| | |
|---|---|
| **Project Title** | Cut flowers: evaluation and development of plastic films and low cost growing structures |
| **Project Number** | PC 168 |
| **Project Leader** | Dr Robin Meeks<br>Horticulture Research International<br>Willington Road<br>Kirton<br>Boston<br>Lincolnshire PE20 1NN |
| **Annual Report** | Year 1 report, April 2000 |
| **Other Staff** | Mr Gordon Hanks, HRI, Willington Road, Kirton, Boston, Lincs, PE20 1NN. |
| **Consultants to the project** | Mr Lyndon Mason, Frank Rowe Ltd., Rylands Nurseries, Wellington, Somerset, TA21 9QB.<br><br>Mr Stuart Coutts, Nightingale Cottage, Felhampton, Church Stretton, Shropshire, SY6 6RJ. |
| **Location of project** | Horticulture Research International, Willington Road, Kirton, Boston, Lincs, PE20 1NN. |
| **Project co-ordinator** | Mr Bob Goemans, Parigo Horticulture, Spalding Common, Spalding, Lincs, PE11 3JZ. |
| **Date project commenced** | 1 May 1999 |
| **Date completion due** | 31 January 2003 |
| **Keywords** | Spray carnation, spray chrysanthemum, godetia, column stock, tunnel structures, spectral modification, plastic films |

The results and conclusions in this report are based on a series of experiments conducted over a one year period. The conditions under which the work was carried out and the results have been reported with detail and accuracy. However, because of the biological nature of the work it must be borne in mind that different circumstances and conditions could produce different results. Therefore, care must be taken with interpretation of the results especially if they are used as the basis for commercial product recommendations.

**CONTENTS**

# PRACTICAL SECTION FOR GROWERS

## Background and commercial objective

A strong UK cut-flower market presents opportunities for domestic growers who can produce to quality and schedule. As an economical alternative to glasshouses, French (single-span) and Spanish (multi-span) tunnel structures, which are already being adopted in the soft fruit sector, offer important quality improvement and season extension for cut-flower growers.

Plastic films offer obvious benefits in crop protection and environmental modification but little, if any, development work has been conducted on their use in cut-flower crops, either as shelter for a complete growing season or as temporary and specifically timed cover at certain growth stages, such as pre-harvest or for late season frost protection as a means of season extension. The introduction of specialist films, with spectral modification characteristics, increases the range and complexity of effects that might be achieved by their use.

Plastic films offer growers a number of properties:

| | |
|---|---|
| Thermal barrier | Reducing temperatures within plastic structures by reducing infra-red light (wavelength above 700 nanometres (nm)) that offers no photosynthetic benefit to plant growth |
| Light diffusion | Increases distribution of photosynthetic light (PAR 400-700nm) in the structure. Some plastics also fluoresce and change the wavelength of received light outside the PAR band to within it |
| Disease control | Control of pathogens by changing ultraviolet (UV) light balance. UV light is separated into three bands:<br>UVA 320-400nm<br>UVB 280-320nm<br>UVC 200-280nm |
| Growth control | Stem length, branching and flowering time are influenced by changes in the ratio of red (670 nm) to far-red (730 nm) light. |
| Physical protection | From wind, hail, rain etc. |
| Season extension | Modification of temperature and frost protection |

This project addresses two issues:

<u>Development of currently available technology for growers</u>

The novel properties summarised above may be present singly in a plastic film or provided in some combination. A range of films are commercially available. Many growers are using these films without fully understanding their effects and may either be buying the wrong film or not using it to its full potential. Effects on the plant do not necessarily add to the marketability of stems.

<u>Increase scientific knowledge for improvement of this technology</u>

Plastic films and structures are still being developed for horticulture and as part of this project significant data will be acquired to aid this development process:

- Stability of the plastics over time (measurements of photo-degradation).
- Spectral modification properties of the plastics (red:far red ratio, infra-red and UV levels) on light within the structure and the effect at different times of day.
- Environmental modification (air temperature and plant organ temperature).
- Physiological effects: bud formation, initiation and development, branching and internode extension, time to flowering, intermediate growth stages, assimilate levels and post-harvest effects.
- Agronomic effects (Stem length and weight, market grading and vase life)

**Summary of results**

The initial results can be summarised as follows:

- The spectral properties of the light within the plastic tunnels were successfully modified by the novel films of XL Sterilite, Visqueen Anti-Botrytis film, Luminance THB, XL SuperGreen and Visqueen FarRed in the manner that was expected.

- Plants did show significant responses to modified light. Physiological effects were significant but varied between crops. Some crops responded to stem length shortening more than elongation; some showed significant change in weight or bud number, some did not. Responses in plant growth in the 1999 trials can be summarised as follows:

| | Godetia | Stocks | Chrysanthemum | Carnation |
|---|---|---|---|---|
| Stem length | □ | □ | □ | □ |
| Fresh weight | □ | □ | □ | □ |
| Bud/flower no. | □ | □ | □ | - |
| Branching | □ | □ | Minor | - |
| Harvest date | □ | □ | □ | □ |

- Modification properties as well as overall transmissibility of PAR slowly degraded over the season and need monitoring.

- Growth control films altering the ratio of red and far-red light changed stem length, branching and time to flowering.

- Marketable characteristics of cut flower stems were affected, in some cases adversely. In chrysanthemum, peduncle extension gave uneven flower sprays that were unmarketable. Stem length extension was also at the expense of stem thickness in chrysanthemum.

- The use of conventional plastic films continues to be justified for high light transmission, thermal retention and anti-condensation properties. In late season crops, Polytherm film was found to provide greater stem length and stem weight over other films.

- No significant benefits or defects were found in vase life.

- Time to harvest stage was affected in all crops and by as much as three weeks longer in carnations. This effect is a combination of temperature lift in the tunnels over outside controls and spectral modification.

- Reduced moisture load under anti-condensation film produced much lower incidence of downy mildew on indicator crops than in all other tunnels.

- Significant reduction in soil temperature was achieved with Luminance THB and XL Supergreen. This may have applications for alstroemeria and freesia crops.

**Action points for growers**

While at this stage it is too early to offer growers specific recommendations, the following points can be noted:

- Removing red light can increase stem length, reduce branching and alter the time to flowering for specific cut flower crops.

- Removing far-red light inhibits stem length, promotes branching and may alter the time to flowering for specific cut flower crops.

  Note: the colour of the film does not necessarily reflect the wavelength of the light removed. There are green films that will offer opposite effects; one removes red light and the other removes far-red light. Blue coloured film has provided good removal of red light.

- Removal of infra-red light reduces heat load in structures without loss of photosynthetically active light. A 50% reduction in infrared energy can theoretically reduce the heat load by 25%.

  However, ventilation is a serious consideration. Small tunnels may have insufficient ventilation, particularly in the ends of tunnels, while larger Spanish tunnels may have less of a problem in this regard.

  The effect of infra-red load should not necessarily be judged in terms of effect on air temperature. Radiation load is on the plant and the soil. Changes in leaf and plant organ temperatures, and to soil temperatures, were significant with some plastic films.

- Ultra Violet light removal can help in controlling some diseases and pests but the mechanisms are not fully understood.

- The use of anti-condensation film can play a significant part in reducing disease risk where leaf wetness and (or) humidity can promote fungal pathogens.

- Some conventional plastics can offer high levels of photosynthetically active radiation (PAR) transmission (up to 85%) while offering physical protection.

- Any filtering effect carries a risk of reducing (PAR) with consequences such as reduced stem weight and changed leaf colour.

- Modification of soil temperature, air and plant temperature varies between films.

- Irrigation requirements under these low cost tunnels are substantially higher than outside.

**Practical and financial anticipated benefits**

Building of new glass (at approximately £30 per metre$^2$) is not likely to be an economic proposition for many cut-flower crops when competing with better overseas climates. However, the use of temporary plastic structures, with costs less than £2 per metre$^2$, may offer the UK grower the opportunity to compete to the required standard. As well as offering crop protection, the novel plastic films offer scope for improvements in plant form and quality, improved shelf life and reduced use of pesticides, including plant growth regulators.

The UK cut-flower market is currently very strong. The growth, which continues, is driven by supermarket demand. Consequently, quality and reliability of supply are essential features required of any crop. The market is characterised by strong import growth and a decline in UK production. Figure 1 below illustrates the stark divergence between import growth and UK decline.

It is not suggested that UK production can substitute for the imported crop but it is clear the market opportunity for UK production is available. The challenge for the grower is not only to produce these economically but to the demanding quality standards set.

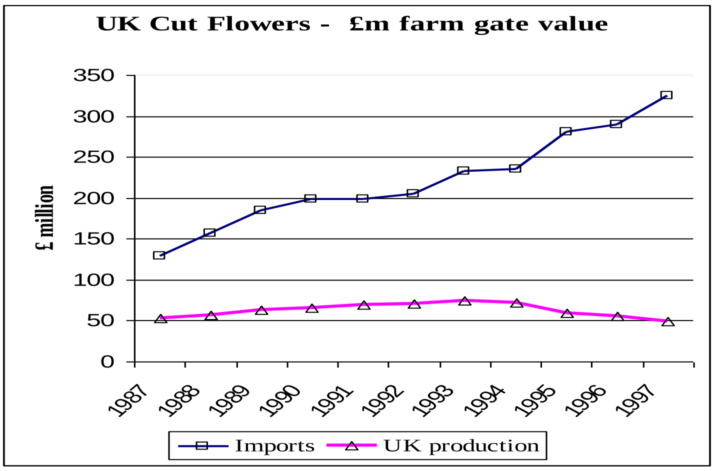



**Figure 1.** Changes in value of imports and UK production for cut-flowers between 1987 and 1997

**Source**: MAFF Basic Horticultural statistics for UK Calendar and Crop Years 1987-1997

## SCIENCE SECTION

## INTRODUCTION

A range of plastic films are currently available to growers. Generally, the benefits of these films are unproven in growing systems for cut-flowers. The underlying principles of plant reactions to spectral modification are well researched at molecular levels but little work is available to suggest how these effects can be brought into play in practical growing situations.

In 1999 flower crops were grown:

- for the complete growing season in French type tunnel structures using a range of films that offer control of infra-red radiation, ultra violet and the ratio of red : far-red light.

- outside, but with tunnel structures erected for short targeted periods using a single film type for protection.

The opportunity to grow a number of important or potentially important cut-flower crops under these materials and structures offers growers the chance to gain a competitive advantage by:

- Improving crop protection strategies
- Reducing production costs compared with traditional glass structures
- Improving product quality and matching product to consumer preference
- Increasing productivity and efficiency
- Reducing application of plant growth regulating chemicals (PGR's) for height control
- Offering innovative production methods to stem the decline in UK cut-flower production value and area

**Scientific objectives of the experiments were:**

- Establish the spectral characteristics of selected available and potentially available plastic films for horticultural use;
- Establish the durability over time of those spectral characteristics;
- Assess the environmental effects of the films;
- Examine effects on the physiology of four flower crops;
- Build a comprehensive data-set for further development work.

**Technical objectives of the experiments were:**

- Identify the most suitable films for protected/semi-protected cut-flower production;
- Assess effects on commercial crops with regard to prospects for season extension, crop scheduling and quality improvement;
- Provide practical guidance to growers for crop production under low tunnels;
- Assess economic implications;
- Identify implications for vase life.

## MATERIALS AND METHODS

Plant material was acquired as either propagated material or seed-raised modules. Irrigation was by low-level T-Tape. Initial fertilisation was by base dressing following soil analysis and subsequent nutrition was provided by liquid feed as necessary.

Weed control was by an experimental reduced rate Metham Sodium 400 (650 l/ha incorporated to 35cm) and Basamid sterilant treatment (200 kg/ha incorporated to 12cm) applied by a contractor (Sands Agricultural Services Ltd).

Statistical design and analysis was provided by the HRI Biometrics Department using modified Latin square models. The experimental design was a balanced row and column design with three replicates of each crop in each tunnel plot. Tunnels and plastic films were not replicated within the same experimental year.

Tunnels

In 1999, single span French tunnel structures (Fordingbridge Ltd.) of approximately 20m x 4.5m were erected for all experimental plots. Four flower crops were grown in each structure to a balanced design. Tunnels consisted of 11 hoops, 2 metres apart mounted on 22 flighted ground anchors. Diagonal braces were bolted between end pairs of hoops.

Plastic film was secured over the top of the tunnels by 4mm 3 strand rope passed over plastic and around the ground anchors. Tunnel ends were formed by tensioning the plastic sheet onto anchors at the ends of the tunnels. Tunnels frames were left erected at the end of the 1999 season but plastic films were removed and stored in November 1999 for re-use in following season.

Three one-metre beds were formed in each tunnel and two irrigation pipes laid in each bed.

Plastic films used

Table 1. Plastic films used in experiments were as follows:

| Experiment | Tunnel number | Supplier | Film |
|---|---|---|---|
| 1 | 1 | Visqueen Agri Ltd | Standard Control |
| 1, 2 | 2 | No cover<br>Outside control | None |
| 1 | 3 | XL Horticulture | XL Sterilite |
| 3 | 4 | Reading University<br>& Visqueen Agri Ltd | Growth control<br>Far Red < Red |
| 3 | 5 | Visqueen Agri Ltd | Growth control<br>Balanced PAR |
| 3 | 6 | Lee Filters | Growth control<br>Far Red >Red<br>(Steel Blue 117) |
| 2 | 7 | Visqueen Agri Ltd<br>Early and late cover | Luminance THB |
| 1 | 8 | Visqueen Agri Ltd | Anti-Botrytis Film |
| 2 | 9 | Visqueen Agri Ltd<br>Late cover only | Luminance THB |
| 1 | 10 | Visqueen Agri Ltd | Luminance THB |
| 1 | 11 | XL Horticulture | Supergreen Film |
| 2 | 12 | Visqueen Agri Ltd<br>Early cover only | Luminance THB |
| 1 | 13 | Visqueen Agri Ltd | Polytherm Anti<br>Condensation |
| 1 | 14 | XL Horticulture | Super Clear 400g |

Flower crops

The flower crops grown were as follows:

Chrysanthemum This crop offered a reference point for both growers and scientists. Varieties from different groups were chosen. The full season tunnels had a Group Two variety while the outdoor, temporary covered, plots had a Group Three late season variety.

Spray carnation This crop is also well understood by growers and scientists and UK summer production may offer a good opportunity to fill a window where imported produce falls in quality.

Column Stocks Two varieties were selected. The first to test the strategy of plastic as an alternative to glasshouse production and the second to test season extension. This crop was not grown in Experiment Two.

Godetia This crop was included as a ‘novel’ crop that has been highlighted as having strong market potential.

The cut-flower varieties grown in the experiments are detailed in Table 2 below.

Table 2. Variety details

| Crop | Variety[3] | Supplier |
|---|---|---|
| Spray carnation | Westek Westpearl Cerise | Frank Rowe |
| Chrysanthemum | Group 2 *Ellen* | Frank Rowe |
| Column Stock | Operetta[1] | Vegmo |
| | Caesar[2] | Nickerson |
| Godetia | F1 *Grace* | Hamer |

Notes:

[1] *Operetta* is chosen due to its commercial popularity and its problem with high temperature 'clubbing' of the flower spike.

[2] *Caesar* is less prone to high temperature problems and has been chosen as a potential variety for season extension

[3] Only 1 colour of each crop was grown

**Experiments**

Statistical analysis of data from all treatments was carried out by HRI Biometrics department. No pest or disease monitoring work was included in this proposal. After recording fresh-weight parameters, dry weight results were obtained after 72 hours oven drying.

Three inter-linked experiments were carried out.

**Experiment 1 Evaluation of the production of flower crops under a range of plastic film covers for the full growing season**

In 1999 eight single span French tunnel structures (Fordingbridge Ltd.) of approximately 20m x 4.5m were erected for all experimental plots. Four flower crops were grown in each structure to a balanced modified Latin square design. Each crop was planted on a single day. The plastics used are given in Table 1 above. Assessments used in this experiment are given below.

**Experiment 2 Evaluation of the use of crop covers for season extension, crop scheduling and quality improvement**

In this experiment, flower crops were grown outside with temporary tunnels, and a single type of plastic film (Luminance THB), erected for short targeted periods and the objectives are specifically to examine the effects on crop quality and season extension.

Four areas of cut-flower crops were grown in replicated, balanced, experimental design. These areas were of the same dimensions as tunnels in Experiment 1. These plots were covered with temporary tunnels as follows:

- At the start of the season – until the end of July
- At the end of the season – from the beginning of September
- Both the start and end of the season, uncovered for August
- No cover, as a control

**Experiment 3 Establish the durability over time of the spectral qualities of the films**

The objective of this experiment was to examine the stability of the spectral characteristics of each film over time and establish the useful life for the film. Monthly samples of plastic were removed and analysed on a spectroradiometer at Reading University. At the conclusion of the field experiments in 2000, samples of films will be transferred to frames and positioned in the field for two years further monitoring of degradation. The first spectral analysis was performed on samples taken when films were initially fixed to tunnels. Subsequent samples were taken monthly and forwarded to Reading University for analysis. Samples from July to November are presented on the same basis but the initial (June) spectral analysis cannot be correctly compared with these, although characteristics from the same initial analysis can be compared with each other. Comparison of the profiles is however valid.

**Assessments in Experiments 1 and 2**

Measurements were made of total Photosynthetically Active Radiation (PAR) and spectral characteristics within structures. Measurements were taken through the day and in different areas of the tunnel structures. A combination of sensors coupled to data-loggers and hand-held meters were used for this work.

The assessments will continue in 2001 and received light characteristics in the structures will be compared with the results of photo-degradation studies conducted on monthly samples delivered to Reading University. Experiment 3 will continue this work in 2001 and 2002.

Air temperatures were recorded by sensors mounted at canopy height in all tunnels.

All tunnels were ventilated by raising sides between 8am and 6pm each day. Tunnels were orientated North-South for uniformity of received light and before midday the tunnel side on the eastern aspect was left down to maintain maximum spectral filtering effect. After midday the eastern facing side was raised and the westward facing side was lowered.

Environmental modification by the film was measured as follows:

- Air temperature
- Soil temperatures
- Plant (leaf) temperature

Effects on plant physiology were measured as follows:

- Time to flowering and harvest stage
- Branching number
- Plant height and number of nodes or buds at harvest stage
- Dry weight of harvested stems

The following aspects of flower yield and quality were measured:

- Cropping date
- Stem length and branching numbers
- Flower characteristics; size and number of flowers in sprays, where applicable

This data was collected manually by cropping fifteen randomly selected plants in each plot.

## RESULTS

### Air temperature within the canopy

Figure 2 below shows the profile of air temperatures for key plastic films over a 24 hour period. This represents a period of high light levels without cloud cover in August 1999.

The air temperature recorded in tunnel 2, no plastic, should be compared to those covered with plastic. The air temperature effects appear to be different to expectations and limitations of ventilation in small experimental tunnels should be considered during any assessment of results. The Luminance film appears to generate higher temperatures than other films while under anti-condensation film there appears to be little difference with outdoor control.

However, the effect of Luminance film on received energy on objects it hits is demonstrated in Figure 3 (below) where soil temperatures are lower for Luminance than for high transmission plastics.

Leaf temperatures will be moderated by the ability of a particular species to control their own temperature by transpiration. Energy load on non-transpiring organs such as flower buds and the apical meristem will be measured more closely in the second year of the experiment as these plant organs have no mechanism to cool themselves.

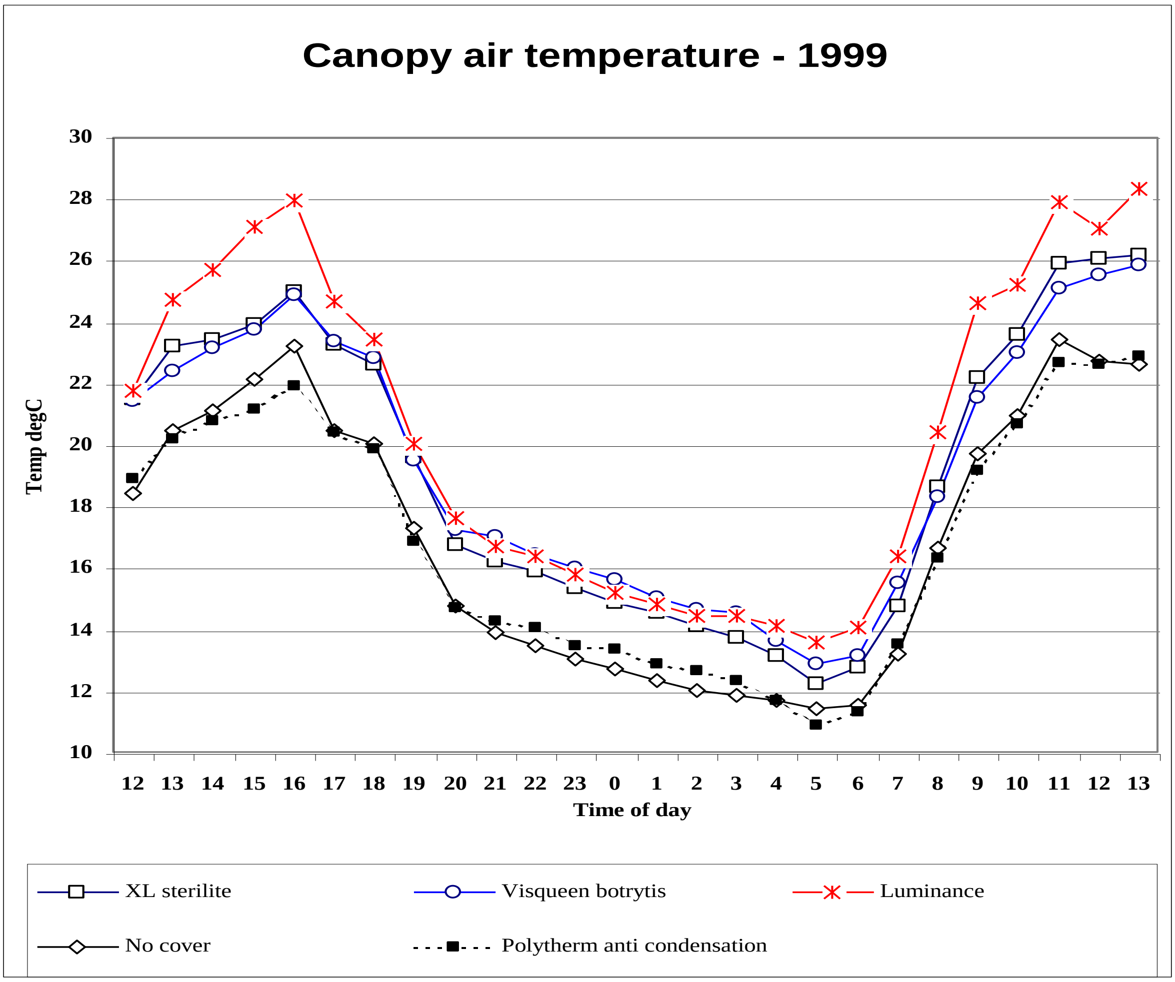



**Figure 2 Canopy air temperature**

## Soil temperatures

Soil temperature control is relevant in a number of flower crops such as alstroemeria and freesia.

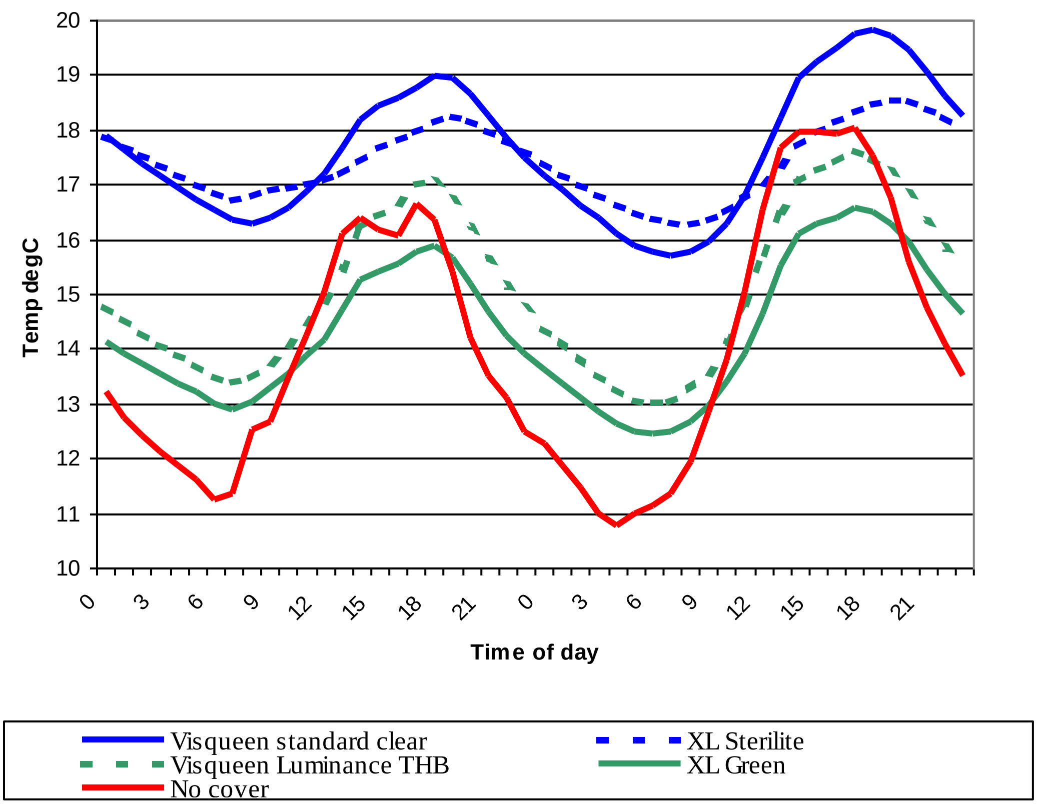
Figure 3 below shows the range of temperatures for the commercial plastics over a two-day cycle. The temperatures are the average readings of two sensors, both positioned centrally in the middle of three growing beds and buried between 10cm and 15cm, equidistant between irrigation tapes. These results carry some reservations regarding accuracy; there may be calibration or recording errors that could give an odd result. However, there was a considerable range of soil temperatures between films, characterised by different limits and ranges.

Soil temperature in uncovered plots was characterised by lower overnight temperatures and a greater range between minimum and maximum temperatures. Two relatively high transmission plastics, Visqueen standard clear (UVI/EVA) and XL Sterilite, produced generally higher soil temperatures while the other plastics had a similar range of temperatures to the outdoor plots but with higher minima.

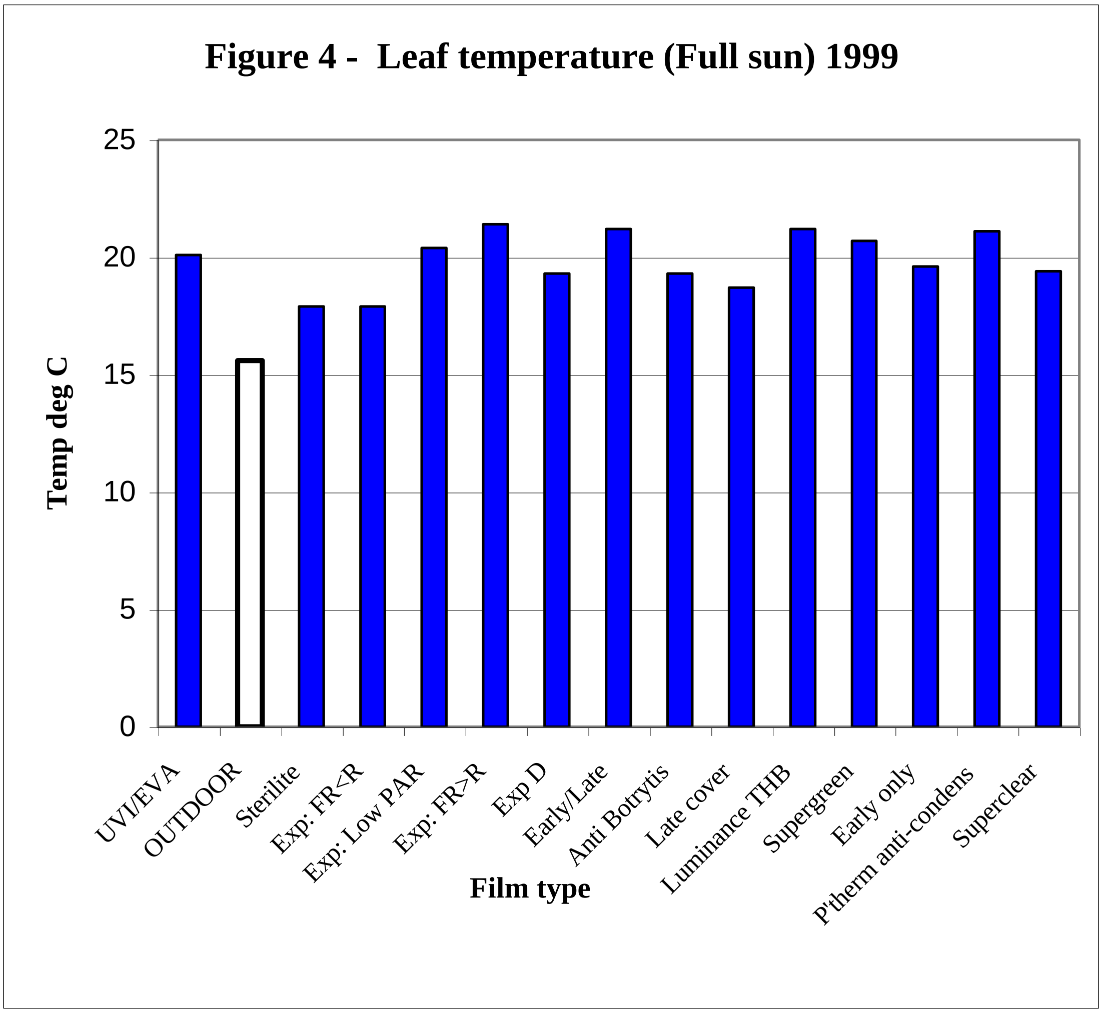
Two films, Visqueen Luminance and XL Green, appeared to offer soil temperatures that were lower than 'normal' films by about two degrees during the day. They also appeared to offer overnight minima about two degrees higher than outside temperatures. Given the limitations in ventilating the small tunnels, it may be possible in a production context to keep temperatures lower still by raising both sides.

Both the plastics identified above will reduce the heat load. However, the consequence of using the XL Green is that photosynthetic energy (PAR) will be halved and flowering will be delayed together with a potential increase in stem length that will be species dependent. (see section on physiological effects).

**Figure 3 - Tunnel soil temperatures - 1999**



**Leaf temperatures**




Leaf temperatures were measured using a hand held infra-red thermometer. Figure 4 (above) represents the averages of fifteen measurements in each tunnel. All readings are for chrysanthemum leaves in full sun 15cm below the canopy top. The hollow bar represents the outdoor control.

Some of the data was not in accordance with expectations and more detailed work on this aspect will be conducted in 2000.

**Red to Far Red balance**

Table 3 below details the ratio of Red to Far Red light received at the canopy in each tunnel. Readings were taken using a Skye hand held meter and are the average in each case of fifteen readings taken at canopy height in each tunnel. The readings reflect the ratio of light at 660 nm (Red) and 730 nm (FarRed).

**Table 3. Red to FarRed ratios**

| **Tunnel – Film** | **Ratio of Red : FarRed** |
|---|---|
| 1 UVI/EVA | 1.1 |
| 2 Outdoor – no cover | 1.1 |
| 3 Sterilite | 1.1 |
| **4 Exp: FR < R** | **1.2** |
| 5 Exp: Low PAR | 1.0 |
| **6 Exp: FR>R** | **0.5** |
| 7 Early / late cover | 1.0 |
| 8 Anti Botrytis | 1.1 |
| 9 Late cover | 1.1 |
| 10 Luminance THB | 1.1 |
| **11 Supergreen** | **0.7** |
| 12 Early only | 1.1 |
| 13 Polytherm anti-condensation | 1.1 |
| 14 Superclear | 1.1 |

Ratios were calculated by measuring light energy at 660nm and 730nm. A ratio of 1.1 reflects a 10% higher level of energy at 660nm than at 730nm. For height reduction the transmission of far-red light has to be less than that for red light, thus producing a ratio >1.1. The ratio above for Tunnel 4 (1.2) reflects some degradation in what was an experimental film. A ratio in the order of 2.0 can be obtained in new production versions of this film.

The ratios of *0.5* in Tunnel 6 and *0.7* in Tunnel 11 reflect reduced levels of red light transmission (660nm) compared with far-red (730nm), and are likely to lead to stem elongation and plant stretch.

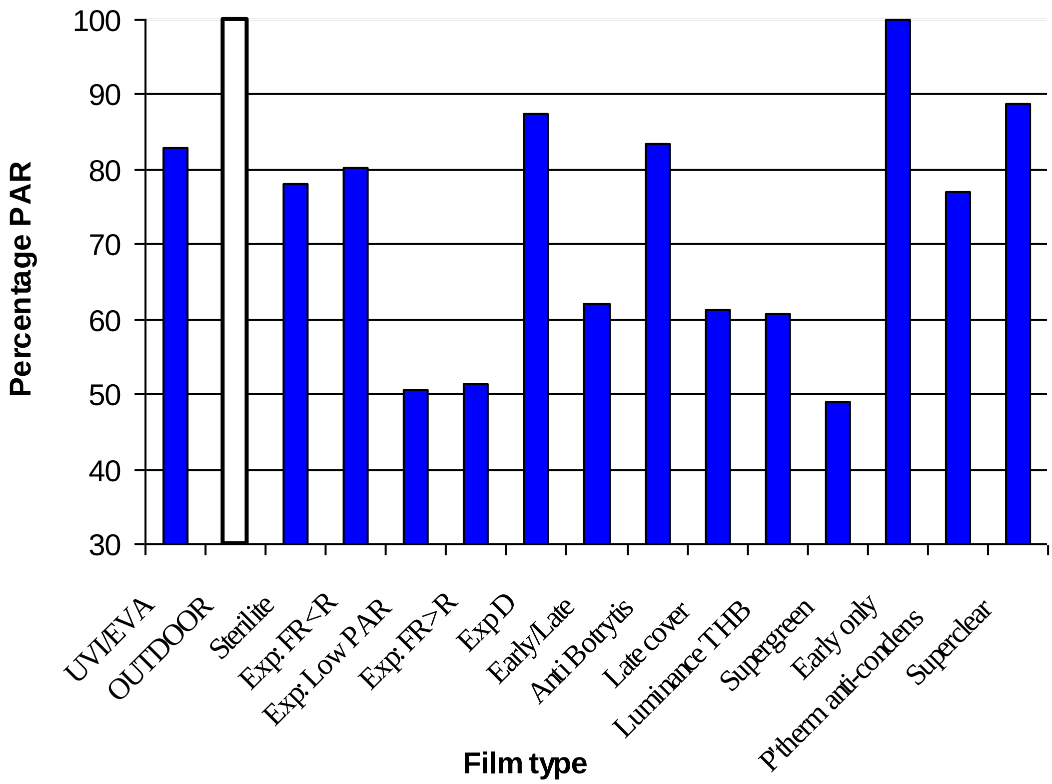
The three films expected to have an effect were the Experimental FR<R (to shorten stems), the Experimental FR>R (to extend stems) and XL Supergreen. They are highlighted in bold in the table. It can be seen that these films do make a substantial difference to the ratio.

It will be seen later (Figure 9.2) that the film Experimental FR<R lost much of its spectral characteristics over the 1999 season. The data given above was recorded in August and the R:FR ratio at the start of the season would have been higher.

The relative loss of PAR for these films can be seen in Figure 5 (below): The Experimental film FR<R transmits 80% of PAR while the Experimental FR>R and Supergreen films only transmit about 50% of PAR.

**Light energy**

**Figure 5 - Percentage of natural PAR received at canopy height - 1999**




The amount of photosynthetically active radiation (PAR) received at the plant canopy in each tunnel was measured using a hand-held quantum sensor at midday during periods of clear sky. The average data for each tunnel, for readings taken throughout each tunnel and avoiding shade cast by tunnel hoops, is presented in Figure 5 above. PAR energy is presented as a percentage of the natural level measured in the uncovered control. The hollow bar represents the outdoor control.

Only one plastic film appeared to suffer a lack of uniformity of pigment in that it caused significant differences in energy level across the tunnel. This will be checked in year two of the experiments.

**Spectral characteristics of films**

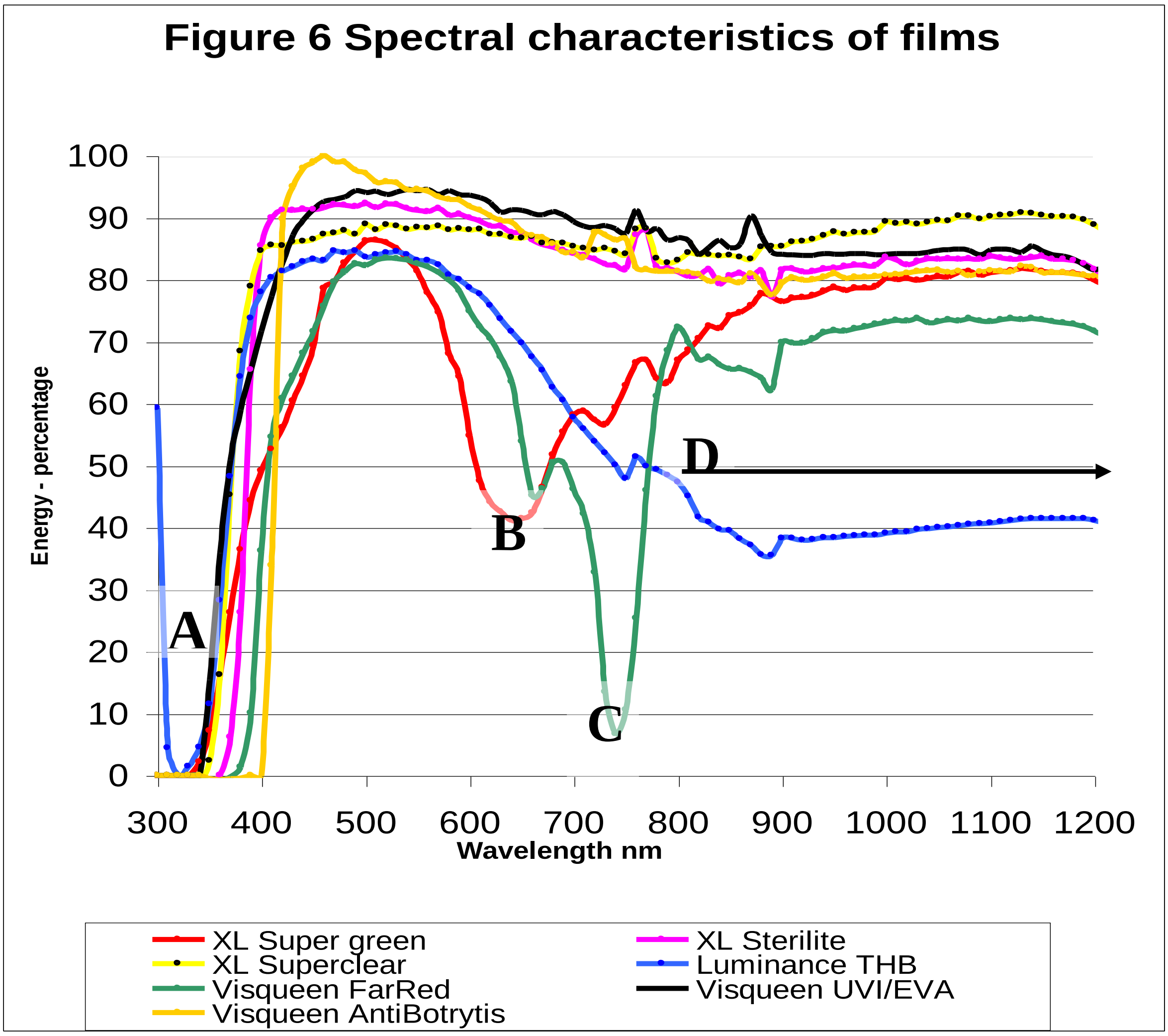



Figure 6 above shows the spectral profiles of a range of the films examined in this project. The graphs represent the percentage energy transmitted by a film at a given wavelength.

The three main mechanisms examined in this study can be seen in this representation of energy levels at given wavelengths:

- Area A represents the area where ultraviolet light modification occurs
- For growth control effects, point B represents the Red (670 nm) wavelength and point C represents the FarRed (730 nm) wavelength.
- Area D (from 730 nm upwards) represents the infra-red area

Figures 7.1, 8.1 and 9.1 (below), present the spectral profiles for films used to modify light transmission in each of these three functional areas. The main graphs represent the spectral profile of each film at the start of the growing season. Subsidiary graphs/figures show the degradation of the properties (if any) from July to November.

**Ultra Violet modification**

Figure 7.1 Spectral characteristics of films modifying UV light

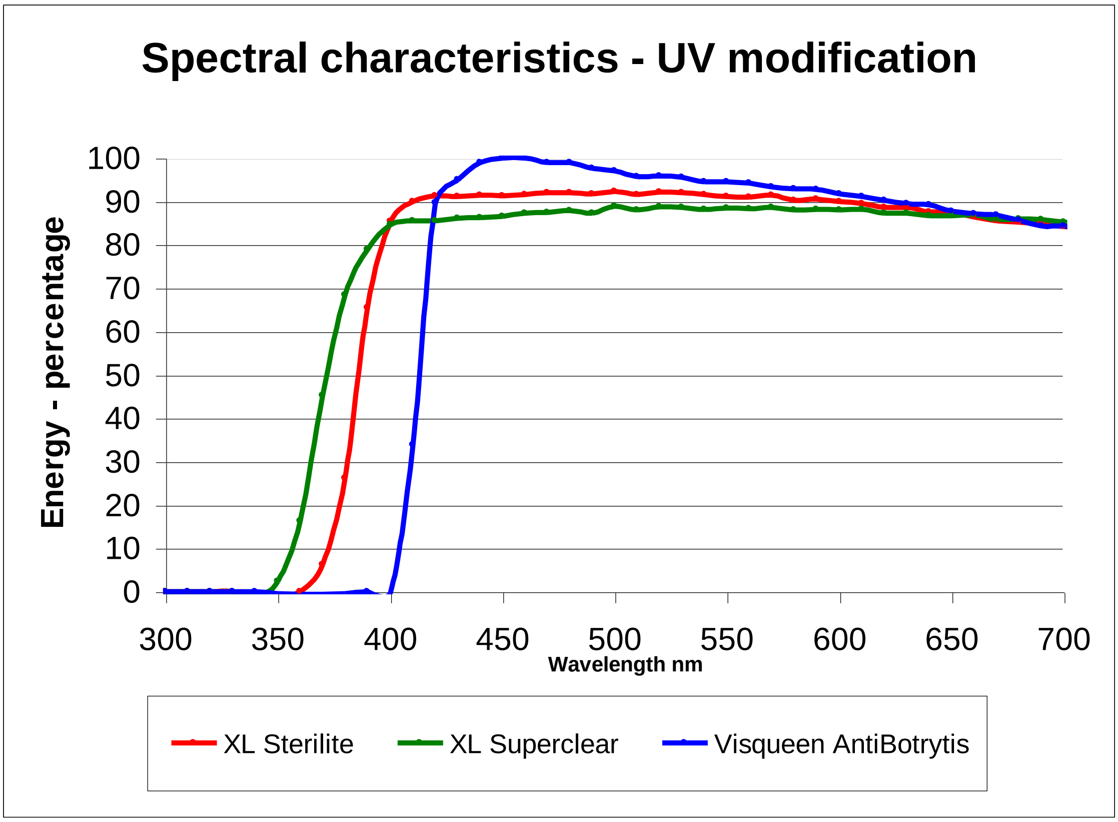



Figure 7.2 Degradation of XL Sterilite over one season

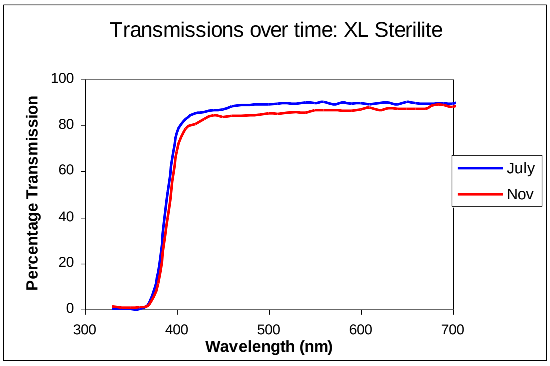
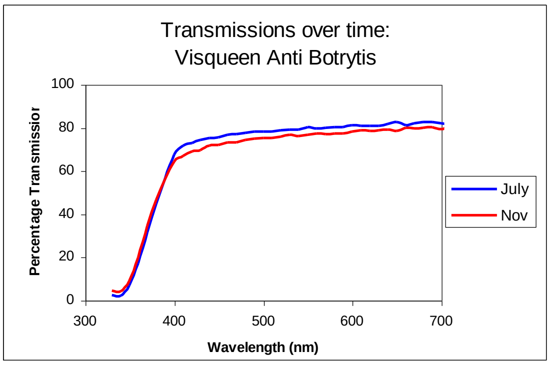



Figure 7.3 Degradation of Visqueen Anti Botrytis over one season




Initial analysis showed a greater modification of UV light by the Visqueen anti-botrytis film. However, subsequent analysis over four months showed less difference in modification of UV light by the XL sterilite and Visqueen anti-botrytis films. Neither suffered much degradation during the short growing period but XL Sterilite appeared to allow transmission of more PAR light. This should be looked at in conjunction with results for light transmission above.

## Infra red modification

Figure 8.1 Spectral characteristics of films modifying infra-red light

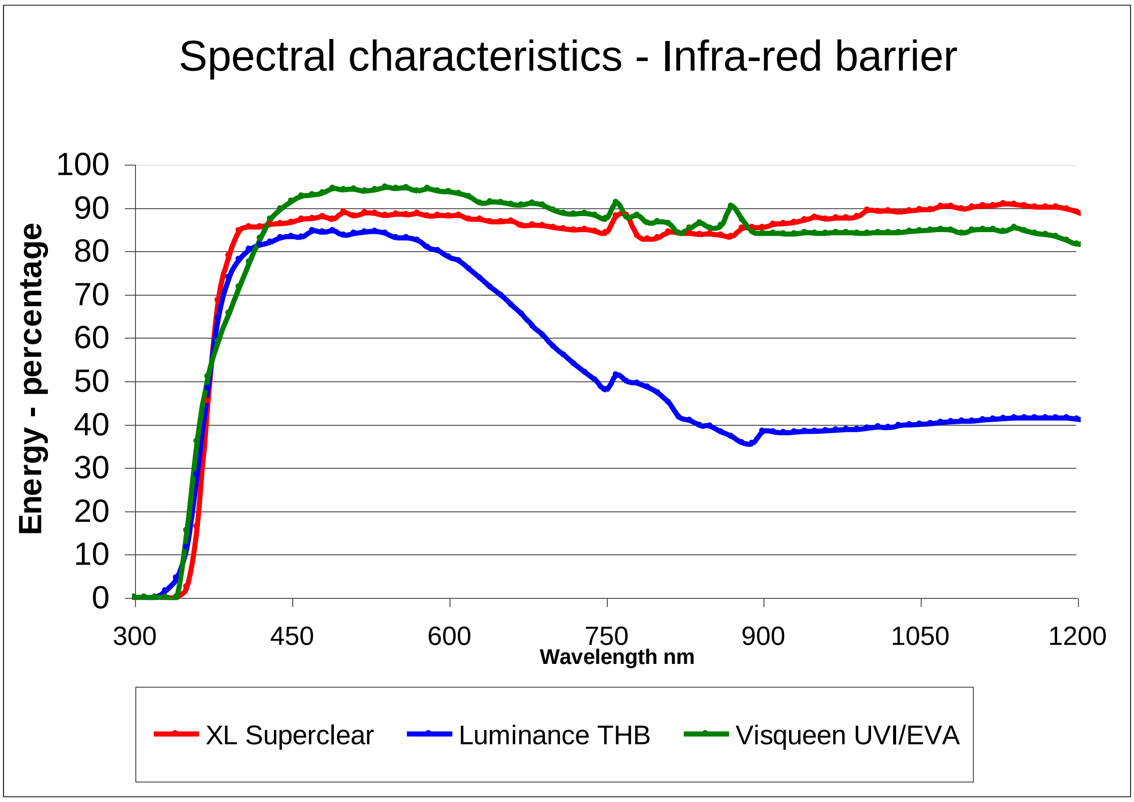



Figure 8.2 Degradation of Visqueen UVI/EVA over one season

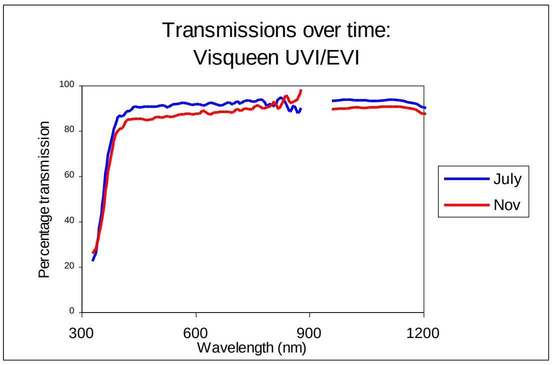



Figure 8.3 Degradation of XL Superclear over one season

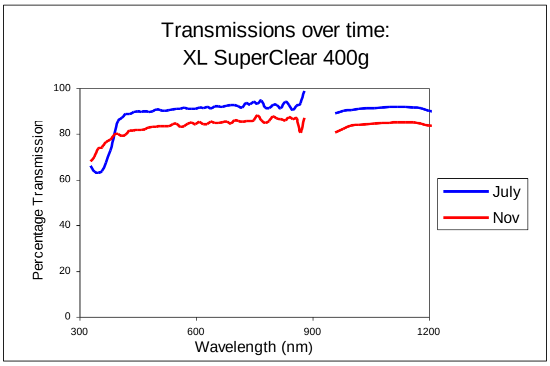



Figure 8.1 above demonstrates the effect that Luminance THB has on removing infra-red radiation compared with two 'high-transmission' horticultural plastics. Light transmission is reduced by over 50% in the wavelength above 700nm. There is some reduction of light energy in the PAR region, between 600nm and 700nm, but the effect is small compared to the reduction in infra-red. Light energy readings are given above to demonstrate the effect on total PAR.

Spectroradiometer readings are not available to show degradation of Luminance THB during the period July to November, 1999.

## Growth modification

Figure 9.1 Spectral characteristics of films modifying growth characteristics

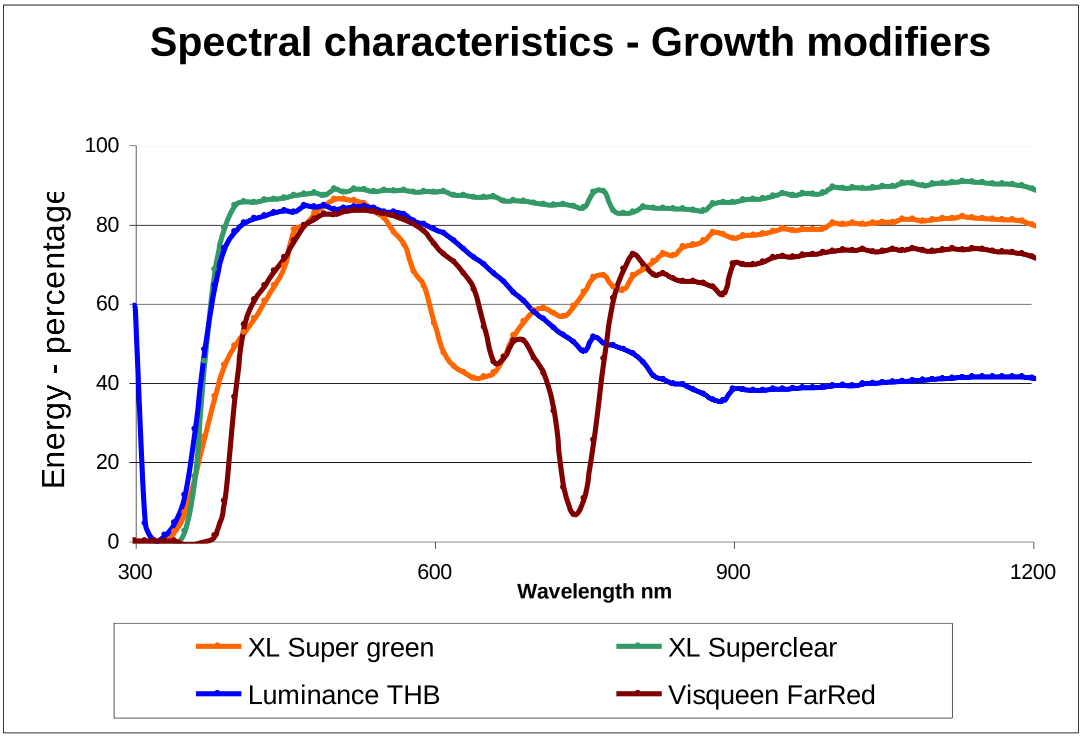



Figure 9.2 Degradation of experimental far-red reducing film over one season

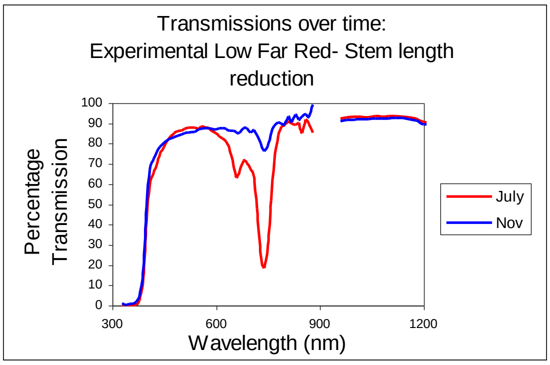



Figure 9.3 Degradation of XL Supergreen over one season

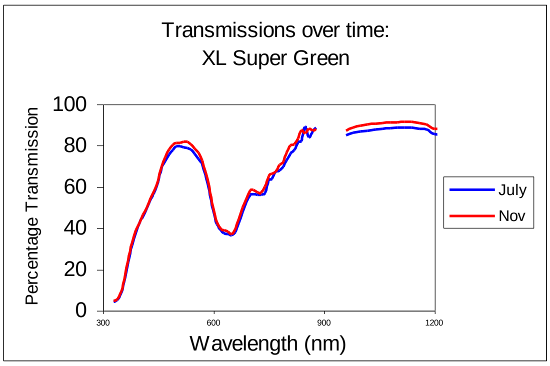
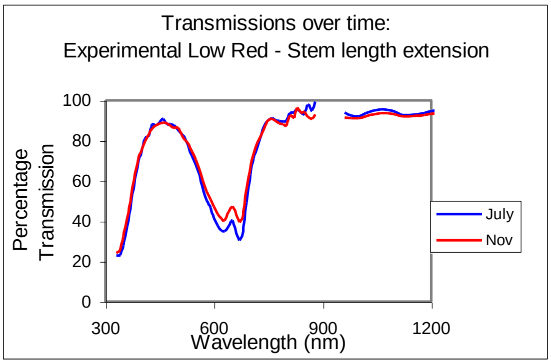



Figure 9.4 Degradation of experimental Red reducing film over one season



**Physiological effects**

The plant physiological effects of spectral modification were expected to be different between species and this was the case in 1999. Spray carnation showed little evidence of effects (although data were weak given late establishment of the crop), effects on column stocks and godetia were modest and chrysanthemum showed strong effects.

Tables 3.1 to 3.4 below detail the preliminary analysis of physiological effects seen in the four flower crops under the range of plastic films. Significance levels are given for each recorded character together with a guide as to the special feature expected of selected plastic films. Despite the small size of tunnels, there was little effect found of position within a tunnel but this is noted where it occurred.

The physiological responses in each crop are described below.

**Godetia**

Significant effects on stem length occurred in Godetia ($p$=0.002) with an outdoor control average of 48.7cm but Polytherm anti-condensation film achieved 60.1cm with most other plastics increasing stem length to 57cm. Stem length was significantly affected by position within tunnels.

Effects on fresh weight were variable and not statistically significant. However, Visqueen Polytherm film produced a treatment mean of 146.3g compared with outdoor control of 129.4g and 108.5g under reduced PAR control film (s.e.d. 15.9g).

There were highly significant differences ($p$<0.001) in the number of buds developed at harvest stage with outdoor control plots having the higher numbers, either as a result of higher light levels or lower temperatures.

Development of branches was significantly affected ($p$=0.027) with treatment mean branch numbers varying between 11.0 and 15.3.

**Stocks**

In column stocks, differences in stem length were highly significant. While growth control films both reduced and extended stem length (as expected) compared with each other, the reduced far-red height suppression film produced stem length the same as the outdoor control, offering no advantage over outdoor production. Luminance THB and XL Supergreen both produced stem length 25% greater than outdoor control at 51.3cm and 53.6cm respectively. However, Luminance THB produced more buds and more open flowers at harvest than XL Supergreen, a more marketable stem.

Reduced stem weight was significant ($p$=0.008) in covered plots. Outdoor plots achieved average stem weights over 92g while standard commercial films produced stem weights as low as 80g.

The number of unopened buds was significantly greater at harvest under both the ultraviolet films (XL Sterilite, 10.0; Visqueen AntiBotrytis, 12.2) and under Luminance THB (12.2). Flower numbers at harvest were also significantly different. XL Sterilite produced the highest number (17.2) but high transmission films (UVI/EVA) and outdoor plots under early cover (17.1) also produced high open flower counts.

**Chrysanthemum**

Highly significant responses ($p<0.001$) occurred in Chrysanthemum for stem length, stem weight and numbers of buds and flowers to open. Branching was only just significantly affected ($p=0.04$). The longest stems were produced under XL SuperGreen where levels of red light were greatly reduced and hence greater far red light. These stems were however unmarketable due to greatly extended flower peduncles. Visqueen Polytherm produced the next longest stems at 101.4cm plot average. This is likely to be as a result of overnight temperature maintenance in this late summer crop. The shortest stems were produced by the growth control film for reduction of far-red light (FarRed<Red), an 85.5cm plot average.

Stem fresh weight was also greatest under the Visqueen Polytherm film, 66.4g plot average.

Luminance THB produced stem lengths and weight very close to that achieved by Polytherm and produced the greatest number of buds and open flowers (30.3 total per plant) but this was not dissimilar to numbers achieved in outside crops.

Growth control films were effective. Low far-red film slowed flowering and increased branching over the low red film.

**Spray carnation**

Low harvest numbers following a late crop establishment allowed insufficient analysis to obtain any statistically significant results.

However the data suggests that:

- There was no difference in stem length between growth control films.
- Stem fresh weight appears to be affected by films.
- Time to flowering was altered by up to 25 days, crops under high transmission (XL Superclear and Luminance THB) being earliest.

## CONCLUSIONS

The initial results can be summarised as follows:

- Spectral characteristics were successfully modified by commercial films in the manner that was expected and during the first growing season.

- Uniformity of properties was found throughout tunnels although one film appeared to have uneven pigmentation. Only limited differences in effects on plants were found between edge rows and centre rows in tunnels.

- Plants did show significant responses to modified light summarised below. Physiological effects were significant; stem length, stem weight, bud and flower number and time to harvest were all modified but varied in degree of response between crops. The type of effect may be different between crops too. For example, some crops responded to stem length shortening more than elongation; some showed significant change in weight or bud number, some did not.

| | Godetia | Stocks | Chrysanthemum | Carnation |
|---|---|---|---|---|
| Stem length | □ | □ | □ | □ |
| Fresh weight | □ | □ | □ | □ |
| Bud/flower no. | □ | □ | □ | - |
| Branching | □ | □ | Minor | - |
| Harvest date | □ | □ | □ | □ |

- Modification properties of the films as well as overall transmissibility of PAR slowly degraded and need monitoring.

- Marketable characteristics of cut flower stems were affected, in some cases adversely. Peduncle extension in chrysanthemum varied and produced flower sprays that were uneven and unmarketable. This suggests that care is required in choice of variety for production under plastic. It cannot be assumed that traditional varieties that perform well outside will do so under plastic. Stem extension in all chrysanthemum and carnation produced marketable length but, in some cases, stems that were too weak to be acceptable.

- The use of conventional plastic films continues to be justified for high light transmission, thermal retention and anti-condensation properties. Indicator crops of lisianthus proved far less susceptible to downy mildew under anti-condensation film than in other plastics. This issue of reduced moisture load deserves further attention.

- No significant benefits or defects were found in vase life.

- Positive effects on reducing soil temperatures were found and could be explained by the characteristics of the plastic film that produced them. Crops such as freesia and alstroemeria may benefit from this feature.

- Air temperatures and leaf temperature differences were also found between films. However, the effects were not immediately understandable in the context of the film properties that caused the differences. More detailed work is required in the second year of field experimentation.

- Data for the carnation crop are weak given the lateness of establishing the crop in the first year experiments.