Thermal Screen Evaluation in Soilless Cucumber Crop under Glasshouse

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Abstract
The objective of this study was to determine the value of the SLS 10 (Ludvig Svensson) thermal screen in cutting energy costs in a first soilless cucumber crop under heated glasshouse. The thermal screen was mostly used during the night in the 2002 trial and was used intensively during both day and night in the 2003 trial. In the 2002 trial, the thermal screen mostly closed on the crop during the night didn’t lead to any significant difference in ambient temperature nor relative humidity in comparison with the treatment without a screen. However, its use for 63 % of the time led to an average night temperature decrease of 9°C in the heating pipes, 30 % energy savings and had no effect on fruit quality nor yield. In the 2003 trial, the thermal screen closed on the crop during both day and night didn’t lead to any significant difference in climatic parameters in comparison with the treatment without a screen. However, its use for 78 % of the time led to an average temperature decrease of 12°C in aerial heating pipes, 41 % energy savings but also a reduction in early fruit yield, which can be linked to a lower light intensity inside the glasshouse with a thermal screen. These trials enable us to calculate a profit earning capacity over a period of 3 to 5 years for a thermal screen in a soilless cucumber crop.

INTRODUCTION
A large amount of cucumber fruits (Cucumis sativus) produced in France (about 130,000 t per year) comes from soilless crops grown under heated glasshouses. As a consequence, energy costs represent one of the major costs, about 30% of the total amount. The increase in energy costs over the past few years has forced growers to search for means of reducing their energy bill. Some of the main ways of achieving this goal are improvement of the heating system efficiency, a decrease in energy losses, climate control improvement, type of energy choice and price, and various systems to reduce energy brought to the plants. Among these possibilities, thermal screen use was intensively studied. Some studies showed energy savings for glasshouse tomatoes are higher when screens are used for a long period of time during the day-night period, without decreasing fruit yield if thermal screens are only used during the night up to 3 hours after sunrise (Sims, 1978). Other studies showed lower light intensity inside the glasshouse immediately leads to lower fruit yield for glasshouse vegetables (Plaister, 1992; Janse and Welles, 1984).

However, the last economic studies for glasshouse cucumbers were made in the 80’s (Stokes and Tinley, 1980) and no specific study was carried out in the North of France on soilless cucumber crops.

This is why we decided to determine the value of the SLS 10 (Ludvig Svensson) thermal screen in cutting energy costs in a first soilless cucumber crop grown under modern heated glasshouse in the area of Nantes (North-West of France – oceanic climate).

In order to optimize thermal screen use, it was drawn mostly during the night in the 2002 trial and was used intensively during both day and night in the 2003 trial.
MATERIALS AND METHODS

General Conditions

The experiment took place in heated glasshouses (250 m²) 4.20 meters high, with roof vents on both sides.

The evaluated material was the SLS 10 (Ludvig Svensson) thermal screen.

In 2002, we used the cultivar ‘Armada’ (Rijk Zwaan), sown on December 1st 2001, planted on December 27th 2001 with Cultilene rockwool slabs, and harvested 3 times a week from January 28th to April 19th 2002.

In 2003, we also used the cultivar ‘Armada’ (Rijk Zwaan), sown on November 23rd 2002, planted on December 19th 2002 with Grodan Master rockwool slabs, and harvested 3 times a week from January 27th to May 30th 2003.

The average inside temperature setpoint was about 20°C and the average inside measured temperature about 21°C.

As a cultural system we used the V system, with a plant density of 1.25 plant/m² and integrated pest management.

For each trial, the statistical analysis included 2 treatments and 6 replicates (12 plants per replicate).

Analysis of variance followed by Newman and Keuls test ($\alpha=5\%$) was used in order to statistically compare both treatments.

Thermal Screen Use Mostly during the Night - 2002 Trial

2 treatments were compared:
- Treatment without a thermal screen,
- Treatment with a thermal screen mostly used during the night.

The experiment lasted from December 27th 2001 to April 19th 2002.

The thermal screen was drawn during the night (from 60 minutes before sunset to 60 minutes after sunrise) if the outside temperature was lower than 12°C and during the day if the outside temperature was lower than 4°C.

Minimum heating pipe temperature setpoint was 10°C lower during the night in the treatment with a screen, in order to obtain equal inside temperature between both treatments.

From March 11th, roof sprinkling was used to improve glasshouse climate for the treatment without a thermal screen, while Fog System® was used for the treatment with a screen.

Intensive Thermal Screen Use during both Day and Night - 2003 Trial

2 treatments were compared:
- Treatment without a thermal screen,
- Treatment with a thermal screen used intensively during both day and night.


The thermal screen was drawn during the night (from 90 minutes before sunset to 90 minutes after sunrise) if the outside temperature was lower than 18°C, and during the day if the outside temperature was lower than 15°C before March 16th and 6°C after.

The minimum heating pipe temperature setpoint was 10°C lower in the treatment with a screen, in order to obtain equal inside temperature between both treatments.

From March 24th, roof sprinkling was used to improve glasshouse climate for the treatment without a thermal screen, while Fog System® was used for the treatment with a screen.

In both experiments, screen opening was progressive (1%/minute up to 30% opening) in order to avoid cold air damage to plants. Screens were also opened if inside Water Deficit was lower than 3 g/kg or the inside temperature was higher than 25°C.

Phytomonitoring® (climate and plant sensors connected to a data logger system - Phytec) was used in both treatments for each experiment in order to detect water stresses.
RESULTS AND DISCUSSION

Impact on Glasshouse Climate

In both experiments, thermal screen use didn’t lead to significant differences for inside temperature and relative humidity in comparison with the treatment without a screen. However, thermal screen used mostly during the night in 2002 led to an average night inside CO₂ rate increase of 65 ppm and an average night heating pipe temperature decrease of 9°C. Thermal screen used intensively during both day and night in 2003 led to an average aerial heating pipe temperature decrease of 12°C and an average vegetation pipe temperature decrease of 4°C, which justifies adapting temperature management setpoints under screens (Plaisier, 1996).

Energy Savings

In the 2002 trial, the thermal screen was used for 1543 hours during the night and 205 hours during the day, which corresponds to 63 % of the time on a day-night period (Table 1). 2347 MWh/ha (including 82 % during the night) were burned in the treatment without a screen, 1593 MWh/ha (including 73 % during the night) in the treatment with a screen. This difference represents 32 % energy savings with a thermal screen.

In the 2003 trial, the thermal screen was used for 1963 hours during the night and 1057 hours during the day, which corresponds to 78 % of the time on a day-night period (table 2). 3069 MWh/ha (including 83 % during the night) were burned in the treatment without a screen, 1825 MWh/ha (including 84 % during the night) in the treatment with a screen. This difference represents 41 % energy savings with a thermal screen.

The comparison between both experiments proves energy savings are greater when thermal screens are used for a long period of time during the day-night period (Sims, 1978).

Agronomic Results

1. Thermal Screen Use Mostly During the Night - 2002 Trial. At the end of March, agronomic results provided no significant difference between both treatments (table 3), which tends to prove that thermal screen used only at night doesn’t lead to a significant fruit yield decrease (Sims, 1978). On April 19th, there was a significant difference in number of fruits per m² between the two treatments. This is probably due to Fog System® use from March 11th in the treatment with a thermal screen, while treatment without a screen was equipped with roof sprinkling (a less powerful system).

2. Intensive Thermal Screen Use During Both Day and Night - 2003 Trial. In mid-March, agronomic results were significantly lower in the treatment with a thermal screen (Table 4), which can be linked to lower light intensity inside the glasshouse in comparison with the treatment without a screen. This tends to prove lower light intensity inside the glasshouse immediately leads to lower fruit yield (Stokes and Tinley, 1980).

On May 30th, there was no significant difference in fruit yield between both treatments, which can be linked to a reduction in thermal screen use from mid-March, comparable climatic conditions in both treatments and a decrease in stress (detected by Phytomonitoring®) due to a lower heating demand at the end of the day in the treatment with a screen.

Thermal Screen Profit Earning Capacity

In order to calculate thermal screen profit earning capacity, we have chosen to compare time with:
- energy savings (in €/m²) linked with thermal screen use, considering a heating system burning methane (the most common energy type used in French glasshouses),
- consecutive yield loss (in €/m²),
- energy savings minus yield loss difference (in €/m²), in order to estimate the thermal screen economical performance in our growing system.

Although there is no significant difference in yield due to screens between both treatments in 2002, figure 1 analysis shows:
- a cumulative energy savings increase more or less constant over the whole season,
- a yield loss more or less constant which stabilized between 0.4 et 0.56 €/m²,
- an increase in energy savings minus yield loss difference up to 1.33 €/m².

As a consequence, it seems interesting to use a thermal screen throughout the season during the night, the benefit increasing gradually from the start to the end of the crop.

Considering thermal screen investment around 6 €/m² and a profitability of 1.33 €/m²/year (linked to CTIFL use in 2002), it can be estimated when used mostly during the night that the cost can be recovered over a period of 4 to 5 years.

Although there is no significant difference in final yield between both treatments in 2003, figure 2 analysis shows:
- a greater increase in cumulative energy savings up to mid-April which slowed down afterwards,
- an increase in yield loss up to the beginning of March, which stabilized around 0.6 €/m² up to the end of April, before increasing again up to 1.34 €/m² at the end of May,
- an increase in energy savings minus yield loss difference up to mid-April, then a fluctuation between 1.78 and 1.19 €/m².

As a consequence, optimum thermal screen use period has to take into account:
- first of all, the high energy consumption period,
- secondly, from the start of the lower energy consumption period, the start of an increase in yield loss, which leads to a decrease in screen benefit.

Considering thermal screen investment (around 6 €/m²), its profit earning capacity with an intensive use during both day and night can be calculated as followed:
- the cost can be recovered over a period of 5 years if we consider a profitability of 1.19 €/m²/year (linked to CTIFL use in 2003),
- the cost can be recovered over a period of 3 to 4 years if we consider a profitability of 1.78 €/m²/year (maximum profit earning capacity according to CTIFL trial in 2003).

CONCLUSIONS

In 2002, a thermal screen mostly used during the night led to similar agronomic results at the end of March in comparison with the treatment without a screen. It also led to 32 % energy savings for the first four months of the year, which corresponds to a profit earning capacity of 4 to 5 years.

In 2003, a thermal screen intensively used during both day and night led to agronomic results significantly lower in mid-March in comparison with the treatment without a screen, which can be linked to a lower light intensity inside the glasshouse.

On May 30th, there was no significant difference in yield between both treatments, which can be linked to lower thermal screen use from mid-March, comparable climatic conditions in both treatments and a decrease in stress due to a lower heating demand at the end of the day in the treatment with a screen.

Using a thermal screen intensively during both day and night also led to 41 % energy savings for the first five months of the year, which corresponds to a profit earning capacity of 3 to 5 years.

These economic results are very different from those obtained in the 80’s when Janse and Welles (1984) concluded that thermal screens were of no economic value, considering the low energy prices.

However, although thermal screen use mostly during the night can be easily recommended to growers nowadays, thermal screen use intensively during both day and
night has to be considered very carefully because of the economic risk of using screen after its optimum yearly period (lower energy savings and higher fruit yield loss).

ACKNOWLEDGEMENTS
Thanks to ARELPAL (Association Régionale d’Expérimentation Légumière des Pays de Loire – Regional Organization for Vegetable Experiments in the Pays de Loire Aera) for financial assistance.

Literature Cited

Tables

Table 1. Soilless cucumber crop under glasshouse – 2002. Energy consumption (MWh/ha) and thermal screen use (hours) from 27/12/2001 to 19/04/2002 with a screen mostly drawn during the night, in comparison with a treatment without a thermal screen.

<table>
<thead>
<tr>
<th></th>
<th>Energy consumption (MWh/ha)</th>
<th>Thermal screen use during the night (hours)</th>
<th>Thermal screen use during the day (hours)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Treatment without a thermal screen</td>
<td>2347</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Treatment with a thermal screen mostly used during the night</td>
<td>1593</td>
<td>1543</td>
<td>205</td>
</tr>
<tr>
<td>Difference</td>
<td>754 (32 %)</td>
<td>1543</td>
<td>205</td>
</tr>
</tbody>
</table>

1748 hours on a day-night period (63 %)
Table 2. Soilless cucumber crop under glasshouse – 2003. Energy consumption (MWh/ha) and thermal screen use (hours) from 19/12/2002 to 30/05/2003 with a screen drawn intensively during both day and night, in comparison with a treatment without a thermal screen.

<table>
<thead>
<tr>
<th>Treatment</th>
<th>Energy consumption (MWh/ha)</th>
<th>Thermal screen use during the night (hours)</th>
<th>Thermal screen use during the day (hours)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Treatment without a thermal screen</td>
<td>3069</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Treatment with a thermal screen used intensively during both day and night</td>
<td>1825</td>
<td>1963</td>
<td>1057</td>
</tr>
<tr>
<td>Difference</td>
<td>1244 (41%)</td>
<td>1963</td>
<td>1057</td>
</tr>
</tbody>
</table>

3020 hours on a day-night period (78%)

Table 3. Soilless cucumber crop under glasshouse – 2002. Evolution of cumulative agronomic results with a thermal screen mostly drawn during the night, in comparison with a treatment without a screen (values followed by a specific letter are statistically different between both treatments with $\alpha=5\%$).

<table>
<thead>
<tr>
<th></th>
<th>up to March 15th 2002</th>
<th>up to April 19th 2002</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Number of commercial fruits per m²</td>
<td>Commercial weight (kg/m²)</td>
</tr>
<tr>
<td>Treatment without a thermal screen</td>
<td>18.1</td>
<td>7.9</td>
</tr>
<tr>
<td>Treatment with a thermal screen mostly used during the night</td>
<td>18.6</td>
<td>7.9</td>
</tr>
</tbody>
</table>
Table 4. Soilless cucumber crop under glasshouse – 2003. Evolution of cumulative agronomic results with a thermal screen drawn intensively during both day and night, in comparison with a treatment without a screen (values followed by a specific letter are statistically different between both treatments with $\alpha=5\%$).

<table>
<thead>
<tr>
<th>Treatment without a thermal screen</th>
<th>up to March 14th 2003</th>
<th>up to May 30th 2003</th>
</tr>
</thead>
<tbody>
<tr>
<td>Number of commercial fruits per m²</td>
<td>Commercial weight (kg/m²)</td>
<td>Number of commercial fruits per m²</td>
</tr>
<tr>
<td>Treatment with a thermal screen used intensively during both day and night</td>
<td>16.7</td>
<td>6.6 a</td>
</tr>
<tr>
<td></td>
<td>15.3</td>
<td>5.9 b</td>
</tr>
</tbody>
</table>

Figures

Fig. 1. Soilless cucumber crop under glasshouse – 2002. Evolution of profit earning capacity with a thermal screen mostly drawn during the night, in comparison with a treatment without a screen (energy and fruit prices – 2003).
Fig. 2. Soilless cucumber crop under glasshouse – 2003. Evolution of profit earning capacity with a thermal screen drawn intensively during both day and night, in comparison with a treatment without a screen (energy and fruit prices – 2003).