Evaluation of Two Cooling Systems in Parral Type Greenhouses with Pepper Crops: Low Pressure Fog System verses Whitening

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Abstract

In the Mediterranean region, the high temperature and low humidity of the air inside the greenhouse during the summer, has traditionally being tackled by whitening the cover to reduce the energy input. In low cost "parral" type greenhouses, alternative systems have started to be incorporated, like low pressure fog systems. This work compares the operation of two cooling systems inside such greenhouses and their effects on the internal climate and production of a pepper crop. Two treatments namely, low pressure fog system to keep a maximum water vapour pressure deficit of 1.5 kPa and normal whitening were tested in two "parral" type greenhouses with a different treatment in each. Significant differences in temperature occurred in the early stages of the crop with the temperature being 8ºC higher under the whitened cover than with the fog system. The water consumption in the fog system during the whole cycle was 219 L/m^2 and no significant differences were found in the commercial production of pepper.

INTRODUCTION

In Almería the "California" type pepper is transplanted into greenhouses between early June and early August, and the crop cycle ends between late January and late February. An extension of the greenhouse production cycles is important in order to guarantee a continuous supply to the market, to maximize the use of the installations and to enhance production to increase profitability (Arbel et al, 2003). The high solar radiation in the Mediterranean region during the spring and summer cycles causes thermal stress and high evaporative demand inside greenhouses which affects the growing and development of crops and diminishes the quantity and quality of the yield (Lorenzo et al., 2003).

In these greenhouses, climate control is limited using natural ventilation to reduce the situations of extreme humidity or temperature (Abreu and Meneses, 1994). Nevertheless, this is not enough to reduce the excess of energy during the sunny days of summer (Baille, 1999). Therefore, the use of other cooling systems namely forced ventilation, reduction of input radiation (whitening of the cover, screens) and evaporative cooling (fan and pad, and fog systems) is needed in combination with natural ventilation (Montero et al., 1998).

The goal of this work was to determine the effects of a low pressure fog system on the internal climate of a "parral type greenhouse and on the yield response of a "California" type pepper in Almería compared with the whitening of the cover.

MATERIAL AND METHODS

The experiment was carried out at the Experimental Station of Cajamar "Las Palmerillas", in El Ejido (Almería), which is located at 155 m height, 36º 47' 40'' north and 2º 43' 10'' west, during the autumn season of 2003-2004.

Two similar "parral" type greenhouses were used (Fig. 1), each of 882 m^2, with automated ventilation in the sides and roof. The cover material was a transparent three-layer plastic with 200µm thickness.

The crop was "California" type sweet pepper (*Capsicum annuum* cv. Vergasa). The seedlings were transplanted on 21 July 2003, and the crop cycle was ended on 12 February 2004, 212 days after transplanting.

The density of plantation was 2.1 plants/m^2, with 3 stems per plant equal to 6.3 stems/m^2. The substrate was perlite.

Two treatments were compared:

- Low pressure fog system, consisting of polyethylene pipes and 7.5 L/h sprinklers over a 1.5x4 m^2 frame. The system was controlled to keep the value of the water vapour pressure deficit (VPD) below a maximum of 1.5 kPa.
- Whitened cover using a solution of calcium carbonate ("Blanco de España") at a concentration of 25 kg per 100 litres of water. The timing was according to the usual practice in the Almeria region. It was applied before transplanting (20 July 2003) and washed off after the summer (23 September 2003).

Wet bulb and dry bulb air temperatures inside the greenhouse were measured using PT-100 sensors in ventilated psychrometers. From these measurements, the vapour pressure deficits (VPD) were calculated.

The management of the climate control by the opening of the windows and the operation of the fog system in the corresponding case was made from measurements taken every 30 seconds and averaged over 5 minutes.

In each greenhouse, photosynthetically active radiation (PAR) was measured and the transmissivity of the cover material was obtained as the ratio of the internal to external radiations measured using linear sensors (LICOR Inc, Lincoln, Nebraska, USA). These measurements were taken in four points along the E-W axis on clear days at about solar noon.

For the analysis of the yield, a unifactorial statistical design was adopted, with two treatments (fog and whitening) and five replicates in each, with 16 plants per replicate (although the five replicates of each treatment were in the same greenhouse).

The fruits were classified in categories, using a precision weight (± 1 g), according to the quality standards set for sweet peppers (Reg. CE 2706/2000).

RESULTS AND DISCUSSION

Climate

A summary of the measured temperatures is shown in Table 1. For the period between the transplanting and washing off the whitening (Period 1, from 21.07.03 to 23.09.03), the mean diurnal temperatures were 29.2ºC for fogging and 31ºC for whiening, higher than the external temperature (Te: 28.6ºC). During the same period, Maillo (2005) measured values higher than 33ºC in a whitened multi-tunnel greenhouse also with a pepper crop at its early stage. The maximum temperatures for the same period showed similar trends, i.e., closer to the outside with the fog and higher with the whitening.

The diurnal temperatures averaged over the whole crop cycle were close in both fog and whitening treatments (22.9ºC and 23.3ºC respectively) and higher than the outside (20.6ºC).

Regarding the VPD, the diurnal mean was significantly higher with the whitening (2.2 kPa) than with the fogging (1.2 kPa) during the first period, corresponding to the maximum operation of the fog system (Fig. 2).

Figure 3 shows the evolution of VPD and temperature for the two treatments on two summer days, before (day 7) and after (day 66) removal of the whitening. In the very early stages of the crop (day 7) in the middle of the day the temperature with whitening was up to 8ºC higher than with the fogging. Pérez-Parra et al. (2005) also measured higher temperatures (differences up to 5ºC) in a whitened multi-tunnel greenhouse compared with a high pressure fog system during the early weeks of a pepper crop. The VPD with fogging was kept below the maximum level of 1.5 kPa, while under whitening the values exceeded 5 kPa. These extreme conditions under whitening are common during days with high radiation, especially in the early stages of the crop, when the leaf area index is low (Lorenzo, 1998). Once the crop has developed and the whitening has been washed off, the stress conditions are not observed, and no differences were observed in the air temperature and the VPD between the two treatments.

The total water consumption of the low-pressure fog system to keep the VPD level below 1.5 kPa was 219 L/m^2. In a study performed during the season 2002-2003 by Meca et al. (2005), a consumption of 319 L/m^2 was required to keep the VPD below 1 kPa in the same greenhouse with a pepper crop.

The transmissivity of PAR radiation during the period of the whitening (until day 64) was approximately 55% and 24% in the fog treatment and under the whitening, respectively. The latter value is similar to Fernández et al. (1998) measured 31% in a “parral” greenhouse with similar whitening applied.

Production

There were 14 harvests, the first took place on day 87, and the last on day 206. The total production at the end of the cycle was similar in both treatments. The commercial production was 0.5 kg/m^2 higher in the whitened greenhouse, but the difference was not statistically significant. There were significant differences in the quality, however 56.2% of the fruits were in the 1st category with the whitening, and only 46.6% with the fogging. Non-commercial production was higher with fogging (1.2 kg/m^2) compared with (0.7 kg/m^2) under whirening. Also, higher precocity was obtained in the total production with fogging (2.8 kg/m^2 compared to 2.4 kg/m^2 for day 127). However, this difference did not affect the commercial production, as the first harvests were mostly non-commercial fruits. Similar results were obtained by Meca et al. (2005), where two cooling systems (low-pressure fog system and shading screen) did not improve the yields compared with whitening.

CONCLUSIONS

1. The low-pressure fog system was found to be the more efficient to control the high temperature and to keep low levels of VPD.
2. The low-pressure fog system caused higher precocity in the harvest, but negatively affected quality, resulting in a lower commercial production of 1st category fruits in comparison to whitening.

3. The results obtained in this experiment suggest that whitening could be the more suitable system for the cultivar and crop cycle under evaluation. Further studies concerning the dosing and timing of its application and washing off are recommended.

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Tables

Table 1. Average air diurnal temperatures (ºC) inside the greenhouse for the two cooling treatments and the outside, over the full crop cycle, Period I (up to day 64) and Period II (from day 65 to day 206).

	Maximum	Mean	Minimum
		Low pressure fog system	
Cycle	27.3	22.9	15.1
Period I	33.0	29.2	21.7
Period II	24.9	20.1	12.1
		Whitening	
Cycle	28.0	23.3	15.2
Period I	36.1	31.0	22.0
Period II	24.5	19.9	12.2
		Outside	
Cycle	23.4	20.6	15.4
Period I	32.1	28.6	21.9
Period II	19.6	17.1	12.6

Table 2. Accumulated production (kg/m^2) during the whole crop cycle together with the average weight of the commercial fruit, PMFC (g/fruit).

Treatment	Total	Commercial	1st cat	2nd cat	Non commercial	Pmfc
Low Pressure Fog System	7.3 a	6.1 a	3.4 b	2.7 a	1.2 a	213.7 a
Whitening	7.3 a	6.6 a	4.1 a	2.5 a	0.7 b	203.6 a

Values followed by different letters mean statistically significant differences (95%)

Figures

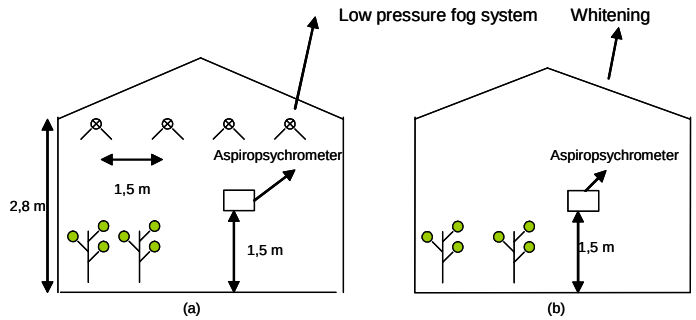


Fig. 1. Scheme of the two treatments evaluated: (a) low-pressure fog system; (b) whitening.

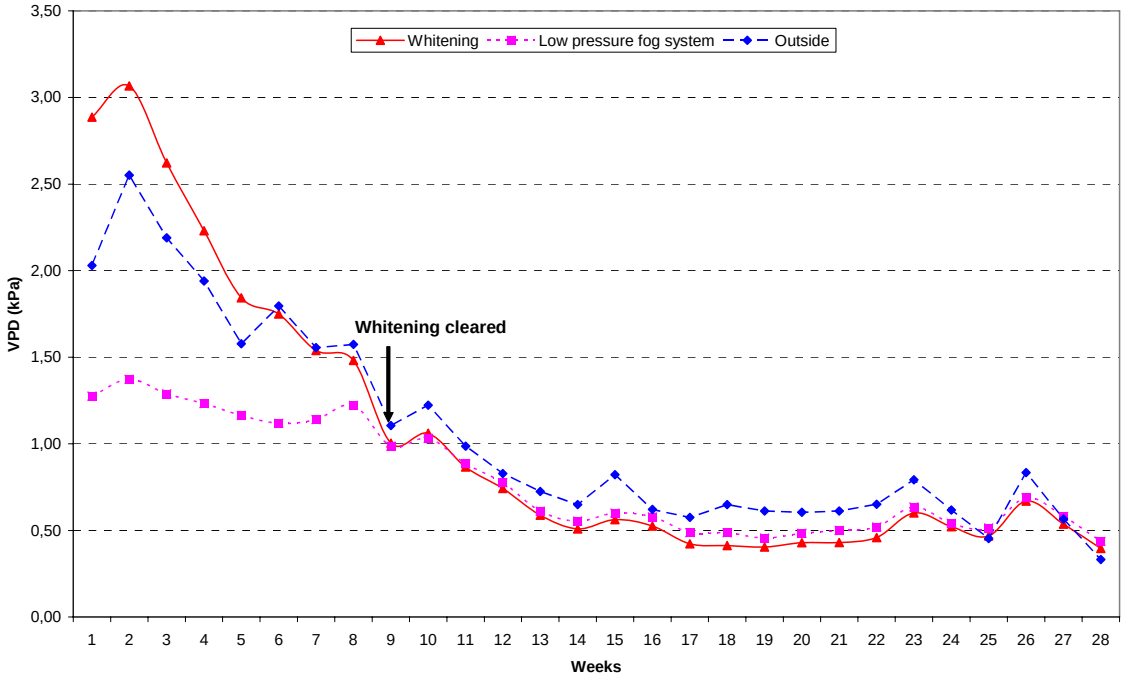
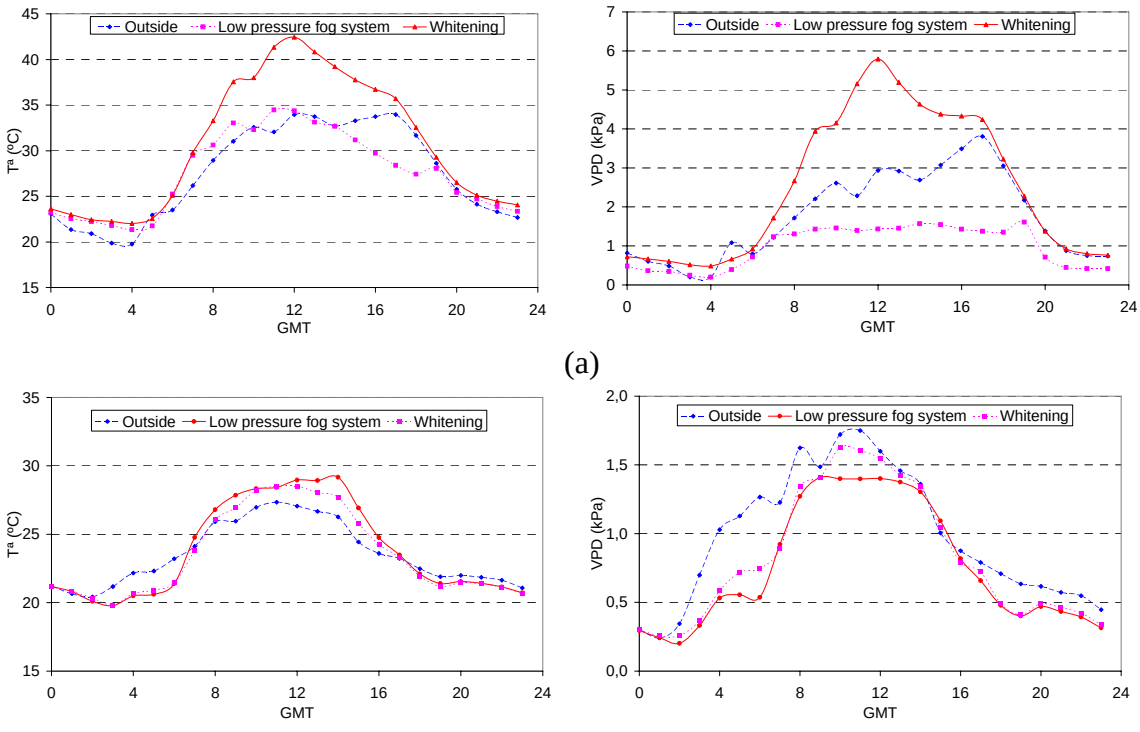


Fig. 2. Weekly evolution of the mean diurnal VPD.



(a)

(b)

Fig. 3. Hourly evolution of the measured T (ºC) and VPD (kPa) for the two treatments; (a) with whitening (day 7) and after washing the cover (day 66).