Use of Cool Plastic Films for Greenhouse Covering in Southern Spain

J. López-Marín and A. González
Departamento de Hortofruticultura
IMIDA, 30150, La Alberca
Murcia
Spain

Y.García-Alonso, E. Espí, A. Salmerón,
A. Fontecha and A.I. Real
Centro de Tecnología de Repsol YPF
Autovía A-5
Km. 18, 28931 Móstoles, Madrid
Spain

Keywords: temperature, NIR, greenhouse climate, sweet pepper

Abstract

The farmers that grow peppers in Murcia, Southern Spain, have serious problems during the summer due to high temperatures reached inside the greenhouse. In modern multitunnel greenhouses, shadowing screens, wet airflows, roof ventilation and whitening can be used, although they are not enough to solve the problems. In traditional "parral" greenhouses, only whitening and lateral ventilation can be used. An alternative system to lower temperatures is the use of near infrared (NIR)-blocking covers. In this work, an experimental plastic film with NIR-reflecting pigments has been evaluated. Under the experimental material and the White Wash, the lower is temperature the greater yield and better fruit quality is obtained.

INTRODUCTION

To reduce solar radiation and to attenuate the effect of temperature in the greenhouse, the following techniques can be used: ventilation (Bartzanas et al., 2004; Sase 2006), water sprays and moist air currents (Arbel et al., 2003; Kittas et al., 2003), thermal screens or mesh shades, and the application of calcium carbonate (whitening) to the cover. All of them increase production costs (Samaniaego-Cruz et al., 2002).

A NIR-blocking covering material, cheap and usable in every type of structure, would be ideal for this purpose. To obtain this effect, different techniques have been used, like pigments for absorbance, reflection and interference (Hoffmann and Waaijenberg, 2002), and coloured liquids in water-filled liquid-roof-systems (Gale et al., 1996). New developments such as plastic films (García-Alonso et al., 2006), glass fibre or moveable screens (Runkle et al., 2002) are being tested. The main problem of these materials is that any alteration in their optical properties also affects partly their heating behaviour during winter, and since PAR and NIR spectra are consecutive, any attempt to reduce the latter will affect the former and the resulting environmental conditions will be unsuitable for plant growth (Hemming et al., 2006). Another characteristic to study would be how long these properties last during the useful life of the covering materials, which should be 2-3 years.

In this work, we have compared the effectiveness of an experimental NIR-blocking film on a pepper crop, compared with the traditional whitening technique and a standard reference film.

MATERIALS AND METHOD

The investigation was carried out in a multitunnel greenhouse in the agricultural experimental field of IMIDA, (Murcia, Southern Spain).

The greenhouse had three separate modules with independent roof ventilation. Each module was formed by a single arc and had a surface of 240 m^2 (8 m width x 30 m length). In order to improve the thermal insulation, it was designed without lateral ventilation and the perimeter was insulated with polycarbonate sheets (PC) 800 micrometers thick. Separation between modules was also made with PC sheets.

Each module of the greenhouse had a different cover:

T1. Standard film (CA-2131, Repsol YPF, 200 micrometers thick)
T2. Standard film (CA-2131, Repsol YPF, 200 micrometers thick) + whitening
T3. NIR-blocking film (CA-3131C, Repsol YPF, 200 micrometers thick)

A Quantum sensor (LI-COR Inc., Lincoln, Nebraska) was placed 0.40 m above the floor in each greenhouse to measure the photosynthetically active radiation (PAR) in $\mu\cdot m\cdot m^{-2}\cdot s^{-2}$, and a pyranometer of the same type to measure the total radiation in $W\cdot m^{-2}$. In order to measure the radiation transmission of the three treatments, similar sensors were placed at the same height in each module.

Optical properties were carried out using LI-1800 spectroradiometer in the 300-1100 nm spectral range. The radiation intensity was measured for spectral intervals of 2 nm (Fig. 1).

Air temperatures were measured and recorded by Hobo RH/T model (Onset, USA) mini-instruments located at a height of 1.5 m in the centre of each module.

A completely randomized experimental design was used; four repetitions of three plug trays each; taking ten plants of each plug tray for a total of 30 plants sampled for repetition, on each evaluated species. The sampled plug trays were not considered for the next sampling.

For agronomic variables, samplings were carried out on 15 July. In sampling four repetitions were made, each one made up of three plug trays, and taking ten plants at random from each tray. Different plant organs (leaves and stems) were sectioned to determine leaf area ($cm^2\cdot plant^{-1}$) with the area meter leaf Model LI3100 of LI-COR Inc.; height to apical growth (cm) with a scale and stem diameter in the stem-root base (mm). All plant structures were placed in paper bags and dried until constant weight in a stove Blue M-Electric Company at 65-70ºC during 48 hours. Later, total dry weight was determined ($mg\cdot plant^{-1}$) in an electronic scale ANDHR120, and with these data the relative growth rate was calculated.

Fruit were harvested on 5 May (H1), 30 May (H2), 20 June (H3), 13 July (H4), and 12 August (H5). At each harvest, the fruit were weighted and graded into marketable and non-marketable. A sample of 30 fruits per treatment and harvest date was randomly collected during the harvesting period and used for quality measurements, which included fruit weight, diameter and height on two opposite sides of the pepper fruit surface at the equatorial region.

RESULTS AND DISCUSION

The total radiation (TR) received inside the greenhouses for all the treatments was about 50% of the exterior values, as has been described by other authors (Drug, 1997). The reduction in TR in the control was less than in shading treatments, although differences were not important, possibly due to the dust accumulated on the films. The TR in the module T3 was slightly higher than in T2 (Table 1 and Fig. 2).

The photosynthetically active radiation (PAR) measured inside the greenhouses was also about 50% less than that outside (Table 1 and Fig. 3), being differences higher than that observed by Cerny et al., 1999.

The maximum radiation values were observed between 12:00 and 14:00 h, a shorter period than determined in previous experiments (Samaniego-Cruz et al., 2002).

The total yield was affected by the covering treatments used: significant differences were recorded for total weight and number of fruit harvested (Table 2), being the values in the control treatment lower than in T2 and T3, confirming previous results (García-Alonso et al., 2006). The yield in the first harvest (H1) in T3 was 50% lower than in the other treatments. However, the percentage of waste in T3 was the lowest in every harvest (Table 3). There is less yield on the first harvest although this is not the case for the following harvests. Earliness is not so relevant during the harvesting period studied because the prices are about the same. Therefore total yield is not affected and with a similar income.

In the fruit formation stage, some significant differences between treatments of the same truss or position were obtained in some of the variables studied (according to the architecture of the plant), while there was substantial similarity between different crosses or positions. For example, in the fifth truss, higher fresh weigh and fruit width values were only found in the radiation-reducing treatments compared with the control (Table 4).

In the destructive treatments carried out at the end of the cultivation cycle, the covering materials induced some differences in plant growth (Table 5). Plant height was significantly greater in T2 and T3. The experimental material produced statistically significant increases in fresh and dry weights, leaf area and leaf number. Stem weight was also significantly greater, but, in this case, only compared with T1.

These results show that the NIR-blocking film tested produces similar results to those obtained with the traditional whitening method, and better than with the standard film. Both NIR-blocking films and whitening can be recommended to improve the quality of peppers with this cultivation cycle in Southern Spain.

Literature Cited

Abdel-Ghany, A.M., Kozai, T. and Chun-Changhoo. 2001. Plastic films vs fluid-roof cover for a greenhouse in a hot climate: a comparative study by simulation. Journal Society of High Technology in Agriculture. 13 (4): 237-246.

Arbel, A., Barak, M. and Shklyar, A. 2003. Combination of forced ventilation and fogging systems for cooling greenhouses. Biosyst Eng. 84: 45-55.

Bartzanas, T., Boulard, T. and Kittas, C. 2004. Effect of vent arrangement on windward ventilation of a tunnel greenhouse. Biosyst Eng. 88: 479-490.

Cerny, T.A., Rajapakse, N.C. and Oi, R. 1999. Recent developments in photoselective greenhouse covers. Proceedings of the 28th National Agricultural Plastics Congress, Tallahassee, FA, USA.

Gale, J., feuermann, D., Kopel, R. and Levi, S. 1996. Liquid radiation filter greenhouses (LRFGs) and their use of low quality hot and cold water, for heating and cooling. Acta Hort. 440: 93-98.

García-Alonso, Y., Espí, E., Salmeron, A., Fontecha, A., González, A. and López, J. 2006 New cool plastic films for greenhouse covering in tropical and subtropical areas. Acta Hort. 719:131-137.

Hemming, S., Kempkes, F., van der Braak, N., Dueck, T. and Marissen, N. 2006. Grenhouse cooling by NIR-reflection. Acta Hort. 719: 97-105.

Hemming, S., Waaijenberg, D., Campen, J.B. and Bot, G.P.A. 2004. Development of a greenhouse system for tropical lowland in Indonesia. Acta Hort. 710:135-142.

Hoffmann, S. and Waaijenberg, D. 2002. Tropical and suptropical greenhouses a challenge for new plastic films. Acta Hort. 578: 163-171.

Kittas, C., Bartzanas, T. and Jaffrin, A. 2003. Temperature gradients in a partially shaded greenhouse equipped with evaporative cooling pads. Biosyst Eng. 85 (1): 87-94.

Runkle, E.S.,Heins, R.D., Jaster, P. and Thill, C. 2002. Environmental conditions under and near infra-red reflecting greenhouse film. Acta Hort. 578: 181-185.

Samaniego-Cruz, E., Quezada-Martin, M.R., De La Rosa-Ibarra, M, Munguía-López, J., Benavides-Mendoza, A. and Ibarra-Jiménez, L. 2002. Tomato and bell pepper seedlings production under reflecting polyethylene covers to decrease temperature in greenhouse. Agroc. 36: 305-318.

Sase, S. 2006. Air movement and climate uniformity in ventilated greenhouse. Acta Hort. 719. 313-323.

Tables

Table 1. Average radiation and temperature with the three treatments (T1= Standard film, T2= Standard film+whitening, T3= NIR-blocking film).

Treatment	TR ($W \cdot m^{-2}$)	PAR ($\mu m \cdot m^{-2} \cdot s^{-1}$)	Temperature (ºC) 9-19 h	13-16 h
T1	436.09	795.40	28.5	37.8
T2	337.75	603.36	24.8	34.4
T3	358.53	671.12	24.2	34.7

TR= Total radiation
PAR= Photosynthetically Active Radiation

Table 2. Fruit yield of sweet pepper with under three different plastic films (T1= Standard film, T2= Standard film+whitening, T3= NIR-blocking film) treatments; fruit were harvested on 5 May (H1), 30 May (H2), 20 June (H3), 13 July (H4), and 12 August (H5).

Treatment		Harvest					
		Total	H1	H2	H3	H4	H5
T1	Weight (kg)	250.913 a	76.202 b	72.300 a	49.680	36.041	16.040 a
T2		271.200 b	82.820 b	77.440 a	46.760	44.620	19.560 a
T3		263.022 b	37.140 a	106.580 b	45.320	43.740	30.242 b
T1	Number	1499 b	382 b	350 a	359 b	221	187a
T2		1363 ab	346 b	350 a	220 a	284	163 a
T3		1318 a	167 a	452 b	202 a	249	248 b

Different letters in columns within each factor correspond to significant dereference at $p \leq 0.05$, using the TSD test.

Table 3. Waste fruit yield of sweet pepper with under three different plastic films (T1= Standard film, T2= Standard film+whitening, T3= NIR-blocking film) treatments; fruit were harvested on 5 May (H1), 30 May (H2), 20 June (H3), 13 July (H4), and 12 August (H5).

Treatment		Harvest					
		Total	H1	H2	H3	H4	H5
T1	Weight (kg)	39.416 b	20.902 b	0.000 a	8.010 b	6.084 a	4.420
T2		30.000 b	12.080 ab	2.200 b	0.000 a	11.300 b	4.420
T3		17.490 a	6.020 a	0.120 a	0.000 a	6.700 a	4.650
T1	Number	382 b	109 b	18 b	120 b	52 a	83 b
T2		216 a	58 ab	18 b	0 a	91 b	49 a
T3		202 a	31 a	1 a	0 a	48 a	60 a

Different letters in columns within each factor correspond to significant dereference at $p \leq 0.05$, using the TSD test.

Table 4. Mean values of measured fruit characteristics in 5th and 8 th truss fruit of sweet pepper with under three different plastic films (T1= Standard film, T2= Standard film+whitening, T3= NIR-blocking film) treatments.

Treat.	5nd truss fruit				8th truss fruit			
	Days to harvest	Fruit weight (g)	Width (mm)	Length (mm)	Days to harvest	Fruit weight (g)	Width (mm)	Length (mm)
T1	34.2	120.0 a	9.2 a	8.0	33 b	120.7a	9	7
T2	33.3	196.6 b	10.9 b	8.4	29 a	150.2 ab	10	7
T3	34.1	197.6 b	10.5 ab	8.7	36 b	200.4 b	10	8

Different letters in columns within each factor correspond to significant dereference at p≤0.05, using the TSD test.

Table 5. Average behaviour of agronomic variables of sweet pepper with under three different plastic films (T1= Standard film, T2= Standard film+whitening, T3= NIR-blocking film) treatments.

Treat.	Plant length (cm)	Leaf number	Total leaves FW (g)	Stem FW (g)	Total leaves DW (g)	Stem DW (g)	Total leaf area (cm^2)
T1	129.2 a	367.01	528.20 a	866.50	78.36 a	135.27 a	1832.60 a
T2	152.43 b	379.50	574.02 a	900.52	88.72 ab	145.30 b	18473.90 a
T3	148.7 b	378.67	625.57 b	906.38	95.32 b	149.15 b	20685.03 b

Different letters in columns within each factor correspond to significant dereference at p≤0.05, using the TSD test.

Figures

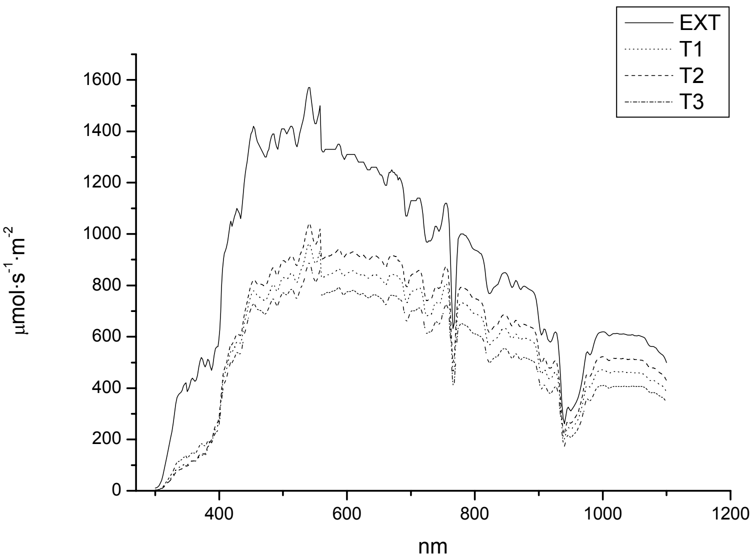

Fig. 1. Optical properties under different plastic film (T1= Standard film, T2= Standard film+whitening, T3= NIR-blocking film) treatments.

.

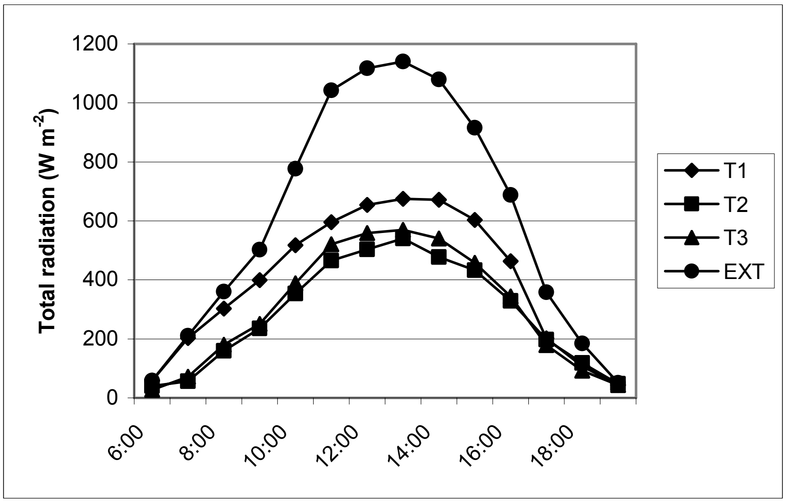

Fig. 2. Total radiation outdoors (EXT) and inside each greenhouse module; T1= Standard film, T2= Standard film+whitening, T3= NIR-blocking film.

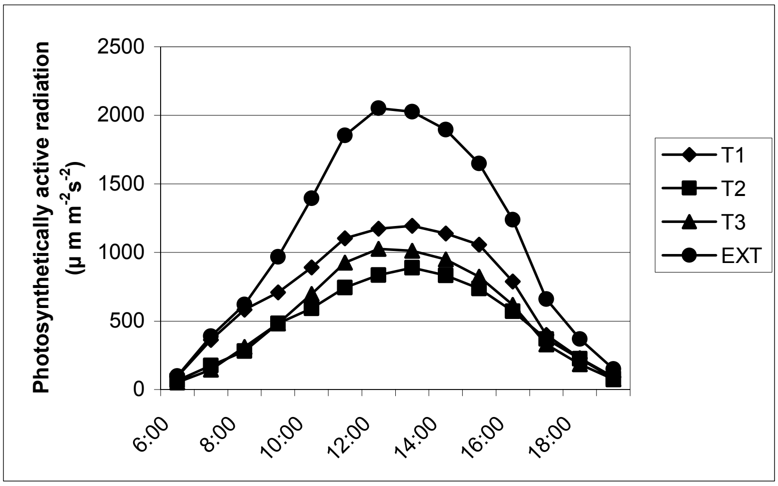

Fig. 3. Photosynthetically Active Radiation outdoors (EXT) and inside each greenhouse module; T1= Standard film, T2= Standard film+whitening, T3= NIR-blocking film.