respectively).

tion values were recorded in I_3 with a lower irrigation interval. On the other hand, regarding deep percolation, the highest values were in $k_{cp}5$ experimental treatments with a high crop-pan coefficient, while the lowest values were in the treatments with a low crop-pan coefficient (Figure 1). In the research, flowers were harvested 12 times in total at 5-day intervals between September 10 and November 4. Variations in the number of harvested flowers by irrigation regime during the period of harvest were shown in Figure 2a-e. Irrigation regimes significantly ($p < 0.001$) affected the number of harvested flowers during the period of harvest. As can be shown in Figure 2a-e, the maximum flower number was obtained on September 15 (101 DAP) under all irrigation intervals of the $k_{cp}1$ irrigation regime (Figure 2a) and on October 20 (106 DAP) in $k_{cp}2$ (Figure 2b). In $k_{cp}3$, the highest flower number was found on October 5 (121 DAP) in I_1, which had been irrigated every day, and on October 20 (136 DAP) in I_2 and I_3 (Figure 2c). Under each of three irrigation intervals of $k_{cp}4$ (Figure 2d) and under the I_2 irrigation interval of $k_{cp}5$, the highest flower number was reached on October 20 (136 DAP). However, the highest flower number in the other treatments of $k_{cp}5$ was obtained on October 10 (126 DAP) (Figure 2e).

In the present study, both irrigation intervals and crop-pan coefficients significantly ($p < 0.01$) affected total yield (Figure 3). In Figure 3, it is shown that the highest total flower number was obtained from the $I_1k_{cp}4$ treatment (89.56 flowers m^{-2}), followed by $I_1k_{cp}5$ (82.89 flowers m^{-2}) and $I_1k_{cp}3$ (82.22 flowers m^{-2}). The lowest total flower number was found in $I_3k_{cp}1$ (10.00 flowers m^{-2}), followed by $I_2k_{cp}1$ (32.67 number of flowers m^{-2}) and $I_3k_{cp}2$ (36.00 flowers m^{-2}). When irrigation intervals were considered in terms of total flower numbers, the highest total flower number was obtained from the I_1 treatments with a 1-day irrigation interval (73.11 flowers m^{-2}), followed by the I_2 (56.49 m^{-2}) and I_3 (48.27 m^{-2}) treatments with 2- and 3-day irrigation intervals, respectively.

Stem length

Stem length was significantly ($p < 0.01$) affected by both irrigation intervals and crop-pan coefficients. No significant interaction was observed between irrigation intervals and crop-pan coefficients in terms of stem length. The longest stems were obtained from $k_{cp}5$ (71.04 cm) and $k_{cp}4$ (69.30 cm), respectively, followed by $k_{cp}3$ (65.02 cm) (Figure 4a) . On the other hand, the shortest stems were recorded in $k_{cp}1$. In terms of irrigation intervals, the longest stems were obtained from I_1 (67.56 cm). However, there were no statistical differences between the I_2 (63.94 cm) and I_3 (61.02 cm) treatments (Figure 4b).

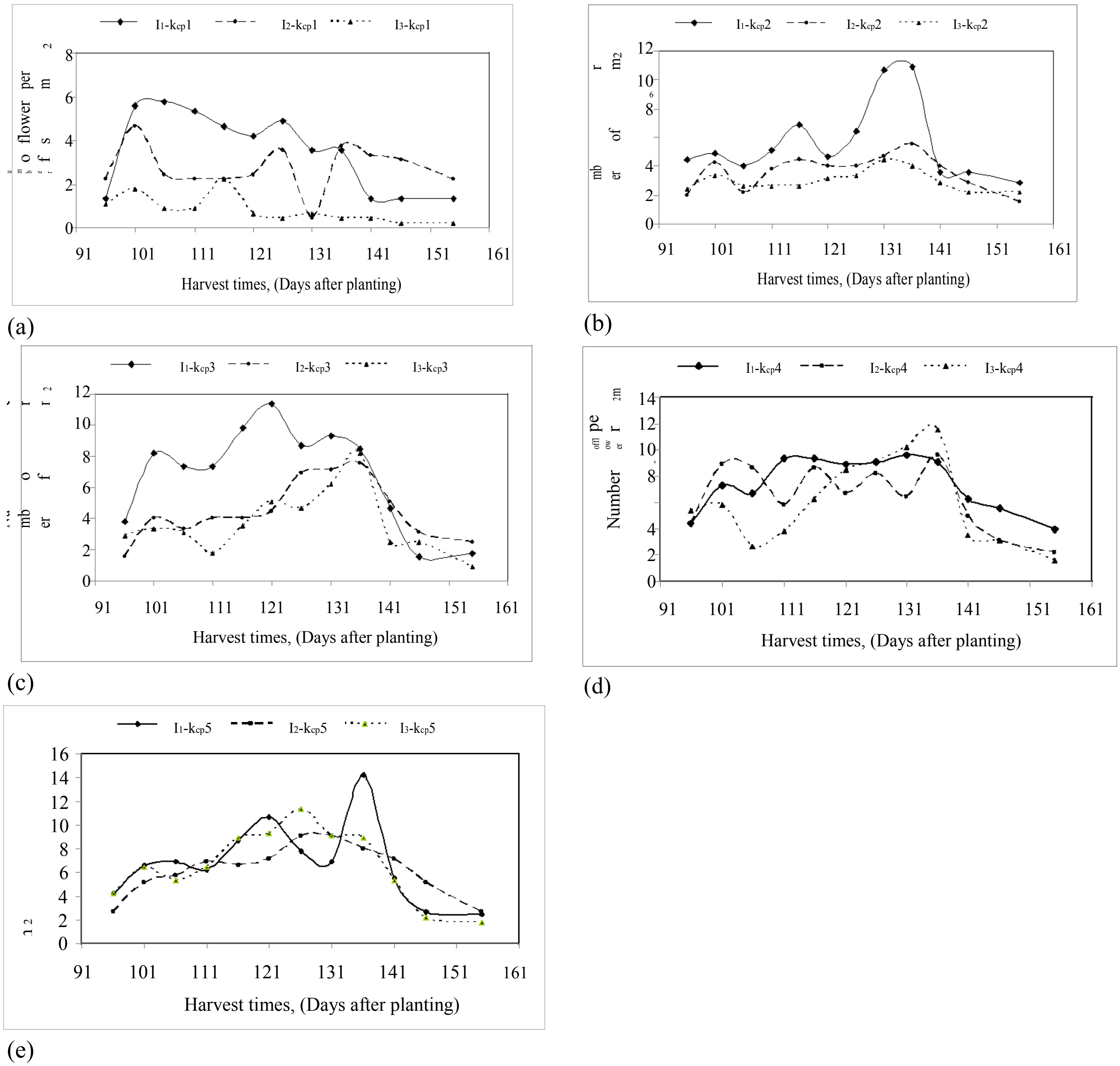

Figure 2. Change of harvested flower numbers per m^{-2} with respect to harvest times during the experiment. (a) Irrigation intervals (I_1, I_2 and I_3) (b) $k_{cp}1$, $k_{cp}2$ (c) $k_{cp}3$ (d) $k_{cp}4$ and (e) $k_{cp}5$.

In the study, the highest number of flower stems with stem lengths 0 to 39 cm (13%) and 40 to 49 cm (45.6%) was recorded in the $I_3k_{cp}1$ treatment. In the stem length 50 to 59 cm, the highest number of flower stems was $I_1k_{cp}1$ (44.8%), whereas the lowest number of flower stems was recorded in $I_1k_{cp}5$ (5.3%). In terms of the stem length 60 to 69 cm, close values were obtained in $I_2k_{cp}3$ (45.9%), $I_3k_{cp}3$ (45.8%) and $I_3k_{cp}4$ (45.8%). In the groups of stem lengths 70 to 79 cm (48.7%) and longer than 80 cm (26.0%), the highest number of flower stems was $I_1k_{cp}5$ and the lowest number of flower stems was recorded in $k_{cp}1$ irrigation regimes (Figure 5).

Stem fresh weight

The effect of crop-pan coefficients and irrigation intervals on stem fresh weight was statistically significant (p <

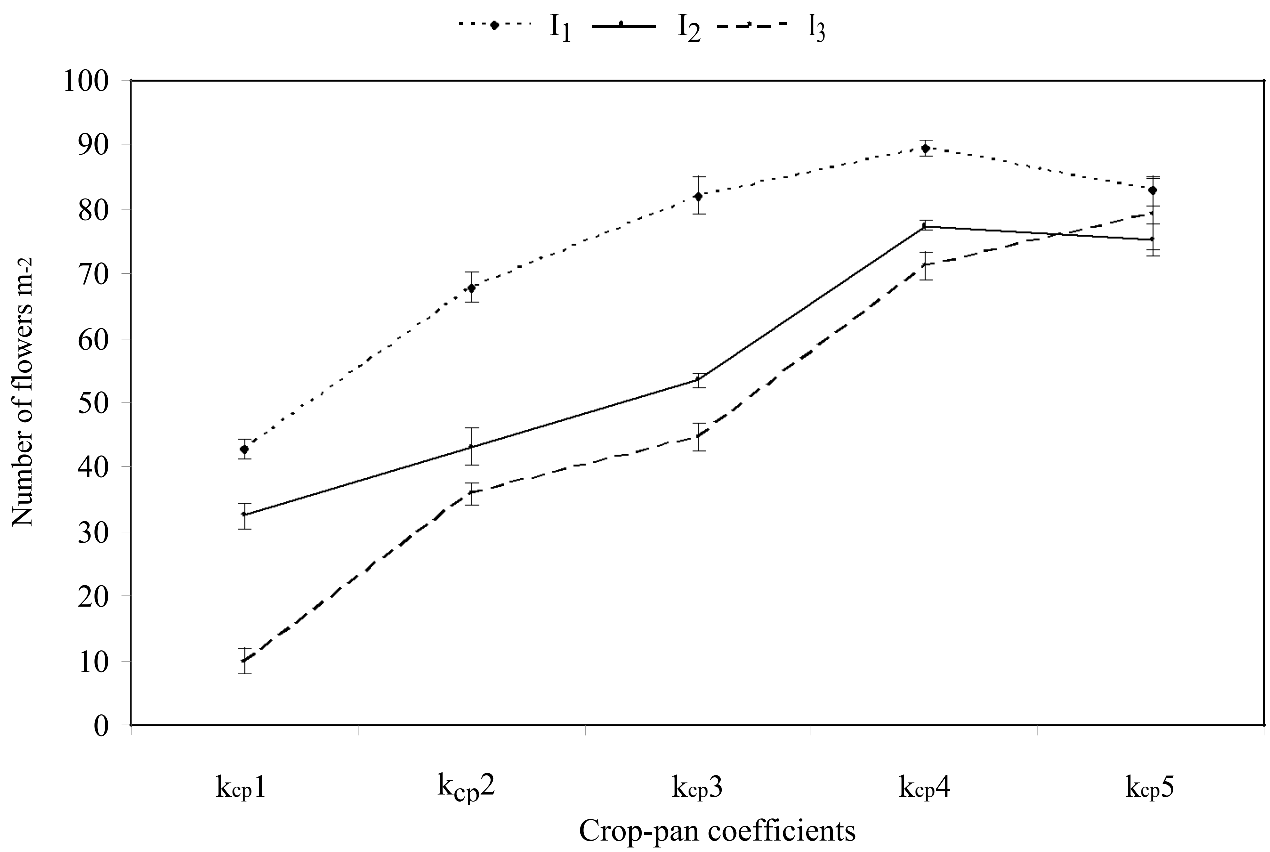

Figure 3. Total yield values for irrigation treatments.

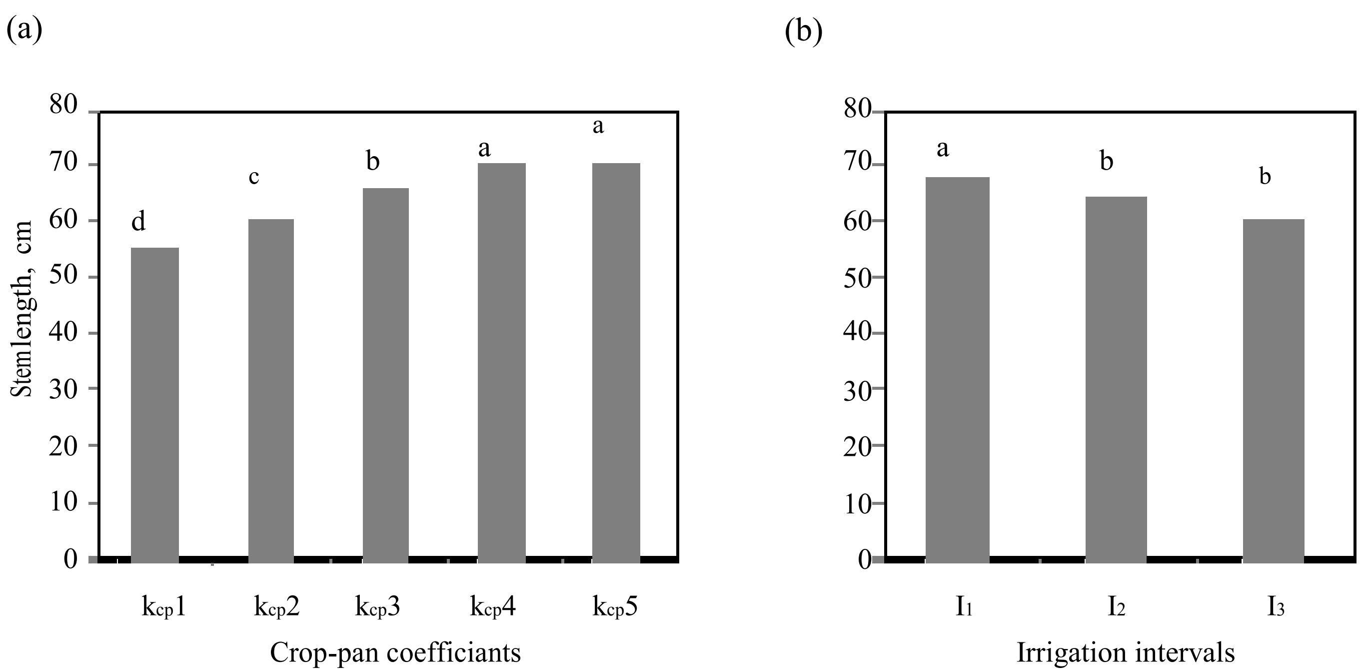

Figure 4. Effect of crop-pan coefficients (k_{cp}) (a) and irrigation intervals (b) on stem length (cm). Different letters indicate significant differences at $p < 0.05$ using LSD test.

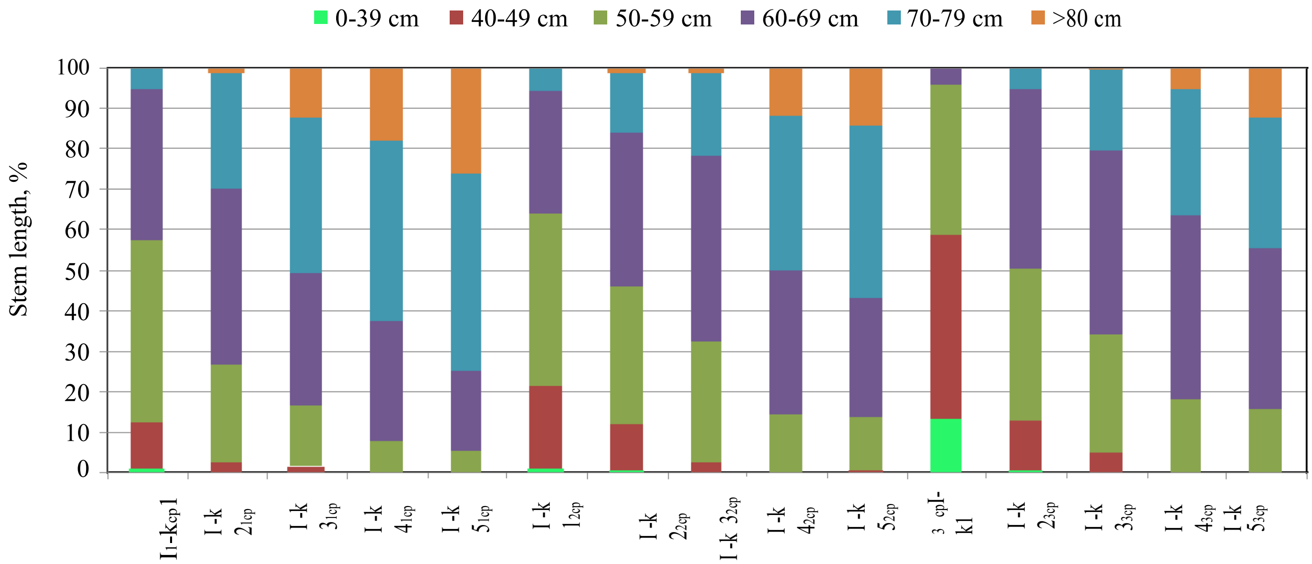

Figure 5. Effect of crop-pan coefficients ands irrigation intervals on the rates of stem length.

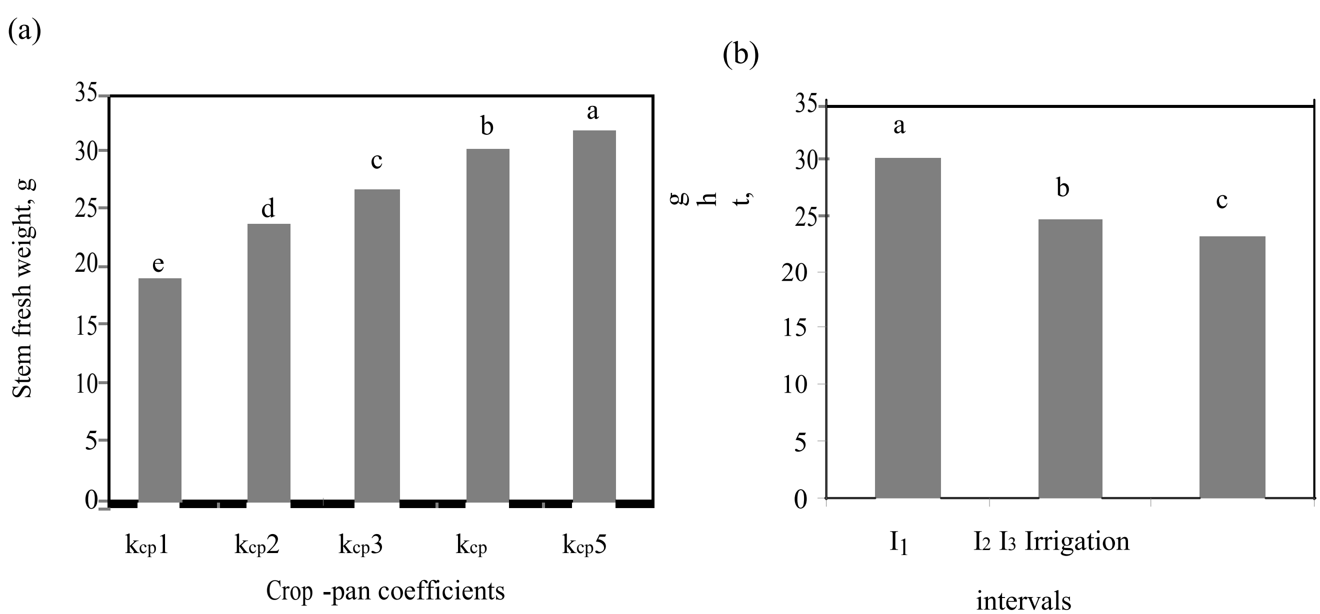

Figure 6. Effect of (a) crop-pan coefficients (k_{cp}) and (b) irrigation intervals on stem fresh weight (g). Different letters indicate significant differences at $p < 0.05$ using LSD test.

0.01), while the interaction between irrigation interval and crop-pan coefficient was insignificant. Among the irrigation coefficients, the highest stem fresh weight was recorded in $k_{cp}5$ (31.53 g/stem), followed by $k_{cp}4$ (29.68 g/stem), $k_{cp}3$ (26.36 g/stem), $k_{cp}2$ (23.36 g/stem) and $k_{cp}1$ (18.86 g/stem), respectively (Figure 6a) . Regarding irrigation interval, the highest stem fresh weight was obtained from I_1 (30.06 g/stem), followed by I_2 (24.64 g/stem) and I_3 (23.17 g/stem), respectively (Figure 6b).

Flower diameter

Crop-pan coefficients and irrigation intervals significantly ($p < 0.01$) increased the flower diameter. Among the crop-pan coefficients, the largest flower diameter was recorded in $k_{cp}5$ (67.55 mm) and $k_{cp}4$ (66.70 mm). On the other hand, the smallest flower diameter was $k_{cp}1$ (61.24 mm) (Figure 7a). Among the irrigation intervals, the largest flower diameter was measured in I_1 (67.49 mm),

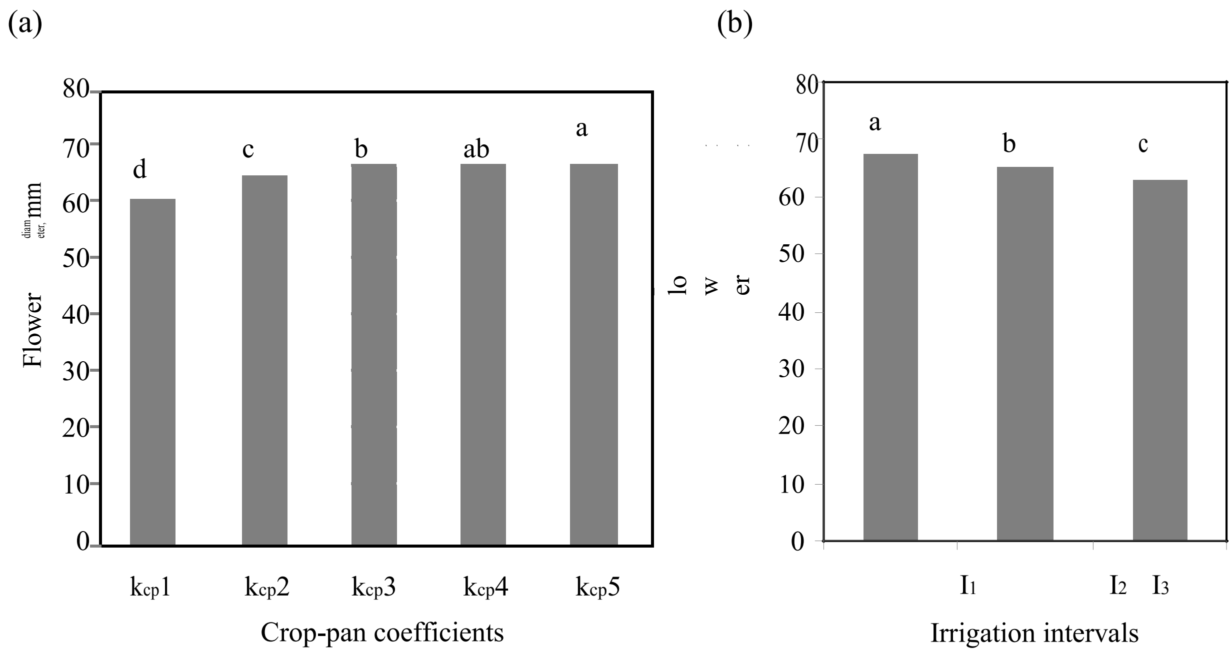

Figure 7. Effect of crop-pan coefficients (kcp) (a) and irrigation intervals (b) on the flower diameter (mm). Different letters indicate significant differences at $p < 0.05$ using LSD test.

while the smallest flower diameter was measured in I_3 (62.86 mm) (Figure 7b). The interaction between irrigation interval and crop-pan coefficient in terms of flower diameter was insignificant.

Stem diameter

Stem diameter was significantly ($p < 0.01$) affected by both crop-pan coefficients and irrigation intervals ($p < 0.01$). The thickest stem was obtained from $k_{cp}5$ (4.43 mm), followed by $k_{cp}4$ (4.28 mm) and $k_{cp}3$ (4.16 mm). On the other hand, the thinnest stem was $k_{cp}1$ (3.71 mm) (Figure 8a). Among the irrigation intervals, the thickest stem I_1 (4.38 mm), and I_2 (4.03 mm) and I_3 (3.98 mm) were included in the same statistical group, respectively (Figure 8b). The effect of the interaction between irrigation interval and crop-pan coefficient on stem diameter was insignificant.

Node number

Among the treatments, crop- pan coefficients significantly increased the node number, while the effect of irrigation intervals on the node number was found insignificant. Among the crop-pan coefficients, all crop-pan coefficients except $k_{cp}1$ were in the same statistical group. The node number in $k_{cp}1$ was 9.04 numbers/stem, and the node numbers among other crop-pan coefficients ranged from 9.35 to 9.51 numbers/stem (Figure 9a). The node number was no affected by irrigation intervals (Figure 9b).

DISCUSSION

Yield and quality of cut flowers are influenced by many pre-harvest and postharvest treatments. The factors influencing pre-harvest yield and quality may include environmental conditions such as light, temperature, season, relative humidity and growing media as well as cultural practices such as irrigation, fertilization, cultivar, supporting, reduction of the buds, and disease and pest management. Irrigation, one of the significant cultural practices in carnation cultivation, like in other cut flowers, has significant effects on yield and quality (Taylor et al., 2004). The harvest of flowers was started about 96 DAP, and flowers were harvested for 55 days. During the harvest, both irrigation intervals and crop-pan coefficients significantly ($p < 0.01$) affected the number of harvested flowers ($p < 0.01$). During the period of harvest, the highest flower number was recorded in $I_1k_{cp}5$ (14.2 flowers m^{-2}) on October 20 (DAP 136) (Figure 2e), followed by $I_3k_{cp}4$ (11.6 flowers m^{-2}) (Figure 2d). However, there were no significant differences between both treatments. In general, among the periods of harvest, the highest yields were recorded in $k_{cp}2$, $k_{cp}3$, $k_{cp}4$ and $k_{cp}5$ about 141 DAP (October 25) (Figure 2b-e), whereas the highest yield was obtained from $k_{cp}1$ approximately 106 DAP (September 15) (Figure 2a). This can be explained by the earlier inducement of generative growth of those plants applied with low amount of water

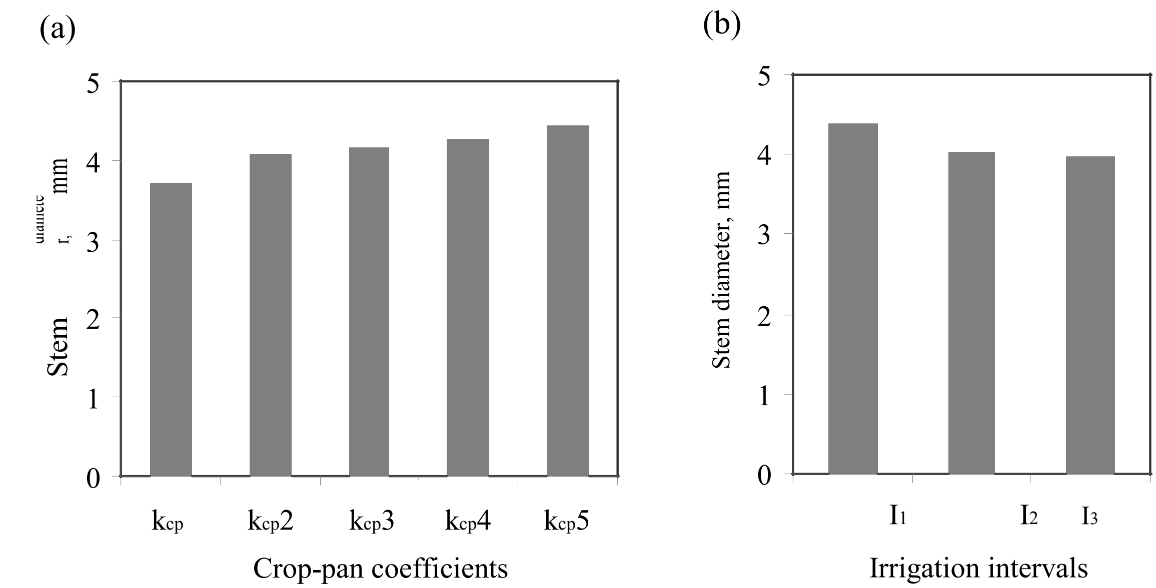

Figure 8. Effect of crop-pan coefficients (kcp) (a) and irrigation intervals (b) on the stem diameter (mm). Different letters indicate significant differences at P < 0.05 using LSD test.

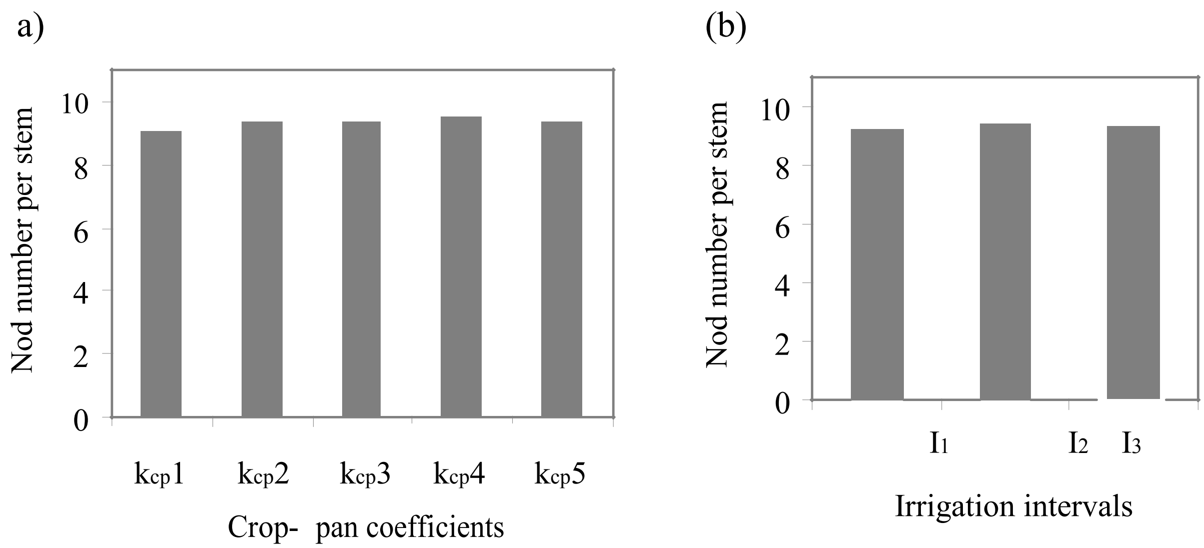

Figure 9. Effect of crop- pan coefficients (kcp) (a) and irrigation intervals (b) on the node number per stem (number). Different letters indicate significant differences at P < 0.05 using LSD test.

and, therefore, exposed to water stress. Water deficit might influence flowering by inhibiting vegetative growth (Cameron et al., 2006). Factors such as timing and duration of degree of stress have significant effects on shoot growth and flower induction (Cameron et al., 1999).

In the present study, there were also significant reductions in the yield, as a result of decreasing irrigation water amounts and decreasing evapotranspiration values. In the I_1 and I_2 irrigation regimes, some increase in total yield up to a specific level ($k_{cp}4$) was observed in increasing water treatments, whereas a reduction was observed in the $k_{cp}5$ treatment (Figure 3). Although, the applied water amount was the same, significant decreases in total yield were recorded in the event of an increase in irrigation intervals (Figure 3). Similar results were reported for carnation by Hanan and Jasper (1969), Taylor et al. (2004) and Aydinsakir et al. (2009), for cut rose by Katsoulas et al. (2006) and for Gladiolus by Bastug et al. (2006). The saturation of all soil pores with water under high irrigation intervals leads to a reduction in oxygen availability in the root zone. This prevents well aeration of the medium and causes reductions in yield. A similar result was reported for gerbera by Tsirogiannis et al. (2010). In parallel to the increasing irrigation interval and crop-pan coefficient, an increase was observed in deep percolation water amount, too (Figure 1). The reduction in deep percolation water amount is also important to prevent pollution of soil and water resources by chemical leaching, besides efficient water use.

One of the most important quality criteria in carnation cultivation is the stem length. The stem lengths above 40 cm are generally considered marketable; however, although varying by country, the stem lengths above 60 cm are generally preferred in the market. Even though stem lengths equal to and above 60 cm were obtained from $k_{cp}2$, $k_{cp}3$, $k_{cp}4$ and $k_{cp}5$ treatments in the study, the longest stems were obtained from $k_{cp}5$ (71.04 cm) and $k_{cp}4$ (69.30 cm), respectively (Figure 4a). These treatments were in the same statistical group in terms of stem length. Although, stem lengths above 60 cm were obtained under all irrigation intervals, the longest stems were obtained from I_1 (67.56 cm) with a higher irrigation interval (Figure 4b). These results obtained in respect to stem length are in agreement with Plaut et al. (1973), Taylor et al. (2004) and Alvarez et al. (2009). One of the most important indicators for the market value in almost all cut flower species is the stem length. The market value of flowers generally increases with increasing stem length. In the study, crop-pan coefficients and irrigation intervals significantly affected the rate of stem length. The rates of stem length equal to and above 60 cm obtained from $k_{cp}5$, $k_{cp}4$, $k_{cp}3$, $k_{cp}2$ and $k_{cp}1$ treatments were found 88.5, 86.7, 72.2, 58.9 and 27.7%, respectively (Figure 5). There was no significant difference in the rates of stem length between $k_{cp}5$ and $k_{cp}4$. In the I_1, I_2 and I_3 irrigation intervals, the highest rate of stem length equal to and above 60 cm was obtained from I_1 (77.2%), followed by I_2 (65.9%) and I_3 (57.3%), respectively (Figure 5). The obtained results are in accordance with the findings of Aydinsakir et al. (2009). Likewise, it was reported that flowers with a shorter stem were obtained under high soil moisture tensions and that flowers with a longer stem were obtained under low soil moisture tensions (Taylor et al., 2004).

Stem fresh weight significantly ($p < 0.01$) increased with increasing irrigation water amount and consumed water amount. Similarly, irrigation intervals also significantly ($p < 0.01$) affected the stem fresh weight. Our results were in agreement with Aydinsakir et al. (2009), Katsoulas et al. (2006) and Alvarez et al. (2009). The highest fresh stem weight was measured in I_1 (30.06 g) irrigated every day (Figure 6b). An increase in stem fresh weight is a reflection of longer, thicker and bigger flowers, with increasing irrigation water and, accordingly, evapotranspiration. In our study, bigger flowers were obtained as the irrigation water amount and irrigation interval increased. Similar results were reported by Aydinsakir et al. (2009). The vegetative growth deficiency of the plants with limited water application and lower irrigation intervals was also reflected on the flower diameter. In other words, limited water application and lower irrigation interval reduce biomass production, which negatively affects flower development.

Frequent irrigation treatment, together with increasing irrigation water, significantly ($p < 0.01$) increased the stem diameter. These results are in agreement with Aydinsakir et al. (2009) who reported that stem diameter increased as the crop- pan coefficients increased. When the effect of treatments on node number was evaluated, it was observed that irrigation water amount significantly ($p < 0.01$) affected node number, while irrigation interval did not affect the node number. In respect to crop-pan coefficients, the node numbers per stem ranged from 9.04 to 9.51 numbers (Figure 9a), whereas they ranged from 9.28 to 9.42 numbers in terms of irrigation intervals (Figure 9b). Safi et al. (2005) reported that the irrigation intervals did not affect the node number in carnations grown in soil under greenhouse conditions and that node numbers per stem varied by cultivar and ranged from 7.2 to 10.4 numbers. Node number might also vary depending on greenhouse climatic conditions, growing techniques and cultivars. Water deficiency in the plant root zone affects not only the vegetative growth of the plant but also yield (Pugnaire et al., 1994).

Conclusion

The effects of different irrigation intervals and irrigation water amounts in carnations grown in soil under greenhouse conditions on yield and some quality parameters were tested in the study. The effects of irrigation water amounts and intervals on yield, stem length, stem fresh weight, flower diameter, and stem diameter were statistically significant. Overall, higher flowers yield and quality were obtained from I_1 with application of the same water amount but with a higher irrigation interval. The use of those irrigation regimes, in which maximum yield can be achieved in irrigation treatments but proportionally less percolation takes place, in carnation cultivation is of importance for efficient water use, profitability and pollution of underground water as well as in order for nutrients not to be removed from the growing media.

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