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Physiological response of a pepper *(Capsicum annuum* L.) crop to different trickle irrigation rates

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Abstract

The present field study was conducted to analyse the physiological response of a pepper *(Capsicum annuum* L.) crop to different trickle irrigation rates, by means of periodical measurements of leaf water potential (ψ_{leaf}) and stomatal resistance (Rs) at predawn during the plant growth cycle and at different times of the day during the fruit-growing stage, from predawn to nightfall. The internal water status of the plants was related to their growth rate (measured as aerial dry matter and leaf area index) and yield (marketable and total). The different irrigation rates tested were determined according to the crop irrigation requirements (IR) calculated on the basis of crop evapotranspiration (ETc). Four treatments were established: 1.25 IR, 1.00 IR, 0.75 IR and 0.50 IR. Irrigation water amounts between 75 and 125% IR did not cause important variations in growth and yield parameters, although a severe water deficit did induce a continuous adaptation of the plants by reducing their size (reflected by less dry matter accumulation and leaf area) and consequently their yield. However, there were small differences between treatments in the measurements of ψ_{leaf} and Rs, which indicates that crop growth was more affected by severe water deficits than these two parameters in pepper crops with daily trickle irrigation. ψ_{leaf} did not justify the mechanisms of stomatal regulation, even on hot and dry middays.

Key words: plant water status, leaf water potential, stomatal resistance, leaf area index, growth, yield.

Resumen

Respuesta fisiológica del pimiento *(Capsicum annuum* L.) a distintas dosis de riego por goteo

Se estudió la respuesta fisiológica de un cultivo de pimiento (*Capsicum annuum* L.) a distintas dosis de riego por goteo, mediante medidas periódicas al alba y a lo largo del día, durante el período de engorde de los frutos, del potencial hídrico (ψh) y de la resistencia estomática (Re) de la hoja. El estado hídrico de las plantas se relacionó con su nivel de crecimiento (materia seca aérea total, índice de área foliar) y rendimiento (comercial y total). Las dosis de riego se determinaron en función de las necesidades de riego calculadas (NRc) a partir de la evapotranspiración del cultivo, ensayándose cuatro tratamientos correspondientes a 1,25 NRc, 1,00 NRc, 0,75 NRc y 0,50 NRc. La aplicación de dosis de riego comprendidas entre el 75 y el 125% de NRc no produjo variaciones importantes en los parámetros de crecimiento y producción, si bien la restricción severa de agua provocó una adaptación continua de las plantas a través de una reducción de su tamaño (menor acumulación de materia seca y menor expansión foliar) y, como consecuencia, del rendimiento. Sin embargo, las diferencias encontradas en las medidas de ψh y Re entre los distintos tratamientos fueron escasas, lo cual indica que el crecimiento se vio más afectado por el déficit acusado de agua que estos dos parámetros cuando el cultivo fue regado diariamente por goteo. El ψh no justificó los mecanismos de regulación de los estomas, ya que en ningún caso se produjo cierre de los mismos como respuesta al déficit hídrico, incluso en las horas centrales de días calurosos y secos.

Palabras clave: estado hídrico de la planta, potencial hídrico, resistencia estomática, índice de área foliar, crecimiento, rendimiento.

Introduction

In the Ciudad Real province (Central Spain), an ever increasing area of land is being given over to pepper crops. This region has a long-standing tradition of family plots, in which the local pepper cultivar Infantes is widely cultivated. Most plantations overly the aquifers denoted numbers 23 («Mancha Occidental») and 24 («Calizas del Campo de Montiel») are presently suffering severe problems of soil overuse and pollution (mainly nitrates and pesticides).

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The pepper crop is considered as sensitive to very sensitive to water stress (Smittle *et al.*, 1994) whether provoked by an excess or deficit of water. Along with the use of a nitrogen fertiliser, irrigation is the main factor conditioning crop growth, development and yield, since the pepper has a very long growth cycle and develops an intense aerial development and a scarce and superficial root system. Moreover, this crop grows in summer, when evaporative demands are high and rainfall is scarce or non-existent.

Besides playing a decisive role in maintaining turgor pressure in plant tissues, water is also needed for leaf temperature regulation (Hatfield and Burke, 1991) and nutrient uptake and transport (Jolliet, 1993). This means that the growth and productivity of the crops are closely related to the internal water status of the plants. An efficient and relatively simple gauge of plant water status is provided by stomatal resistance (Rs), transpiration rate and leaf water potential (ψ_{leaf}) measurements (Dettori, 1985). Transpiration is the main component of the plant energy balance and, along with CO_2 exchange, determines the water use efficiency (Pearcy *et al.*, 1991). The relationship between Rs and ψ_{leaf} is particularly significant since a potential drop in response to water stress to below the particular threshold for each crop induces stomatal closure (Hsiao, 1973; Gil, 1995). As a consequence, both transpiration and photosynthetic rates decline, since gas exchange is prevented (Srinivasa Rao and Bhatt, 1988). This state of stress leads to reduced rates of organ development and also has many indirect effects on physiological processes and plant growth (Horton *et al.*, 1982). Hsiao (2000) considers that, in general, the first parameter affected by water stress is cell growth, being leaf growth the most susceptible and root growth the most resistant. For this reason, on a long-term the plant controls the size of its leaves to balance the water lost through transpiration with the water supplied through the roots, provided the soil has a high water retention capacity.

Leaf water potential and stomatal resistance vary according to climatic demands, which determine the intensity of transpiration. This process increases as the relative humidity of the atmosphere diminishes, and as incident radiation, temperature and wind increase. According to several authors (e.g., Aikman and Houter, 1990; Jolliet, 1993), the climatic factors that most affect stomatal conductance and transpiration are solar radiation and air humidity.

The aim of this study was to evaluate the internal water status of an Infantes pepper crop subjected to different trickle irrigation rates by measurements of leaf water potential and stomatal resistance at predawn along the growth cycle and at different times of the day, from predawn to nightfall, during the fruit-growth period. These parameters were related to both plant growth and yield.

Material and methods

The trial was performed over the year 1999 at the experimental farm «La Entresierra», belonging to the Junta de Comunidades de Castilla-La Mancha, situated on the irrigation zone of the «El Vicario» reservoir in Ciudad Real, Spain (3º56'W - 39º0'N, altitude 640 m).

The soil was loam-sandy, with a calcic rock horizon at a depth of some 50-60 cm, slightly basic (pH 8.0) and non-saline (EC = 0.37 dS m^{-1}, soil:water 1:5), corresponding to a suitable salinity level for crop growing (Doorenbos and Kassam, 1986). Chemical analysis revealed low contents of phosphorous (12 mg kg^{-1}, Olsen), normal levels of organic matter (2.32%) and total nitrogen (0.11%, Kjeldahl), high contents of potassium (347 mg kg^{-1}, ammonium acetate) and calcium (3490 mg kg^{-1}), and very high levels of available magnesium (639 mg kg^{-1}). The soil water retention capacity was 167 mm m^{-1} and the basal average infiltration rate was 0.17 cm min^{-1}. The irrigation water used was saline (ECw = 3.5 dS m^{-1}) with a high Ca^{++} and Mg^{++} content (means 340 mg l^{-1} and 260 mg l^{-1}, respectively).

A randomised complete block statistical design was adopted with four irrigation treatments and four replications.

The experimental field was 78 × 63 m. Within this area, a 60 × 51 m rectangle was established, the external perimeter preventing any problems of advection. This rectangle was divided into 16 plots of 15 × 12 m, separated by 1 m-wide. Each plot was considered as a replication of the four tested irrigation treatments and contained 480 pepper plants, arranged as 10 double-rows, 1.5 m apart. Within a row, the plants were separated by a distance of 0.33 m. The two lateral rows and the first and last metres of the remaining eight ones served as control.

A trickle irrigation system, consisted in one trickle line for each crop row and self-regulating emitters of 3 l h^{-1} separated by 0.35 m, was employed. The installation was periodically checked and sand and mesh filters cleaned to ensure adequate water flow.

Planting took place in the open air on 14 May 1999, using nursery seedlings with 3-4 mature leaves, on black polyethylene mulch (55 gauges). The vegetative cycle lasted 179 days (14 May to 9 November). During the period 28 May to 23 September, the crop was provided with 210 kg N ha^{-1}, 80 kg P_2O_5 ha^{-1} and 144 kg K_2O ha^{-1} as 33.5% monoammonium phosphate, potassium nitrate and ammonium nitrate supplied via the irrigation system. At the end of May, two applications of humic compounds were realized (10% p/p humic acids, 5% p/p fulvic acids), at a rate of 10 l ha^{-1} each to promote root growth.

During the days after planting, about 20 mm of water were provided to favour crop establishment. The irrigation treatments were applied daily from 28 May to 23 September, though the regimes were programmed weekly. The weekly crop irrigation requirements (IR) were established by calculating the crop evapotranspiration (ETc) for each period as ETc = ETo × Kc (Doorenbos and Pruitt, 1986). Effective rainfall was negligible. The reference evapotranspiration (ETo) obtained in the previous week was considered, assuming a similar climate for the week in progress. ETo was determined in a weighty lysimeter of radius 0.75 m, sown with a mixture of three varieties of *Festuca arundinaceae* and placed in a well-watered gramineae field close to the test plot. The crop coefficient (Kc) was calculated from the ETc values of the preceding week determined in a lysimeter located in the experimental plot and similar to that used to calculate ETo. This ETc was corrected for the week in progress according to the crop phenology and the results obtained in the previous years in this area.

The following irrigation treatments were tested: 1.25 IR (TR1), 1.00 IR (TR2), 0.75 IR (TR3) and 0.50 IR (TR4). The water doses to be applied in each treatment were calculated as the ratio between this value and the efficiency of the system estimated at 0.81 (Doorenbos and Pruitt, 1986; Rincón and Giménez, 1989). This result was divided by the number of days to obtain the daily irrigation requirements. The control of the amount of water supplied, and thus the deviations from the planned and the true amount applied, was made using water meters installed at the outflow of each electrovalve supplying the water for each treatment.

Throughout the crop cycle, the response of the total aerial plant biomass and the leaf area index (LAI) to the different irrigation rates was recorded by sampling nine times at roughly two week intervals. The first sampling was undertaken 32 days after transplant (DAT) and the final one was performed a few days before the end of the harvesting period, at 173 DAT. The time between the last two samplings was longer than the other intervals (35 days) due to rainfall hindering the measuring procedure. Each sample consisted in three consecutive plants that were representative of each plot. These plants were located in rows assigned for this purpose such that they did not to interfere with those assigned for yield measurements, and were surrounded by others to avoid possible interference in their growth. These samples were dried in a forced-ventilation oven set at 80°C until constant weight. Leaves were previously measured for leaf area, using a leaf area meter (Δ-T Devices LTD., Burwell, Cambridge, UK). LAI was defined as the ratio between the leaf area of the three sampled plants and the soil area occupied by them according to the plant density (0.75 m^2).

The internal water status of the plants was also monitored during the growth cycle as a function of the irrigation dose received by periodical measurements of Rs and ψ_{leaf} in each experimental plot. These determinations were conducted at approximate 15 day intervals at predawn (between 4:00 and 5:00 solar hour, hs), since there are less environmental effects on these variables at this time of day (Araki, 1993; Cointepas, 1993). A further two sets of determinations were made on sunny days from predawn to nightfall (20:00 hs), at intervals of roughly two hours during the fruit growing stage (27 July, 74 DAT) and at the time of maximum fruit production (7 Sept, 116 DAT). The first two Rs determinations were missing in this last diurnal data series since the leaves were covered in dew and therefore this parameter could not be estimated.

Rs was determined for both the adaxial and the abaxial surfaces using a diffusion porometer (Δ-T Devices LTD., Burwell, Cambridge, UK), calibrated in each series of measurements. A young, healthy and fully developed leaf taken from the top of the plant (non shaded) was chosen because this type of leaves has been shown to react best to the environmental conditions (Koutaki *et al.*, 1983). Since it is the case of parallel resistance, the total leaf Rs was calculated as the inverse of the sum of inverses of the adaxial and abaxial resistances. The measurements of ψ_{leaf} were performed on the same leaves with a xylem-pressure chamber (mod. 301564, Eijkelkamp, Netherlands) according to the method described by Schölander *et al.* (1965). Global radiation (GR) and air temperature (T) were obtained in an automated meteorological station (Thies, Göttingen, Germany) placed at a 50 m distance from the experimental field. Relative humidity (RH) was measured by the sensor head on the porometer.

A total of five harvests were made over the cycle in each plot (9 and 24 Aug, 16 Sept, 4 Oct, 9 Nov, corresponding to 87, 102, 125, 143 and 179 DAT, respectively), controlling marketable and total yield. The latter included damaged, deformed and blossom-end rot fruits.

Results were subjected to analysis of variance and a Duncan's multiple range test ($P \leq 0.05$) was applied to the significant results.

Results

Table 1 provides the values of ETo, ETc, and estimated and applied irrigation rates in the different treatments. The estimated irrigation rate is the amount of water to be applied in the programmed regime for each treatment. The applied dose is the amount registered by each of the four water meters.

The small differences recorded between the net estimated irrigation rate in TR2 (496.4 mm, accounting for the system efficiency) and the ETc registered over the treatment period (503.2 mm) can be explained by the fact that the irrigation requirements corresponded to the ETc estimated for the week in progress, while the ETc shown in Table 1 was that recorded by the lysimeter at the end of this week.

Evolution of leaf water potential and stomatal resistance during the growth cycle

The ψ_{leaf} determined at predawn (Fig. 1b) underwent an increase in the last two determinations as a consequence of the notable drop in temperature and rise in relative humidity (Fig. 1a).

The minimum ψ_{leaf} value corresponded to TR4 (–0.57 MPa) at 89 DAT, though in the remaining treatments, this value was reached at different times in the cycle. In general, no appreciable differences in ψ_{leaf} were observed according to the irrigation treatment; significant differences ($P \leq 0.05$) were only noted at 41 DAT, being significantly higher in TR2 (–0.34 MPa) than in the remaining treatments (minimum –0.50 MPa for TR1), and at 89 DAT, with values ranging from –0.38 MPa in TR1 to –0.57 MPa in TR4.

The climatic factor most affecting stomatal behaviour was the air temperature (Fig. 1a and 1c), since throughout the growth cycle, total leaf Rs showed an inverse relationship with T. Lowest Rs values were recorded at 41 DAT (mean 6.1 s cm^{-1} in all four treatments) and 103 DAT (5.8 s cm^{-1}), corresponding to both the highest temperatures (18.2 and 22.7ºC, respectively) and the lowest relative humidity values (50 and 40%, respectively). Highest Rs data were obtained in the last determination, with values ranging from 29.1 s cm^{-1} in TR4 to 44.6 s cm^{-1} in TR1.

No significant differences were found between the Rs values obtained in the different irrigation regimes, nor it was observed a clear stomatal response to the amount of water received.

Evolution of leaf water potential and stomatal resistance during the day

Figures 2a and 3a show the GR, T and RH values recorded on 27 July and 7 September.

Highest GR values were obtained between 11:00 and 12:00 hs on July 27 (1009 W m^{-2}) and at 13:00 hs on 7 September (834 W m^{-2}). Air temperature increased throughout the day until midday peak temperatures of 30ºC on the first day and 34ºC on the second one. RH

Table 1. Estimated/applied irrigation rates in the different treatments, crop evapotranspiration (ETc) and reference evapotranspiration (ETo) of a pepper crop in Central Spain

Rate	Period	Irrigation amount (mm)				ETc (mm)	ETo (mm)
		TR1	TR2	TR3	TR4		
Estimated	Starting	30.7	30.7	30.7	30.7	20.2	67.5
	Treatment	765.9	612.8	459.6	306.4	503.2	625.4
	Total	796.6	643.5	490.3	337.1	523.4	692.9
Applied	Starting	21.6	20.9	21.0	20.1		
	Treatment	812.1	626.9	496.5	343.6		
	Total	833.7	647.8	517.5	363.7		

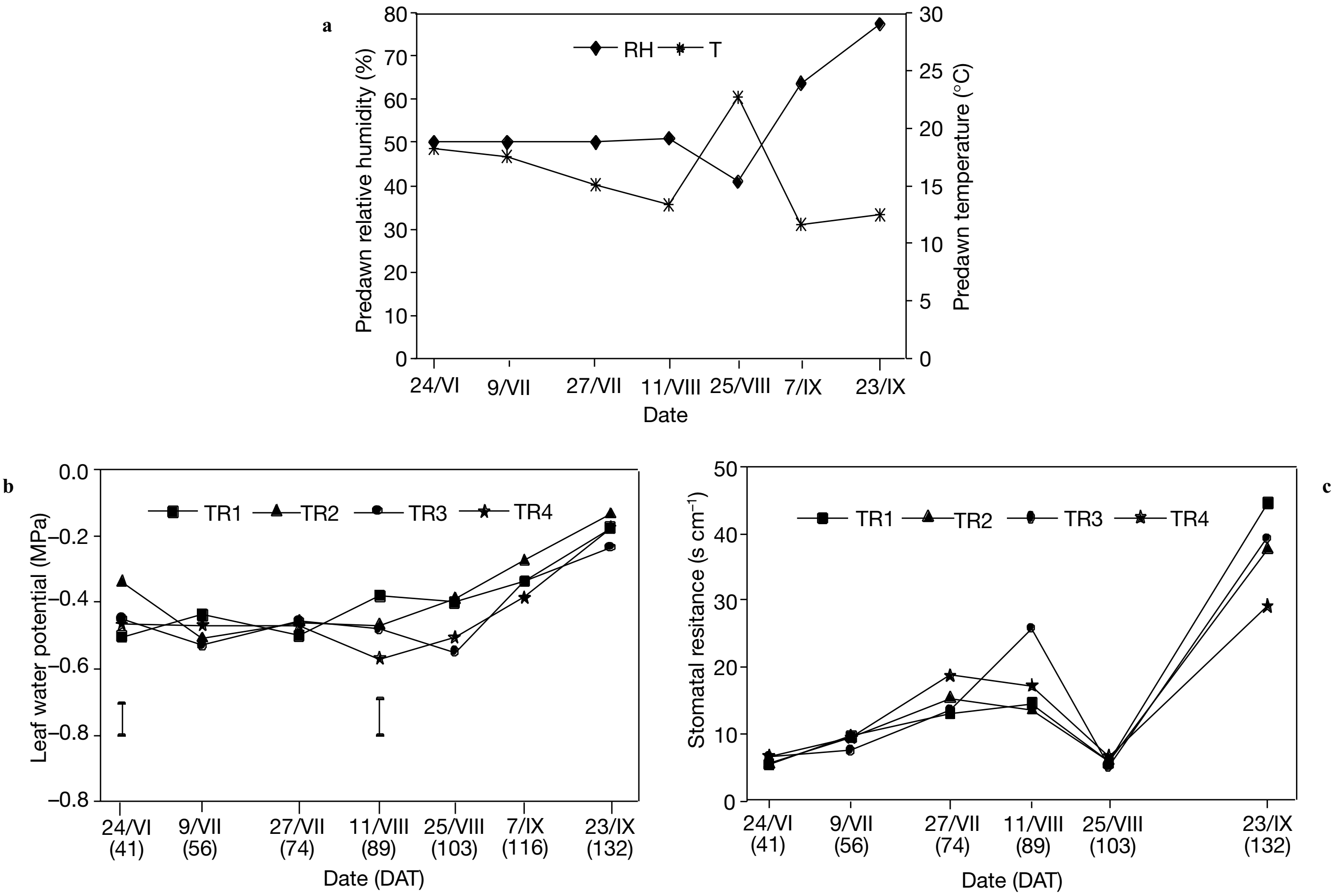

Figure 1. Predawn evolution of relative humidity (RH) and air temperature (T) (a), leaf water potential (b) and stomatal resistance (c) of pepper leaves in the irrigation treatments. Each point is the average of four measurements. Vertical bars represent LSD within treatments ($P \leq 0.05$). TR1 = 125% calculated crop irrigation requirements (IR), TR2 = 100% IR, TR3 = 75% IR, TR4 = 50% IR. DAT: days after transplanting.

was lowest between 14:30 and 16:00 hs, with values around 25% on both days.

On both days, the leaf water potential was observed to change according to the climatic factors (Fig. 2b and 3b), behaving like relative humidity and unlike both global radiation and air temperature.

At sunset, leaf water potentials recovered their balance due to the drop in radiation and temperature and the increase in relative humidity, such that transpiration decreased and the plants became rehydrated. This balance was maintained until dawn.

On 27 July, the lowest ψ_{leaf} corresponded to TR4 (–1,55 MPa) and coincided with the highest temperature. On 7 September, this occurred in TR1 (–1.41 MPa) at 10:30 hs, although for the rest of the treatments, the ψ_{leaf} was lowest between 12:30 and 14:30 hs.

On the first day examined, significant differences in ψ_{leaf} among treatments were recorded for determinations performed at 6:00, 8:00 and 10:00 hs. Throughout the day, ψ_{leaf} increased according to the amount of water received (maximum in TR1, minimum in TR4). On the second day, no significant differences were noted in any case, and the behaviour shown by the leaf water potential according to the treatment regime was not as clearly defined as on the July day.

Stomatal resistance changed according to the incident radiation (Fig. 2c and 3c). Hence, on 27 July, Rs suffered a marked drop after dawn until reaching a minimum value of around 1 s cm^{-1} at midday and showed a sharp rise at mid-afternoon for the four treatments. On 7 September, the values recorded in the morning (8:00-14:30 hs) were similar to those of 27 July, though the rise in this parameter started a little earlier.

In no case the fall in water potential in the middle hours of the day due to the higher evaporative demand did provoke the stomatal closure.

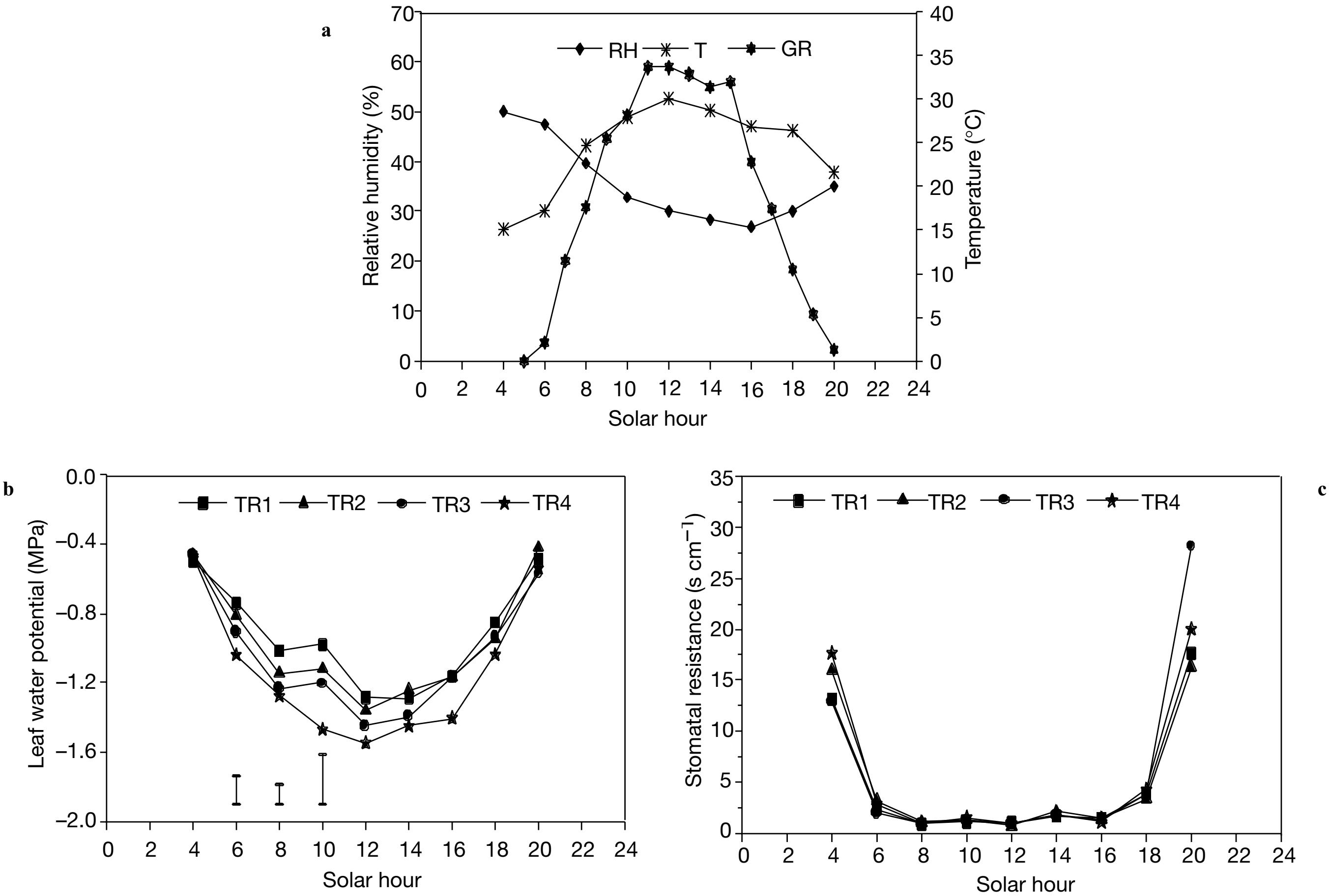

Figure 2. Evolution of relative humidity (RH), air temperature (T) and global radiation (GR) (a) leaf water potential (b) and stomatal resistance (c) of pepper leaves in the irrigation treatments on 27 July 1999. Each point is the average of four measurements. Vertical bars represent LSD within treatments ($P \leq 0.05$). TR1 = 125% IR, TR2 = 100% IR, TR3 = 75% IR, TR4 = 50% IR.

Growth and yield

Figure 4 shows the changes in aerial plant dry matter (a) and LAI (b) during the crop cycle. Both variables remained unchanged until the setting of the first fruits (39-47 DAT) and after that they showed a rapid increase more marked in the most irrigated treatments.

The highest values of cumulative dry matter were recorded at 138 DAT in each treatment except TR1, in which this factor underwent a slight decrease in samplings performed at 122 and 138 DAT followed by a recovery at the end of the crop cycle. The fall in dry matter recorded in the last determination for the other three treatments was the result of the loss in biomass comprised of stems and leaves, which abolished the increase in fruit biomass. Throughout the cycle, the most severe watering regime gave rise to least cumulative dry matter (significantly lower at 76 and 109 DAT), the highest value attained in TR2 (894 g m^{-2}) being 26% higher than that corresponding to TR4 (707 g m^{-2}).

LAI showed a similar behaviour to cumulative dry matter, though peak values were recorded at 109 DAT in all the treatments except TR4 (138 DAT). The deficient watering regimes gave rise to the lowest LAI values from the start of the crop cycle ($P \leq 0.05$ at 76, 94 and 173 DAT), the maximum value reached in TR2 (3.4) being 26% higher than that corresponding to the most deficitary regime (2.7). In no case the over-watering had an effect on this variable.

Table 2 presents the yield values obtained for each treatment. Marketable and total yields showed similar behaviour related to the amount of water received, since marketable and unmarketable yields decreased in the same proportions. The three most irrigated treatments presented similar yield values, the lowest ones

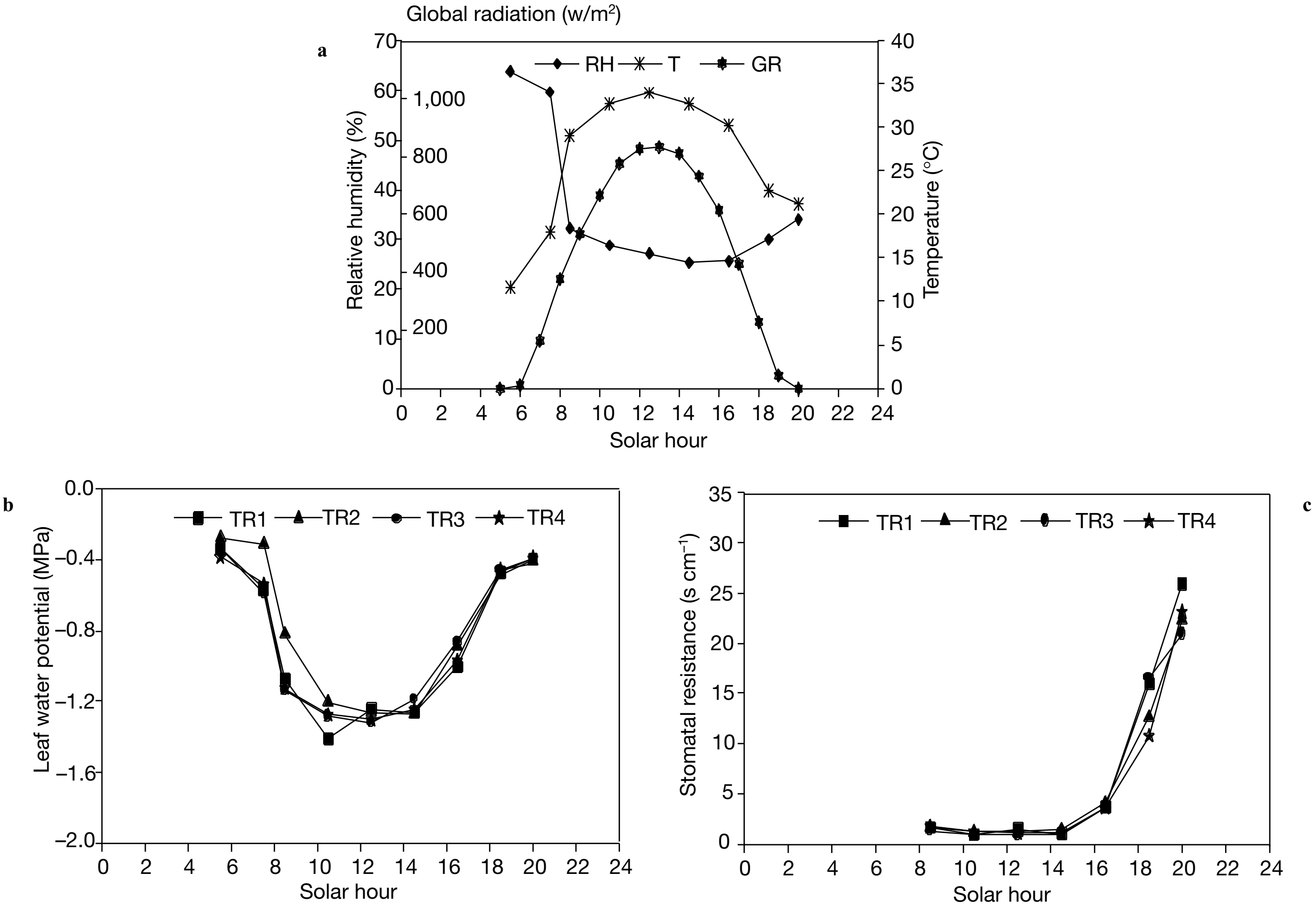

Figure 3. Evolution of relative humidity (RH), air temperature (T) and global radiation (GR) (a) leaf water potential (b) and stomatal resistance (c) of pepper leaves in the irrigation treatments on 7 September 1999. Each point is the average of four measurements. TR1 = 125% IR, TR2 = 100% IR, TR3 = 75% IR, TR4 = 50% IR.

corresponding to the most restrictive regime. The total yield for TR2 was 32% higher than that for TR4, while the marketable yield was 41% higher.

Discussion

Throughout the crop cycle and during the day, the ψ_{leaf} was found to depend on the climatic conditions, in accordance with reports by Turner and Begg (1981) and Gil (1995). The fact that ψ_{leaf} suffered a drop in the middle hours of the day in all the irrigation treatments confirms the findings of Katerji (1977), who maintains that, even in conditions of sufficient available water, there is always a deficit of greater or lesser extent throughout the day, especially between 12:00 and 16:00 h, when evapotranspiration is maximum and exceeds the water absorption by the roots. Turner and Begg (1981) consider that ψ_{leaf} shows marked diurnal fluctuations and very little dependence on soil water potential, which only sets the limit recovery possible by the plant during the dark period. This pattern of diurnal variation in leaf water potential is consistent with what was reported by Hanson and Hitz (1982) and Horton *et al.* (1982) in a pepper crop.

In relation to Rs, incident radiation has been identified as the main climatic factor causing the stomatal opening (Jolliet, 1993; Chamont *et al.,* 1995; Gil, 1995). The considerable increase in Rs registered at mid-afternoon is in agreement with observations made by Horton *et al.* (1982) in pepper, Ribas (1999) in melon and Chamont *et al.* (1995) in cucumber, and could be the consequence of the low relative humidity and the rapid drop in radiation.

Throughout the day, ψ_{leaf} was slightly more sensitive to the different water supplies than Rs. This first

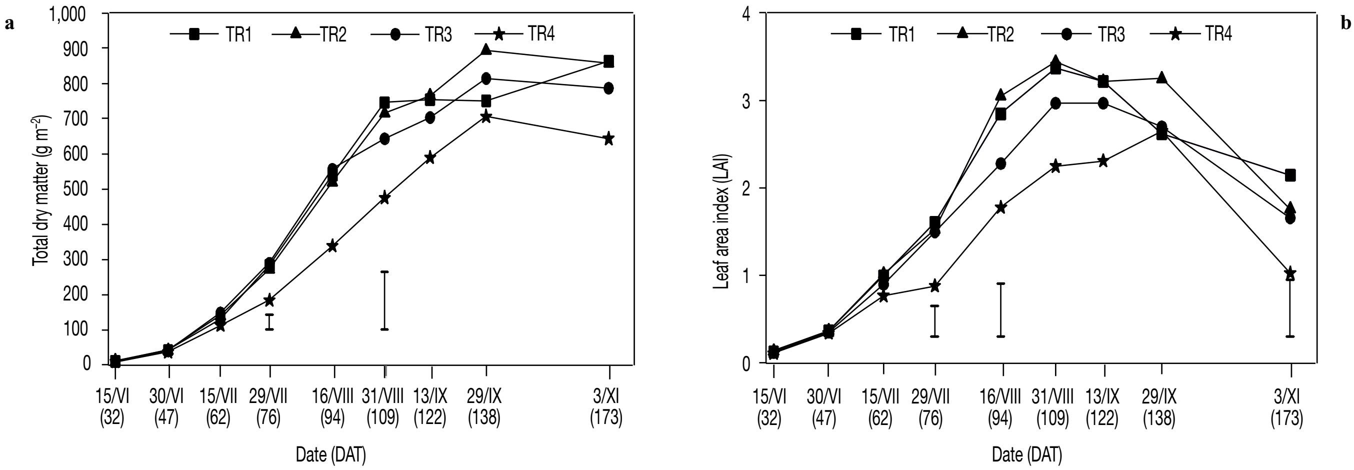

Figure 4. Evolution of aerial dry matter (a) and leaf area index (b) in a pepper crop subjected to different irrigation treatments. Each point is the average of four measurements. Vertical bars represent LSD within treatments ($P \leq 0.05$). TR1 = 125% IR, TR2 = 100% IR, TR3 = 75% IR, TR4 = 50% IR. DAT: days after transplanting.

factor did not seem to be related to stomatal regulation, since fluctuations produced in stomatal opening were independent of the ψ_{leaf} reached. In no case the fall in ψ_{leaf} produced in the middle hours of the day gave rise to stomatal closure, which means the stomatal behaviour was solely dependent on the climatic conditions. This is probably because in no case the critical threshold ψ_{leaf} value for stomatal closure was reached (Hsiao, 1973; Hanson and Hitz, 1982; Gil, 1995). However, Horton *et al.* (1982) noted a slight increase in Rs for both the adaxial and abaxial leaf surfaces at midday due to the fall in ψ_{leaf} in pepper plants drip-watered every three days. Srinivasa Rao and Bhatt (1988), Janoudi *et al.* (1993) and Ismail and Davies (1997) also observed reduced stomatal conductance arising from a diminished ψ_{leaf} in pepper plants subjected to severe water deficit.

The ψ_{leaf} and Rs values obtained in this study indicate that in no treatment the plants suffered a severe water stress during the cycle since irrigation was applied daily. The small variations observed in these parameters were, in general, attributable to the climatic conditions rather than to the soil water content, since daily trickle irrigation guarantees the formation of a wet bulb where the roots develop, only varying in size (not in state of moisture) according to the amount of water supplied. Thus, the situation in this experiment is more consistent with trials in which the plant root system was divided and different water doses applied to each root section (Tan *et al.*, 1981) and with those in which a root volume limit was adopted (Ismail and Davies, 1998), than experiments in which plants were subjected to severe water deficit by suspending irrigation during some part of the cycle (Alvino *et al.*, 1990a, b; Pellitero, 1998). Horton *et al.* (1982) and Ribas *et al.* (2000) reached the same conclusions for pepper and melon crops, respectively.

Table 2. Marketable and total yield (t ha^{-1}) in the irrigation treatments for a pepper crop in Central Spain

Yield	TR1	TR2	TR3	TR4
Marketable	41.9 a	42.3 a	42.1 a	30.1 b
Total	63.8 a	63.4 a	62.5 a	48.2 b

For each parameter, treatments followed by different letters differ at $P \leq 0.05$.

Daily application of a deficient water rate led to a reduction in plant size which, in turn, diminished its water requirements with respect to optimum watering as the plant cycle progressed, such that 50% IR (TR4) resulted in a lower relative irrigation deficit.

The small differences in the water status of the plants produced by watering rates lower than the crop requirements are probably responsible for a lower leaf area and consequently for a reduced cumulative dry matter of the aerial plant parts, since photosynthesis per unit soil surface decreased. Horton *et al.* (1982) also observed that deficient drip irrigation strongly reduced plant growth, whereas ψ_{leaf} and Rs were sligthly affected.

The present results support the reports by Bradford and Hsiao (1982), cited by Hsiao (2000), that mild water stress, not enoughly severe to inhibit stomatal conductance and photosynthesis per unit leaf surface, reduces leaf growth, considered as extremely sensitive to water stress. According to different authors (Hsiao, 1973; Hsiao and Acevedo, 1974), reduced growth is probably the direct result of the loss of turgor pressure for cell enlargement.

The little differences in ψ_{leaf} among the different irrigation treatments indicate that the measurements of this parameter are not an appropriate method for quantifying the effect of different water doses on crops with daily trickle irrigation and is even less suitable for irrigation scheduling, in agreement with Horton *et al.* (1982). Hanson and Hitz (1982) also noted that the rates of change in ψ_{leaf} and its diurnal oscillations in well-irrigated plants can be quite similar to those in non-irrigated plants. This is because ψ_{leaf} basically depends on the evaporative demand of the atmosphere, as mentioned above.

The response of the total yield to watering is consistent with the behaviour of the photosynthesising leaf area (LAI) and the aerial biomass accumulation, these three parameters varying in almost the same proportions according to the amount of water received. Thus, the lower LAI recorded for the most deficient treatment, resulting in less interception of solar radiation, gave rise to a continuous decrease in photosynthesis rates (Hsiao, 1993) and therefore to a reduced cumulative biomass and yield, though no stomatal response was observed.

As conclusions, the measurements of leaf water potential and stomatal resistance must not be used for quantifying the effects of different water rates on a pepper crop subjected to trickle irrigation. Moreover, in open air pepper crops, the severe restriction of water applied on a constant, daily way leads to the continuous adaptation of the plants, which adjust their leaf area and cumulative aerial biomass to the water available in the soil, in turn, leading to a reduced yield. Irrigation rates between 75% and 125% ETc do not provoke significant changes in these variables.

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