Tomato Response to a High Light Transmission Greenhouse Film

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Abstract

Increasing greenhouse light transmission has a positive effect not only in Northern latitudes but in Mediterranean countries as well. A greenhouse, H2, with a tetrafluoroethylene copolymer 60 microns film, (Asahi Glass company, Aflex) characterised by its high light transmission and durability was compared to another greenhouse with a co-extruded film considered as a control, H1. Tomato crop response to the increase in light during winter and summer with high temperature and light was evaluated. Light transmission in H2 remained very high in spite of the observed dust accumulation and the low angle of incidence of the winter solar radiation. Transmissivity was clearly higher for H2 (81 to 83 % throughout the season) than in the control (around 63 %). The rest of the climatic parameters were similar in both greenhouses, either in the winter or in the summer evaluations. In spite of the high solar radiation in H2, the summer temperature could be maintained at the desired levels by using evaporative cooling. Accumulated tomato yield and quality was better in the H2 greenhouse (15 % more for the winter crop and 27% more for the summer crop). Fruit size was bigger in the winter crop. As an overall conclusion, the use of high light transmissive films in Mediterranean areas is very convenient for many vegetable crops. This is valid not only in winter but in summer, provided the greenhouse has good ventilation or evaporative cooling to overcome the increase in sensible heat caused by this increase in light..

INTRODUCTION

Most plastic films have lower light transmission than glass, although this negative effect is compensated by the reduction in opaque members of the supporting frame of plastic greenhouses. A few years ago, it was a general belief among growers that light availability in Mediterranean areas was above crop requirements even in winter. For this reason, film manufacturers did not pay much attention to the light transmission of greenhouse films, while the emphasis was put in the improvement of the infrared properties. (Montero, et al., 2000). It has been reported that increasing the greenhouse light transmission in Mediterranean countries enhances winter crop quality, early and total yield (Castilla, et al., 2000). A high light transmission film is the tetrafluoroethylene copolymer from the Asahi Glass Co, Japan (comercial name Aflex) also characterised by its durability. In Japan there are greenhouses with this cover of more than 20 years old without lost of light transmission.

MATERIALS AND METHODS

Two greenhouses with different cladding, a three-layer film, H1, and Aflex (tetrafluoroethylene copolymer 60 microns film from Asahi Glass Co, Japan), H2, were compared. Both greenhouses had three spans, being the covered surface 19.2 x 12 m^2. The height of the gutter was 2.5 m. and the maximum height 4 m. The width of each span was 6.4 m. The roof was formed by a number of arches separated 2 m from each other. Two experiments conducted in different period of year were carried out in order to study the influence of the film characteristics on a tomato crop: 1) winter test to study the effect of the increase in light: Transplantation was carried out the 15 of September 2000 and the crop ended in late February and 2) summer test aimed to know the effect of enhanced light on tomato plants under high temperature and high light levels: Transplantation was done the 5th of June 2001 and crop finished in early October. During the summer a fog system was used to keep the vapour pressure deficit less than 1.5 kPa in both greenhouses. In both experiments cultivar BOND® was grown in both greenhouses in perlite bags. Plant density was 2.2 plants per square meter. Plant growth, yield and size fruit was measured.

Evaluation of the greenhouse climate was done by continuous measurement of: total solar radiation (Pyranometers), greenhouse air temperature in an aspirated box (RTD sensors), greenhouse air humidity (Vaisala capacitors), leaf temperature (thermocouple sensors), substrate temperature (PT100). Open-air environmental conditions (solar radiation, air temperature and humidity, wind speed and direction) were also measured.

RESULTS

Climate response

1. Winter evaluation

A summary of the climatic parameters for the period between 11 October 2000 and 14 February 2001 is shown in table 1.

Light transmission for H2 remained very high in spite of the observed dust accumulation and the low angle of incidence of the winter solar radiation. Transmissivity was clearly higher for H2 greenhouse than in the control. No important differences were observed between the temperature regimes of both greenhouses. Ventilation controlled the daytime temperature while heating controlled the nighttime temperature regardless the cladding material. Leaf temperature was approximately one to two degrees higher in the H2 greenhouse, probably due to the highest solar radiation level. With regard to the humidity regime the maximum vapour pressure deficit was 1.3 kPa in both greenhouses. So the increasing light transmission did not have any important effect on humidity. Soil temperature was also similar in both cases even when the soil heating system was not connected.

2. Summer evaluation

A summary of the climatic parameters from 6 June 2001 to 3 October 2001 is shown in table 2. Light transmission in H2 remained around 81 % while that of H1 was 63 % on the average. No important differences were observed between the temperature regimes of both greenhouses. Ventilation and evaporative cooling controlled the daytime temperature. Leaf temperature was very similar in both greenhouses. Soil temperature was higher in the H2 greenhouse during the first month of the crop due to the higher solar radiation levels. Later in the season, when plants shaded the perlite bag, soil temperature was similar in both greenhouses.

Crop Response

A statistical analysis was done for each of the measured parameters. The General Linear model was used for statistical analysis and using the Duncan's test mean values were compared.

1. **Winter crop**

Plant height: Average plant height in Asahi film greenhouse was lower and significantly different than in the control greenhouse, 285.7±5.66, in H2 versus 313.3±3.33, in H1. This means plants in H2 were more compact. This is a well-known phenomenon: plants grown under shade tend to be more elongated.

Dry weight: No significant differences were found between both greenhouses neither in the leaves nor in the stems. Nevertheless dry weight was bigger in H2, which is typical of more compact plants.

Leaf area: Leaf area index was bigger in H1 (5.2±0.8 against 4.95±0.53 in H2). According to the statistical analysis this difference was not significant.

Specific leaf weight: Statistically, no significant differences were found between both greenhouses. Specific leaf weight was slightly bigger in greenhouse H2, 0.004 gr cm^{-2} as compared to 0.003 gr cm^{-2} in H1. This indicates the adaptation of the crop to high radiation conditions.

Yield: Final Yield in the control greenhouse was 8.3 kg m^{-2}, while in greenhouse H2 was 9.5 kg m^{-2} (figure 1a). These differences were not statistically significant, but it has to be pointed out that the average increase in production of H2 was 15%. Figure 1b shows the fruit size distribution of greenhouses H1 and H2 for the first harvest. Some differences were found on the fruit size. Fruits were bigger for the H2 greenhouse, 31 % of the fruits being 8 cm of diameter, while in the control greenhouse 25 % of the fruits were of 7 cm diameter.

2. **Summer crop**

Plant height: Similar observation can be derived from summer and winter results. Plants respond to higher solar radiation levels by decreasing their height. There were no significant differences between greenhouses, but the average plant height in H2 was 266 cm, which was lower than 283.7 cm for H1.

Dry weight: Results showed higher dry weight in greenhouse H2 for the leaves and stems. Comparing to winter conditions summer values are higher as a result of the increase in solar radiation.

Leaf area: There were not significant differences between greenhouses, but again H2 leaf area index, 3.2, was lower than in greenhouse H1, 4.15. Both LAI were lower for the summer than for the winter conditions.

Specific leaf weight: specific leaf weight was higher in greenhouse H2, .0117 g cm^{-2}, in relation to H1, 0.0089 gr cm^{-2}

Yield: Harvesting started at the beginning of August. Since the early start the yield of H2 was higher. Final accumulated yield was 27% higher in H2 (figure 1c). For the summer crop, no differences in fruit size have been observed. The fruit diameter with higher percentage in the sample was of 8 cm in both greenhouses (figure 1d).

CONCLUSIONS

Regarding the climatic conditions, the highly transmissive film clearly outperformed the three-layer film in the amount of light transmitted to the greenhouse. The remaining parameters (air temperature, soil temperature and humidity) were similar in both greenhouses. During the summer, ventilation and evaporative cooling helped to mitigate the potentially adverse effect of increasing light levels on the greenhouse temperature.

The increase in light led to an increase in yield for both the summer and winter crop. This shows the importance of promoting light transmission in Mediterranean summer production. Light enhancement also produces shorter and more compact plants, which is a positive asset for most ornamental plants while it has little practical interest for edible crops.

For the winter crop, fruit size was bigger in the greenhouse with more light transmission. This phenomenon was not observed for the summer crop.

Aflex is a very interesting material for cladding greenhouses. Aflex maintains its high light transmission, which has a positive effect on the quality and yield of all tested crops. Technically no important drawbacks have been detected after more than two years of evaluation. Since it is a long lasting material its environmental impact is expected to be much lower than that of standard plastic films. Aflex should gain popularity in Mediterranean horticulture if the cost of the material is affordable for the growers of the area.

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Table 1. Summary of climatic parameters in greenhouse H1 (three layer film), greenhouse H2 (Aflex film) and Outdoors during winter evaluation.

		H1	H2	Outdoors
Global solar radiation	$MJm^{-2}d^{-1}$	5.5	7.2	8.8
Transmitance	%	64	83	
Temperature max.	ºC	24.3	25.9	25.7
Temperature min.	ºC	13.8	15.5	3.5
Temperature avg.	ºC	18	18.6	13.6
Leaf temperature	ºC	16	17.5	
Substrate temperature	ºC	17.9	17.3	
Temperature avg. 8-17	ºC	20.3	21.5	15.1
Leaf temperature 8-17	ºC	18.1	20.3	
Relative humidity avg Min	%	51	48	
Relative humidity avg. 8-17	%	68	66	68

Table 2. . Summary of climatic parameters in greenhouse H1 (three layer film), greenhouse H2 (Aflex film) and Outdoors during summer evaluation.

		H1	H2	Outdoors
Global solar radiation	$MJm^{-2}d^{-1}$	13.7	17.6	21.7
Transmitance	%	63	81	
Temperature max.	ºC	34.3	36.4	33.2
Temperature min.	ºC	13.9	14.2	11
Temperature avg.	ºC	27.3	28.1	23.7
Leaf temperature	ºC	25.7	25.8	
Substrate temperature	ºC	25.3	26	
Temperature avg. 6-19	ºC	27.3	28	23.7
Leaf temperature 6-19	ºC	26.1	25.7	
Relative humidity avg Min	%	58	52	53
Relative humidity avg. 6-19	%	68	64	68

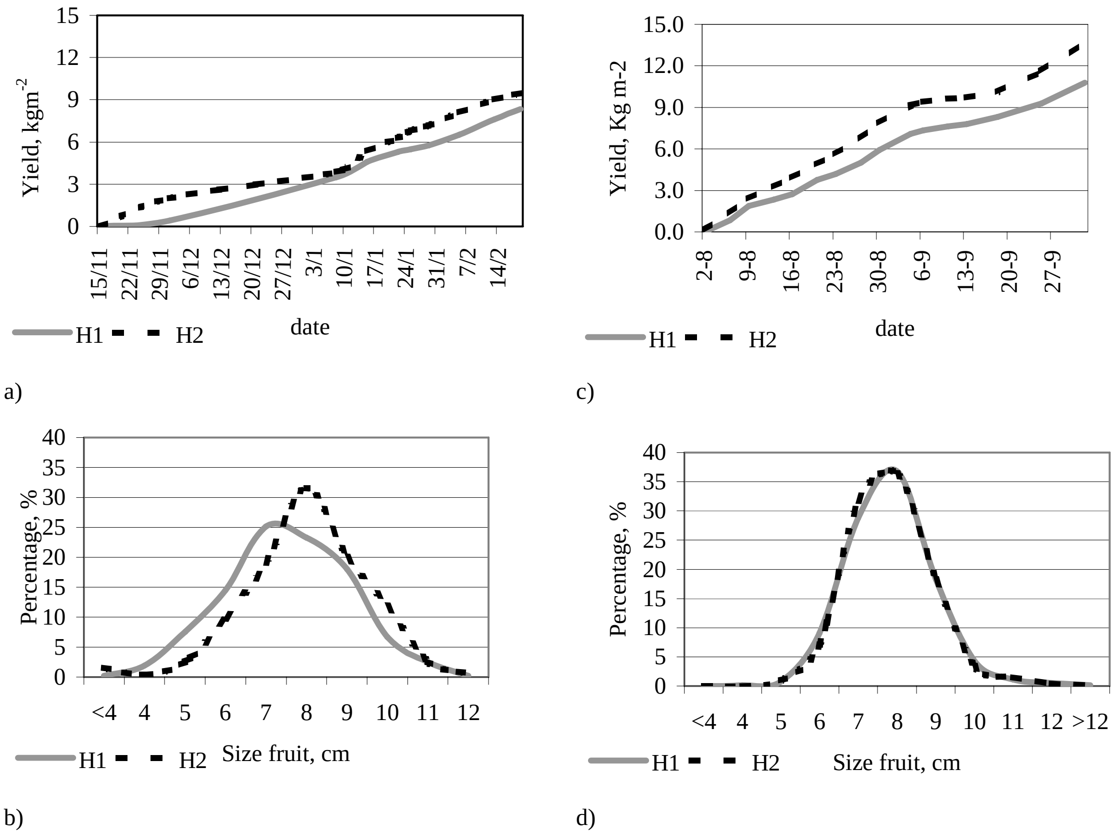

Figure 1.Crop response in greenhouse H1 (three layer film) , and greenhouse H2 (Aflex film) a) yield during winter time; b) size fruit during winter time; c)yield during summer time and d) size fruit during summer time.