Effect of Irrigation Scheduling on Gerbera Flower Yield and Quality

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Abstract. Better understanding of the effects of irrigation frequency and dose on flower production of gerbera plants (*Gerbera jamesonii*) can lead to optimal water management and crop yield. Measurements of greenhouse microclimate and production and quality characteristics of a gerbera crop were carried out under two irrigation frequency regimens in soilless cultivation in a greenhouse located in Arta, Greece. Irrigation scheduling was based on solar radiation and performed whenever accumulated solar radiation energy outside the greenhouse reached 1650 kJ·m⁻² [high irrigation frequency (HIF)] or 3300 kJ·m⁻² [low irrigation frequency (LIF)]. The amount of water applied was 0.125 mm and 0.250 mm for HIF and LIF, respectively. Stem fresh weight, length and thickness, and number of harvested gerbera flowers were measured along with crop evapotranspiration, crop leaf area, and greenhouse microclimate variables. Measurements started 8 months after transplanting and lasted 90 days (May to July). Leaf area, fresh weight, harvested cut flowers, and the main quality characteristics of gerbera flowers (stem length and flower diameter) were unaffected by the irrigation frequency. In the framework of the experiment, simple formulas for calculation of leaf area index were developed. Finally, a first approach study of an alternative remote sensing irrigation control method using a reflectance index was made and the results are presented.

Optimal irrigation scheduling could lead to higher water use efficiency, an objective of very high importance nowadays. Adequate supply of water and nutrients results in higher water and nutrient use efficiency, better production control, and avoidance of stress situations (Raviv and Blom, 2001). Irrigation control involves determination of both timing and quantity of each watering event. Methods for irrigation scheduling are usually based on calculation of crop evapotranspiration commonly performed by means of an energy balance method (Allen et al., 1998; Donatelli et al., 2006) and estimation of the couple frequency–dose.

Automatic control of irrigation events in the greenhouse is usually based on solar radiation (Katsoulas et al., 2006; Stanhill and Scholte, 1974). A solar energy integrator transmits a switching-on signal to the water supply system after a preset level of energy is reached. An irrigation control system based on the main factor affecting crop evapotrans-

piration in the greenhouse can supply nutrient solution to plants without unnecessary water and nutrient losses (Roh and Lee, 1996). However, this method implies the knowledge of several crop parameters, most of them varied in function to crop phenological stage. Gerbera plants, because of frequent removal of old or damaged leaves, exhibit a fluctuation of leaf area, something that implies extra difficulties when attempting to formulate any model for scheduling irrigation.

An alternative, optimal irrigation control approach would also include real-time plant water status monitoring and crop water stress indices. A variety of indices have been used to express crop water status and control irrigation events. Leaf water potential and stomatal conductance provide evidence of water stress, but they cannot be measured online and accordingly cannot be incorporated in automated systems (Katerji et al., 1988). Cure et al. (1989) found that crop water stress induced changes in the daily patterns of canopy temperature and canopy radiation reflectance. Similar results have been also found by other authors (Ceccato et al., 2001; Moran et al., 1989, 1994; Peñuelas et al., 1992; Riggs and Running, 1991) relating crop water stress to crop radiation reflection. Canopy radiation reflectance is mainly affected by crop leaf reflectance behavior, but also by the non-uniformity of incident solar radiation, by the plant structure, the leaf area index, possible

shadows, and background reflectance (Thenot et al., 2002). In case that crop is under stress, reflectance properties of individual leaves are affected with the most obvious changes occurring in the visible spectral region rather than in the infrared because of the sensitivity of chlorophyll to physiological disturbances (Knipling, 1970). According to Cure et al. (1989) and Moran et al. (1989), characteristically, the primary sign for stress conditions detection by reflectance sensors is not a change of the reflectance characteristics of individual leaves, but a reduction of the total leaf area exposed to sensors. However, for short time periods, reduction of leaf area exposed may be observed as a result of leaves' orientation changes. It has been reported that the yellow–red visible region (≈ 560 nm to 710 nm) reflectance tends to increase with increasing water stress, whereas the near infrared region (above 760 nm) reflectance tends to decrease with increasing water stress (Nantt, 2008). Peñuelas et al. (1994) found that at sunflower cultivation, the physiological reflectance index ($PRI = R_{550} - R_{530} / R_{550} + R_{530}$) decreases and, on the contrary, the water band index ($WBI = R_{970} / R_{902}$) increases with water stress, whereas other authors (Thenot et al., 2002) agreed that PRI could be used as a water stress index. Ceccato et al. (2001) concluded that the simple ratio (R_{1600} / R_{820}) could be used as a first approximation to retrieve vegetation water content at leaf level.

As far as the irrigation dose is concerned, this depends mainly on crop substrate characteristics such as easily available water (EAW). EAW is relatively low in pumice (Gizas and Savvas, 2007) and, therefore, more frequent irrigation with low water doses is recommended when this substrate is used for soilless cultivation. Maloupa et al. (1996) found that for mild climate conditions, a low irrigation frequency (approximately eight irrigation events per day) satisfies the water requirements of gerbera grown in various substrates. Additionally, setting up an irrigation schedule is also linked to container size (Gizas and Savvas, 2007; Manios et al., 1995).

The main objective of the present study was to evaluate the effects of two irrigation frequencies on gerbera flower yield (flower number and quality) grown in pots filled with pumice in an open hydroponic system. A secondary objective of this work was to carry out a first approach study of irrigation control based on remote sensing methods.

Materials and Methods

Greenhouse facilities and plant material.

The experiment was carried out from May to July 2008 in an east–west-oriented, twin-span, glass-covered greenhouse located at the Technological Education Institute of Epirus, near Arta (long. 39°7' N, lat. 20°56' E, altitude 5 m) on the coastal area of western Greece. The geometrical characteristics of the greenhouse were as follows (Fig. 1): eaves height = 3.15 m, ridge height = 4.40 m, span width = 6.50 m, total length = 46 m, ground area = 600 m², volume = 2270 m³.

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Fig. 1. Experimental greenhouse and meteorological instruments: T, RH = air temperature and relative humidity sensor (subscripts: o = outside, i = inside); R_G = pyranometer (subscripts: o = outside, i = inside); RV = drained nutrient solution; IV = volume of irrigation water supplied to each bench.

Ventilation was performed by means of roof and side openings. The greenhouse was equipped with a single continuous roof vent per span located at the north side and a side vent at the south wall. The roof vents were 45.90 m long and 1.55 m wide with a maximum opening area per vent of 43 m², whereas the side vent was 45.90 m long and 1.00 m wide with a maximum opening area equal to 23 m². The vents were opened whenever air temperature was higher than 22 °C (Katsoulas et al., 2007). Furthermore, the greenhouse was equipped with a movable, aluminized thermal screen located horizontally at the eaves level, which was used for the reduction of solar radiation reaching the plant canopy.

The greenhouse floor was completely covered by concrete. The experiment was conducted at the central part of the greenhouse (160 m²) on 12 benches (height, length, width: 0.86 m, 4.96 m, and 1.10 m, respectively). Each bench accommodated two channels (4.96 m × 0.25 m, 0.40 m apart) on its upper surface, which were independently supplied with nutrient solution by a drip irrigation system. All channels were covered by a double-sided (black downward, white upward) plastic film to prevent nutrient solution evaporation. Eighteen pots (with one plant each) were placed in each channel and thus the total crop density was 2.7 plants/m². It has to be noted that under commercial gerbera cultivation, plant density is approximately eight to 10 plants/m² (Rogers and Tjia, 1990).

Gerbera plants (*Gerbera jamesonii* cv. Balance®), which had been raised in Jiffy plugs (6 cm), were transplanted on 21 Sept. 2007 in 4-L pots (one plant per pot). The pots were filled with Nisyros pumice, not washed before use, with particle size ranging from 0 mm to 5 mm. The characteristics of the substrate were: bulk density = 720 kg·m⁻³, porosity = 72% (Manios et al., 1995), and actual water content at container capacity = 37.6% (Gizas and Savvas, 2007).

Irrigation: system, schedule, and control. Water and fertilizers were supplied through a drip system. Two pressure-compensating emitters of 2.2 L·h⁻¹ each were stapled on each pot. The system was automatically controlled by a fertigation computer (Autonet Ltd., Athens, Greece). The target pH and electrical conductivity values were 5.6 and 1.72 dS·m⁻¹, respectively.

As can be estimated using the water retention curve of pumice 0 to 5 mm (Gizas and Savvas, 2007), the water volume to be supplied per irrigation event to a 4-L pot filed with pumice should not exceed 100 mL to maintain the moisture status within the range of easily available water (10 to 50 cm). Two different irrigation frequencies were applied in a randomized block design with six blocks. The amount of water applied (IR) per irrigation event to each treatment was 0.125 kg·m⁻² (50 mL/pot) and 0.250 kg·m⁻² (100 mL/pot) for high irrigation frequency (HIF) and low irrigation frequency (LIF), respectively. Accordingly, because the HIF treatment was irrigated twice the times the LIF treatment was, the total water applied was equal in both cases.

The amount of water applied IR can be calculated using the relation (Katsoulas et al., 2006):

$$IR = T_r / (1 - dr) \quad (1)$$

where dr is the drainage rate and T_r is the crop transpiration in kg·m⁻², which can be estimated using the simple relation:

$$T_r = \zeta R_{Go} \quad (2)$$

where R_{Go} is the time integral of solar radiation outside the greenhouse in kJ·m⁻² and ζ a coefficient given by:

$$\zeta = K_c \tau \alpha / \lambda \quad (3)$$

where K_c is the crop coefficient; τ is the greenhouse cover transmission to solar radiation; α is the evaporation coefficient and

represents the part of the energy of incoming solar radiation that is transformed to latent heat through transpiration; and λ is the latent heat of vaporization of water in kJ·kg⁻¹.

The drainage rate was maintained near 40% to maintain optimal conditions of water supply to the plants (Akat et al., 2009; Maloupa et al., 1993). The greenhouse cover transmission to solar radiation, τ , was calculated as the mean ratio of incoming to outside solar radiation. During the period of measurements, a thermal screen was used for greenhouse shading, and the average greenhouse cover transmission was 0.41. The mean value of the crop coefficient, K_c , was taken equal to 0.45 (Maloupa et al., 1993, 1996; Papadopoulos et al., 1995) (slight alterations of K_c were made based on crop leaf area index changes and on the percentage of drainage solution), and the evaporation coefficient, α , was taken as equal to 0.6, as is usually observed for greenhouse cultivations (Baille, 1999).

The frequency of irrigation was based on solar radiation measured by a pyranometer located outside the greenhouse (to avoid transient sensor shading problems resulting from structural elements). Using Eqs. (1), (2), and (3), the solar radiation integral outside the greenhouse R_{Go} needed for an irrigation event to start was calculated and the values found were 1650 kJ·m⁻² for HIF and 3300 kJ·m⁻² for LIF.

Measurements. The following data were recorded inside the greenhouse (Fig. 1):

Air temperature (T_i , in °C) and relative humidity (RH, in %) by means of four temperature and humidity sensors homogeneously distributed inside the greenhouse compartment and one pair of sensors outside the greenhouse (Model HD9008TR; DeltaOhm, Padua, Italy). Using these data, the mean value of greenhouse air temperature and RH and water vapor pressure were calculated (Allen et al., 1998);

Outside and incoming solar radiation ($R_{G,o}$ and $R_{G,i}$ in $W \cdot m^{-2}$) by means of solar pyranometers (Model SKS 1110; Skye Instruments, Powys, U.K.) located at ≈ 4.5 m and 2.5 m above the ground, respectively; and Volume of irrigation water (IV) supplied to each bench by means of digital flow meters (Model DN 25; Actaris, Boulogne-Billancourt, France).

All the mentioned measurements were collected on a data logger system (DL2e Logger; Delta-T Devices Ltd., Cambridge, U.K.). Measurements took place every 30 s, and the 10-min average values were recorded.

Furthermore, all drainage water was collected in tanks at the edge of each bench and the volume of drainage water (RV) of each bench was measured manually every week. The leaf area index (I_{LA} : m^2 leaf/ m^2 ground) of the crop was estimated by destructive measurements of the leaf area of sample plants by means of a scanner (GT 9500; Epson, Nagano, Japan). The plants removed for destructive measurements were replaced by buck-up plants of the same size. Leaf area measurements were carried out three times during the experimental period, namely on 15 May, 15 June, and 15 July; and the leaf area, the length, and width of the individual leaves of four plants per treatment and date were measured. To calculate the leaf area, the Monte-Carlo arithmetic integration method (Robert and Casella, 2005) was applied to leaf scanned images.

Inflorescences were considered ready for harvesting when at least two full circles of ripened male flowers were seen. Harvest was made during the morning once per week. Flower yield measurements included measurements of the number, fresh weight (by means of a weighting balance, Model 60000 G SCS; Precisa Gravimetrics AG, Dietikon, Switzerland), stem length and flower diameter of the harvested gerbera flowers (by means of a measure tape), and stem thickness (by means of an electronic caliper).

Finally, during 1 d of the experimental period (16 June), leaf stomatal resistance (r_c) was measured by a porometer (LI-1600M; LICOR Inc., Lincoln, NE) and the radiation reflected by the canopy (R_R) was measured using a portable multispectral radiometer (Model MSR87; CropScan Inc., Rochester, MN) in eight narrow bands centered at the following wavelengths (in nm): 460, 510, 560, 610, 660, 710, 760, and 810. The radiometer was located 1.5 m above the canopy level (sampled canopy area of $0.44 m^2$, manufacturer data), whereas during the period of radiation reflection measurements, the thermal screen was in the collect position. At the same time, r_c measurements were carried out. The radiation data measured were used to calculate a reflectance index (RI) using a formula similar to the PRI formula:

$$RI = R_{560} - R_{510}/R_{560} + R_{510} \quad (4)$$

where R_{510} and R_{560} are the radiation reflectance at 510 nm and 560 nm, respectively. It has to be noted that PRI uses the radiation

reflected at 530 and 550 nm; however, the instrument used in this study to measure radiation reflectance could not measure at these narrow bands and thus, the values measured at 510 and 560, respectively, were used.

Selected data were analyzed and comparison of means was performed by applying the Student *t* test at a confidence level of 95% using the PlotIT software package (Scientific Programming Enterprises, Haslett, MI).

Results and Discussion

Greenhouse microclimate. The mean values of the greenhouse and the outside climate variables (average over the period 0800 to 19:00 HR local time) during the period of measurements are presented in Table 1.

Leaf area. A good correlation was obtained between leaf area (S , cm^2) and the product $L \times W$ of length (L , cm) and width (W , cm) of each leaf. The relationship obtained by linear regression was:

$$S = 0.57 L \cdot W \quad (5)$$

for both irrigation treatments with a value for the coefficient of determination (R^2) of 0.83. Simple linear formulas for calculation of gerbera leaf area have already been proposed (for example, $S = 6.166 + 0.308 \cdot L \cdot W$; Maloupa et al., 1996) but did not fit our data, probably because a different gerbera cultivar was used in the present study.

A simpler and more convenient for practical purposes, expression for the calculation of leaf area index (I_{LA}) involving the number of leaves per plant (n) and the plant density (p) was also found:

$$I_{LA} = 0.0083 n p \quad (6)$$

for both irrigation treatments with an R^2 value of 0.84.

The overall average number of leaves per plant for both treatments was 16.78 (with a sd of ± 5.61 leaves). The mean value of I_{LA} was $0.45 (\pm 0.1)$ and $0.41 (\pm 0.1)$ for the HIF and LIF treatments, respectively (10% higher I_{LA} values under HIF than under LIF). However, these values were not significantly different between the two treatments. Fluctuations of I_{LA} values during the period of measurements (Table 2) are the result of continuous removal of old or damaged leaves and emergence of new leaves (Rogers and Tjia, 1990). Similar results have been also found by Katsoulas et al. (2006) who studied the effect of two irrigation frequencies on leaf area of a rose crop grown on rockwool slabs in a closed hydroponic system.

Cut flower yield and quality. As can be seen in Figure 2, a fluctuation on the number of harvested flowers was observed during the period of measurements with the number of harvested flowers being most of the time higher for the plants irrigated with LIF. However, statistical analysis of the data revealed that there were no significant differences between the two treatments. The decrease of harvested flowers during the end of June to the beginning of July was probably the result of high temperature levels observed during this period (above $38^\circ C$), which may induced diminution in growth and blooming [optimal temperature range for gerbera is between 17 and $27^\circ C$ (Rogers and Tjia, 1990)]. The total number of harvested flowers/ m^2 after a cultivation period of 3 months was 35.20 for the LIF and 30.12 for the HIF treatments with no statistical differences between the values observed for the two treatments. Katsoulas et al. (2006) found that for a rose crop and for the irrigation frequencies tested under their study, the higher the irrigation frequency, the higher the yield, because the total number of cut flowers measured was $\approx 28\%$ higher under HIF than under LIF.

With respect to fresh weight per flower, both treatments follow almost the same trend during the period of measurements (data not shown) and the statistical analysis showed that there were no significant differences in terms of fresh weight per flower between the two treatments. The mean value of flower fresh weight (in grams per flower) was $22.9 (\pm 5.1)$ for HIF and $24.4 (\pm 6.2)$ for LIF. However, the evolution of cumulative harvested flower fresh weight per greenhouse ground area (Fig. 3) followed a similar trend in both treatments with the values for LIF being always higher than those for the HIF treatment. The cumulative values observed after a harvesting period of 3 months were $933.94 g \cdot m^{-2}$ and $764.27 g \cdot m^{-2}$ for the LIF and HIF, respectively. Accordingly, a higher cumulated fresh weight of $\approx 22\%$ was observed for the LIF plants.

Stem length and flower diameter are the primary indicators for the market value of cut-flower gerbera yield. The expected quality characteristics of cv. Balance used in the present study were stem length of 60 cm and flower diameter between 10 cm and 12 cm (Anonymous, 2007). Figure 4 shows the evolution of mean cut flowers' stem length during the period of measurements. Mean stem length value was 59 cm (± 7 cm) for both treatments with no significant differences between the two treatments. Under LIF, gerbera plants produced slightly bigger

Table 1. Average values of greenhouse and outside climate parameters during the period of measurements.^a

Period	T_i ($^\circ C$)	RH_i (%)	D_i (kPa)	R_{Gi} ($W \cdot m^{-2}$)	T_o ($^\circ C$)	R_{Go} ($W \cdot m^{-2}$)
May	31.6 (± 6.3)	53.2 (± 12.4)	2.6 (± 0.6)	272 (± 175)	24.8 (± 4.1)	639 (± 299)
June	37.4 (± 7.1)	49.9 (± 13.2)	3.2 (± 0.5)	274 (± 170)	29.9 (± 4.6)	669 (± 294)
July	38.8 (± 6.4)	50.6 (± 12.0)	2.8 (± 0.6)	288 (± 177)	31.6 (± 3.6)	673 (± 287)

^aThe sd of the values is given in parentheses.

T_i = greenhouse air temperature; RH_i = greenhouse air relative humidity; D_i = greenhouse air vapor pressure deficit; R_{Gi} = internal solar radiation; T_o = outside air temperature; R_{Go} = outside solar radiation.

flowers than under HIF (Fig. 5), but no significant differences were found in flower diameter between the two treatments. Mean flower diameter was 11.5 cm (± 1) for both treatments.

According to Rogers and Tjia (1990), gerbera plants require a constant supply of water, but the surface of the substrate should be dry between irrigation events. Although it is possible that the constant wet substrate surface induced by HIF and the possibility

that pumice's particle size (0 to 5 mm) combined with HIF did not provide good aeration conditions to the plants negatively (no statistically significant) affected gerbera yield. The application of a frequent irrigation schedule is possible to create excessive moisture conditions in the root zone that might reduce oxygen availability (Schroder and Lieth, 2002; Sonneveld, 1989).

Crop transpiration and total water consumption. Crop transpiration rate (Tr , in kg/plant/day) was estimated using weekly measurements of the water volume supplied to the crop (IV) and the water collected by the drainage system (RV) by means of a simplified water balance model (Maloupa et al., 1996; Papadopoulos et al., 1995):

$$Tr = (IV - RV \pm \Delta SM) / n \quad (7)$$

where ΔSM is the difference in substrate moisture between measurements and n is

the corresponding number of days referred to the period of IV and RV measurements. As a result of the low frequency (once per week) of measurements, the difference in substrate moisture can be neglected, because its magnitude is very small compared with the other parameters of Eq. [7] (Allen et al., 1998; Papadopoulos et al., 1995). Water losses from the substrate and the channels and any losses resulting from technical failures were considered negligible. The crop transpiration rate values (equal to crop water consumption) observed, as calculated using Eq. [7], were similar (no statistical difference) for both irrigation frequency treatments (Fig. 6). Crop water consumption ranged between 0.35 kg/plant/d and 0.70 kg/plant/d and the average number of irrigation events per day was 10 and 20 for LIF and HIF treatments, respectively. The mean value of the water applied to the crop during the period of measurements (May to July) was 2.40 kg·m⁻²·d⁻¹ (0.96 kg/pot/d), whereas the corresponding water needs (crop transpiration) were ≈ 1.53 kg·m⁻²·d⁻¹ (0.61 kg/pot/d). Similar values for gerbera crop transpiration rate during Mediterranean summer conditions have been also found by other authors (Maloupa et al., 1996).

Water use efficiency. Water use efficiency (WUE) is typically defined as the crop yield divided by the amount of water needed for irrigation (Burt et al., 1997). Yield may be given in terms of weight (fresh or dry) or in terms of flower number (Bastug et al., 2006). The corresponding values observed under the two tested irrigation frequencies were 5.87 and 7.64 g of fresh weight produced per liter of water used for HIF and LIF, respectively. In terms of flower production, the corresponding values found were 0.23 and 0.29 flowers per liter of water used for HIF and LIF, respectively. It was found that to produce one gerbera cut flower, 4.32 L and 3.47 L of water were needed under HIF and LIF treatments, respectively.

Crop water status and irrigation scheduling indices. A first attempt to evaluate a RI with a format similar to that of PRI, PRI as an index for crop water status and irrigation scheduling was made in the study. In Figure 7A–B, the variation of leaf stomatal resistance and of RI during the period of measurements along with the indication of time that irrigation was performed for LIF and HIF treatments, respectively, is presented. Despite the lack of a clear correlation between RI values and irrigation events, RI seems to be connected with irrigation events because the different irrigation treatments led to different RI fluctuation rates. RI seems to increase after irrigation events with a hysteresis, indicating improved crop water status after irrigation. Similar variations are presented in the values of leaf stomatal resistance (r_c) observed with r_c values decreasing after irrigation events. These variations seem to be better correlated to irrigation events for the LIF treatment. Time series analysis (using SPSS 17) was implemented to access the correlation between RI and stomatal resistance.

Table 2. Leaf area index (I_{LA}) of the crop measured under high (HIF) and low (LIF) irrigation frequency.^z

Date	HIF	LIF
15 May 2008	0.41 (± 0.10)	0.37 (± 0.08)
15 June 2008	0.49 (± 0.09)	0.45 (± 0.11)
15 July 2008	0.44 (± 0.12)	0.42 (± 0.11)
Mean value	0.45 (± 0.10)	0.41 (± 0.10)

^zSD of the values is given in parentheses.

Fig. 2. Evolution of number of harvested stems/m² of greenhouse ground area; circles: low irrigation frequency; triangles: high irrigation frequency (vertical bars depict $\pm$ SES of means of six measurements).

Fig. 3. Development of cumulative harvested stem fresh weight/m² of greenhouse ground area; circles: low irrigation frequency; triangles: high irrigation frequency (vertical bars depict $\pm$ SES of means of six measurements).

Fig. 4. Evolution of harvested stems' mean length during the period of measurements; circles: low irrigation frequency; triangles: high irrigation frequency (vertical bars depict $\pm$ SES of means of six measurements).

Fig. 5. Evolution of harvested flowers' mean diameter during the period of measurements; circles: low irrigation frequency; triangles: high irrigation frequency (vertical bars depict $\pm$ SES of means of six measurements).

Fig. 6. Evolution of crop transpiration rate during the period of measurements; circles: low irrigation frequency; triangles: high irrigation frequency (vertical bars depict $\pm$ SES of means of six measurements).

Stomatal resistance values for HIF and LIF were modeled using the AR(1) model. Residuals were then used to study crosscorrelations with RI values measured under HIF and LIF, respectively. RI and r_c values measured under HIF were not correlated, whereas they were found to be correlated with a lag = -3 under LIF. The mean values of stomatal resistance found were 288 (with a SE of ± 6.8) $s \cdot m^{-1}$ and 461 (with a SE of ± 21) $s \cdot m^{-1}$ for HIF and LIF, respectively, indicating a difference in plant water status between the two treatments. This difference may also explain the difference of the average values of RI observed for the two treatments, but further investigation is needed to clearly support the findings. Nevertheless, to the authors' best knowledge, no relative information exists on reflectance indexed measurements and use under greenhouse conditions and this may be a first step in this research.

Concluding Remarks

In the present work, two different irrigation frequencies were tested to evaluate the effect of irrigation frequency on gerbera crop fresh weight, leaf area, and flower yield and quality. The same total amount of water was applied per day to the crops following two schedules, HIF and LIF; and irrigation events were triggered when accumulative solar radiation outside the greenhouse reached 1650 $kJ \cdot m^{-2}$ and 3300 $kJ \cdot m^{-2}$, respectively.

The applied irrigation frequencies did not affect gerbera yield and quality characteristics (stem length and flower diameter), which followed the same trend and were almost equal for the two treatments. Taking into account these results, it could be concluded that the irrigation frequencies applied were both appropriate because it applied the correct amount of water at acceptable time intervals, which did not significantly affect the physiological status of the crop. Nevertheless, WUE was higher under the LIF treatment than under HIF, which means that for the same amount of water and nutrients consumed, more production was observed under LIF. However, the results observed in this study could not be simply generalized for other crops cultivated to different substrates with different physiological response to irrigation and substrate water status.

Irrigation scheduling has to be applied by a reliable control system that could efficiently online calculate the actual water status of the crop. The development of direct, noncontact, nondestructive and wider sample area methods for data collection for irrigation control purposes is of great interest. In this framework, the reflectance index tested under this work seems to be a promising area for research. Probable issues regarding its use for greenhouse irrigation control use may be related to noise removal (such as interferences by greenhouse framework and machinery shadows, reflectance from crop background, and so on) and definition of threshold values for irrigation scheduling.

Fig. 7. (A) Evolution of the reflectance index (continue line) and leaf stomatal resistance (discontinue line) during 16 June for high irrigation frequency treatment. Triangles indicate irrigation events. (B) Evolution of the reflectance index (continue line) and leaf stomatal resistance (discontinue line) during 16 June for high irrigation frequency treatment. Triangles indicate irrigation events.

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