What was very positive for me was just how much I enjoyed working with and learning about a new flora. As a propagator working within the RHS garden at Wisley, I have found it very difficult to enjoy working simply with the plants in their own right as we are always looking at ways of producing them more quickly, efficiently, to a higher standard, with the use of less pesticide, and in the most environmentally neutral compost possible. It was, therefore good to have the chance to remind myself just why I am involved in horticulture.

I did score very well on my objective of learning about and seeing a new flora, this actually became my passion and I am sure it will stay with me long after much of my trip has been forgotten. To all of you who are thinking of taking some time out from work, to undertake study overseas, I say, go on, give it a go.

Acknowledgement. David Hide's Tour was aided by a Royal Horticulture Society Bursary.

Results From Some Research on Spectral Filters in the United Kingdom©

Les Lane
Devonshire Lavenders & Herbs, Exmouth Road, West Hill, Ottery St. Mary, Devon, EX11 1JZ

INTRODUCTION

There has been a vast body of research on spectral filters, using small-scale trials, going back many years, some of which is listed in Table 1 (Table 1 with acknowledgement to Leigh Morris). However, it is only in recent years that the technology has become available to incorporate these spectral filters into commercially produced PE films for cladding horticultural structures. Most of the work reviewed in this paper uses films developed by the author and the manufacturer Plastika Kritis, together with some films from other suppliers. The key point for the grower is the spectral transmission of the film, not who makes it. The paper reviews three main areas of research:

1) **Pest and Disease Control.** How to Use spectral filters to control whitefly, which is the vector for tobacco mosaic virus, and aphids without using pesticides. (XL Horticulture has copyright on, the term "photological control" to describe this property of its films).
2) **In Micropropagation.** Altering plant growth by using spectral filters in the tissue culture laboratory.
3) **In Conventional Propagation.** Spectral filters can improve both the viability of the cutting material and also the rooting of the cuttings through photological control of *Botrytis*.

PEST CONTROL

Whitefly. The research on whitefly was undertaken by Dimitri Doukas, a Greek research student at Reading University, who was looking at the potential of spectral filters to control whitefly and whether they also affected the whitefly biological control predator, *Encarsia formosa*. The research paper he produced formed part of his final for the degree of MSc in Horticulture.

Table 1. Chronolgy of experimental research into the use of UV-blocking plastic greenhouse covers for insect pest control.

Reference	Country	Insect pests	Crop(s)
Nakagaki, et al., 1982	Japan	*Aphis gossypii* *Frankliniella intonsa* *Myzus persicae*	Sweet pepper Cucumber
Kajita, 1986	Japan	*Trialeurodes vaporariorum* *Encarsia formosa**	Tomato
Murai, 1988	Japan	*Frankliniella intonsa*	Tomato
Hachiya, 1989	Japan	*Frankliniella intonsa*	Garden pea
Shimada, 1994	Japan	*Bemisia tabaci*	Tomato
Shibao, 1995	Japan	*Scirtothrips dorsalis*	Grape
Kakizaki, 1996	Japan	*Frankliniella intonsa*	Garden pea
Antignus et al., 1996a	Israel	*Aphis gossypii*	Tomato
Antignus et al., 1997		*Bemisia tabaci* *Frankliniella occidentalis*	Cucumber
Antignus et al., 1996b	Israel	*Aphis gossypii* *Bemisia tabaci* *Frankliniella occidentalis* *Liriomyza trifolii*	Tomato Cucumber
Chen and Ho, 1997	Taiwan	*Aphis gosypii* *Bemisia argentifolii* *Liromyza bryoniae* *Spodoptera exigua* *Thrips palmi*	Mellon
Antignus et al., 1998a	Israel	*Aphis gossypii*	Tomato
Antignus et al., 1998b		*Bemisia argentifolii* *Franklinella occidentais* *Liriomyza trifolii* *Tetranychus telarius***	Cucumber
Kashima and Matsui, 1998	Japan	*Bemisia argentifolii* *Liriomyza trifolii* *Dacnusa sibirica** *Diglyphus isaea** *Encarsia formosa** *Eretmocerus californicus**	Tomato
Costa and Robb, 1999	U.S.A.	*Bemisia argentifolii*	(Laboratory trials)
Antignus et al., 2001	Israel	*Bemisia argentifolii*	Tomato
Amaud, 2001	U.K.	*Chaetosiphon fragaefolii*	Strawberry
HRI, 2001	U.K.	*Macrosiphon euphorbiae*	Strawberry

HDC, 2001a	U.K.	Aphids Leaf miners Leaf hoppers Thrips Caterpillars	Godetia Stocks Chrysanthemum Carnation
HDC, 2001a	U.K.	*Macrosiphon euphorbiae* *Thrips tabaci* *Pemphigus bursarius* *Trialeurodes vaporariorum* Sciarid flies *Aphidius colemani** *Macrolophus caliginosus*	Lettuce Viola Geranium
Doukas, 2001	U.K.	*Trialeurodes vaporariorum* *Encarsia formosa*	Cucumber
Costa et al., 2002	U.S.A.	*Trialeurodes vaporariorum* Aphids Thrips	Chrysanthemum sp. Solidago sp. Lisianthus sp.

*= Beneficial predator or parasitoid insect.
** Spider mite (not an insect).

Table 2. Whitefly and *Encarsia* counts on plants covered with four film types.

Film type	Whitefly			*Encarsia*
	caught on plants	found in traps	overall	
Normal PE (UVI EVA 720 gauge)	68.3	121.7	190.06	42.81
Solatrol	6.7	25.3	31.9	19.0
SteriLite HDF	3.6	13.9	17.56	15.9
Anti Botrytis	4.3	13.5	17.81	15.06

Four films were used in the trial:

- Ordinary UVI EVA 720 gauge film was used as the control.
- SteriLite HDF from XL Horticulture blocks ultra violet radiation (UV) at up to 380 nm. It also has 65% diffusion and it reflects a proportion of near-infra-red (near IR) radiation so reducing temperatures beneath the cladding in hot sunlight.
- Anti Botrytis film, a trial film from BPI Agri.
- Solatrol, a film that blocks light in the near-red to far-red (NR-FR) part of the spectrum. It is used as a temporary film in growth manipulation of poinsettias, bedding plants etc. inside a greenhouse.

The spectral transmission comparisons can be seen in Figure 1.

The trial was conducted by making four chambers each covered by a different film type. They were fixed together in a cross pattern which formed a central area in which the whiteflies were released. They were then free to fly into any of the four chambers. The central area had a roof of black plastic so that the whitefly was not influenced upon release. In each chamber there were two cucumber plants and a sticky trap.

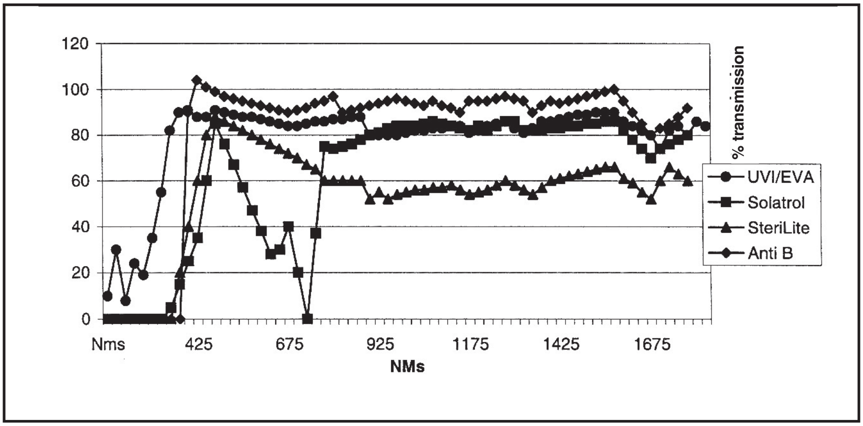

Figure 1: Film type transmission comparisons.

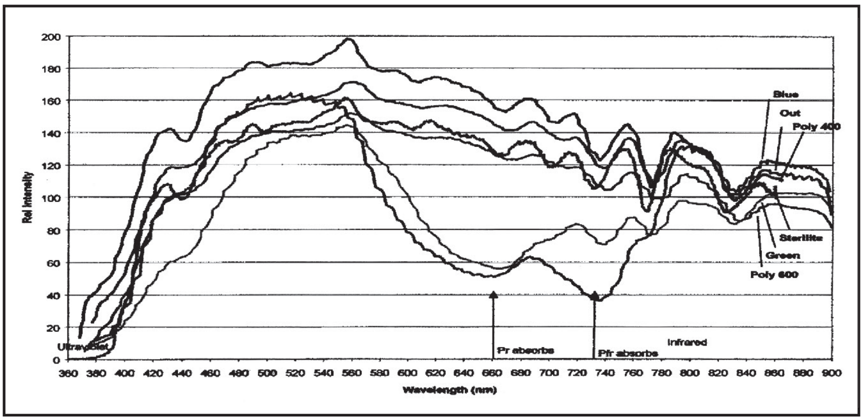

Figure 2: Spectral comparisons of all XL Horticulture films.

To count the whiteflies on the plants in each chamber, the plants were placed inside a polythene bag for transport to the laboratory, where they were cooled down so that the whiteflies no longer flew. They could then be counted on the plant. Sticky trap counts were carried out in the normal manner. A number of releases and countings were made between 18 June and 18 July 2001. The mean statistical analysis of all releases and countings is shown in Table 2.

The results show that UV blocking films are clearly effective at reducing the amount of whiteflies entering into a structure covered with this type of film.

The same four-way choice-chambers were used in an experiment to find out whether spectral filters also influenced the whitefly biological control agent *Encarsia formosa*. In this experiment a tube of *E. formosa* was inserted into each chamber for 3 to 5 minutes. The counts were made in each chamber 24 h after release. Table 2 presents the mean statistical analysis of the results. Doukas observed that, unlike the whiteflies, few of the *E. formosa* settled on the plants and so only the numbers found on traps were recorded.

Table 3. The effects on propagation performance when spectral filters (five films Xlpoly range) were used to cover stock plants.

	Super Strength600	Super Strength400	SteriLite	Super Green	Super Blue
Choysia ternata					
Rooted(%)	100	100	100	100	98
Root No	8.4	13.8	9.6	12.2	10.4
Nectrotic (%)	0	0	0	0	7.5
Cutting growth (mm)	33	51	43	46	47
Potentilla fruticosa 'Red Ace'					
Rooted(%)	100	100	100	100	100
Root No	10.6	10.9	11.9	12.7	11.7
Nectrotic (%)	7.5	12.5	7.5	0	2.5
Cutting growth (mm)	60	32	52	61	63
Viburnum tinus 'Eve Price'					
Rooted(%)	100	100	100	95	100
Root No	7.5	6	8	7.8	7.9
Nectrotic (%)	0	0	0	0	0
Cutting growth (mm)	13.6	11.9	12	11.7	15.3
Convolvulus cneorum					
Rooted(%)	97	100	97	97	100
Root No	2.4	2.5	2.9	2.9	3.2
Nectrotic (%)	30	43.3	30	13.3	20
Cutting growth (mm)	19	21	19	31	41
Cupressocyparis Leylandii 'Castlewellan Gold'					
Rooted(%)	48	38	50	50	53
Root No	2	3.1	2.9	1.8	2.3
Nectrotic (%)	0	0	0	0	0
Cutting growth (mm)	21.5	23.3	19.2	13.8	16.2

Like bees and many other insects, whiteflies can see in the UV spectrum as well as in the parts of the spectrum visible to us. They also fly towards plants that are reflecting some UV. Where spectral filters reduce the amount of UV entering a structure, the whitefly cannot see the UV reflections from the plants and therefore do not recognise them. Because the standard PE film transmits high levels of UV light the whiteflies head for that area of the choice-chamber. *Encarsia formosa*, on the other hand, are believed to hunt by scent. They are less influenced by light quality and will head for the greatest concentration of whiteflies.

Aphids. The research on aphids was carried out by Leigh Morris who looked at the effect of UV blocking films on the black bean aphid. He chose this species because it was quick to reproduce and similar enough to other members of the aphid family to give an indication of the potential of these films to control aphid pests of nursery stock.

Two films were compared. The standard "daylight control" was XL's Super-Strength 600 HDF, which has a similar spectral characteristic to UVI EVA 720 used in the whitefly experiments, except that it also transmits in the UV range of light down to 350 nm. This was compared against SteriLite HDF, the same UV-blocking film as used in the whitefly experiments. See Figure 2 for spectral comparisons of all XL Horticulture films.

The trial used a two-way choice-chamber with a central release area. The aphids were introduced by putting six heavily infected plants into the central area, which was covered with aphid net. The aphids were then able to make their initial migratory flight as well as subsequent movement flights. The aphids were counted on a number of occasions and the mean results are presented in Figure 3 and 4.

Figure 3 shows the total number of aphids counted on the plants under the SteriLite UV blocking film, compared to the non-blocking film. Figure 4 shows the numbers counted on the sticky traps under the two films. As in the whitefly experiments, this clearly demonstrates that UV blocking films can help reduce pest activity. More work is required to expand our knowledge on the behaviour under these films of a wider range of pests.

PROPAGATION PERFORMANCE

Research undertaken by Dr. Ross Cameron (formerly of HRI East Malling, Kent) showed some effects on propagation performance when spectral filters were used to cover stock plants. The films used were the XLpoly range.

Both field-grown and container-grown stock plants of *Choysia ternata* 'Sundance', *Convolvulus cneorum*, ×*Cupressocyparis leylandii* 'Castlewellan Gold', *Potentilla fruticosa* 'Red Ace', and *Viburnum tinus* 'Eve Price' were treated. Cuttings were assessed for percentage rooted, the number of roots, percentage nectrotic, and the amount of growth in millimeters. The results can be seen in Table 3**.** Overall the SuperBlue resulted in the best propagation "take". However the trial should ideally be repeated at different times of the year.

With the difficult-to-root *Cotinus,* the best cutting material came from the plants, which were outside on sand beds because they had the most vigorous growth at time of harvest. Rooting was generally poor under all covered treatments.

MICROPROPAGATION

Sam Earp, an undergraduate student at Plymouth University, undertook this research. He was trying to find out whether spectral filters would affect the tissue culture process. Cauliflower was used as the in vitro plant because of its speed of growth.

The films compared were SteriLite MDF, SuperGreen, SuperBlue, and Super-Strength 400. The films were used as lids on standard petri dishes with ordinary petri dish lids used as the control. The lighting used was the standard Philips 32W.

To measure the effect of the different treatments, plantlet weights were recorded four times over a period of 2 months and figures plotted. Figure 5 shows the difference that the different spectral filters can make.

A second experiment was performed in the same way but in this case each treatment also received 2 h of UV light every 24 h. Figure 6 shows the result.

SuperBlue resulted in the highest plant weight. It also resulted in the longest stems, contrary to other known research, which predicts that the FR/NR modification results in shorter stems. However there were also many basal shoots, and good

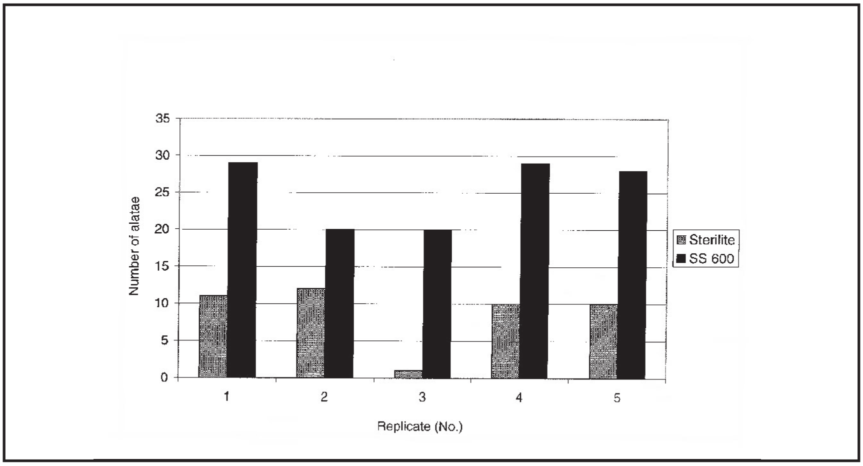

Figure 3. Total number of *Aphis fabae alatae* counted on *Vicia faba* plants under Sterilite and SS 600 polythene films during Experiment A1 (22/5/02 to 12/6/02) and Experiment A2 (22/6/02 to 22/7/02).

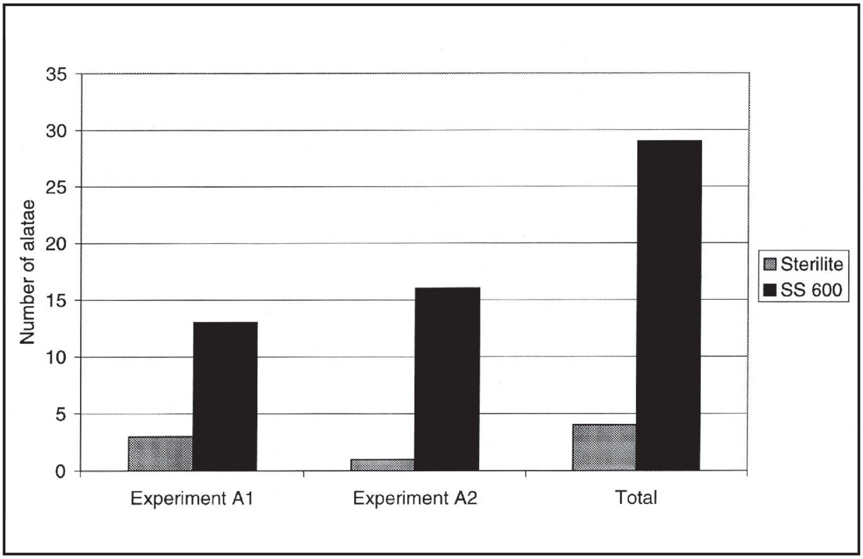

Figure 4. Numbers of *Aphis fabae alatae* trapped under Sterilite or SS 600 during the five repeats of the experiment (between 27/5/02 and 12/6/02).

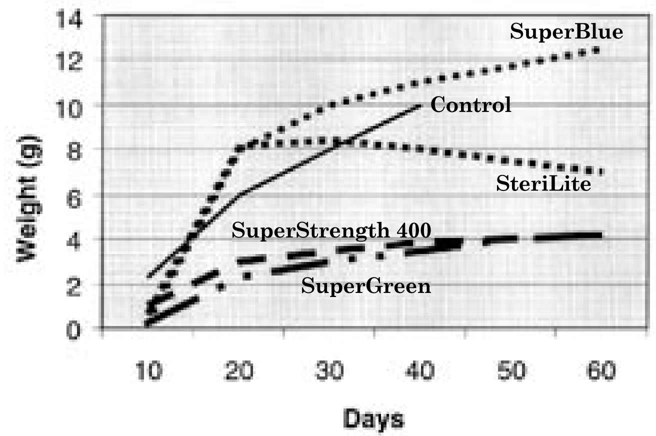

Figure 5. Mean weight under the 5 trials.

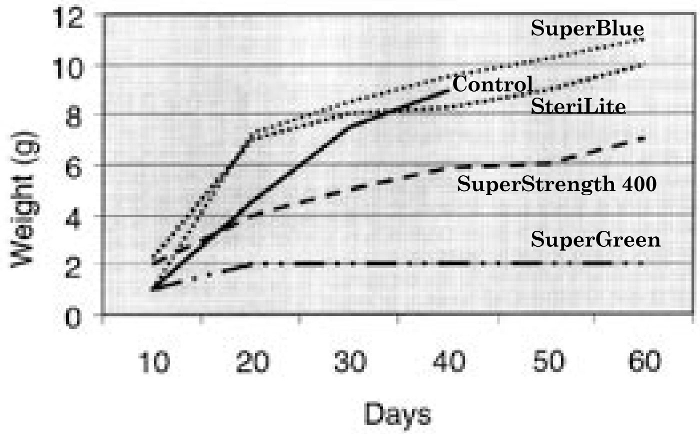

Figure 6. Mean weight under the 5 trials plus 2 h UV radiation.

leaf colouration. SteriLite resulted in a similar growth pattern to SuperBlue. There was prolific growth with many basal shoots, good leaf colour and good root growth. SuperGreen resulted in the smallest plantlets.

SuperStrength 400 did not produce as good a propagule as SuperBlue or SteriLite, with smaller, darker, and purplish leaves indicating stress.

The plants treated with UV supplementary light suffered considerable losses to disease.

BOTRYTIS CONTROL

Research on the use of spectral filters to control botrytis has been undertaken by Dr. Mark McQuilken (Horticulture LINK project: Effect of different spectral filters on the incidence and severity of *Botrytis* on cuttings of *Calluna vulgaris*).

Standard white propagation film was compared with three trial films supplied by Visqueen (no technical data available), SteriLite HDF, and an imported film known as HH1 (no technical data available). Cuttings were inoculated with *Botrytis cinerea* before inserting.

The UV filters made no significant difference to the incidence of *Botrytis* on the cuttings. This makes sense because UV blocking only reduces sporulation. If you put a cutting which already has botrytis spores on it into a propagation frame, disease will develop.

However, UV filters have been shown to inhibit fungal reproduction. Therefore UV blocking films in propagation might be useful to keep disease down, or reduce its spread, in a propagation house.

All of the UV blocking films produced significantly heavier dry weights of rooted cuttings. This may have been simply because the light transmission was higher than under the white film, allowing for greater photosynthesis.

FURTHER INFORMATON

More information on spectral filters in propagation can be found in the Horticultural Development Council's research report on project HNS 108, and from DEFRA project HH1214SHN.

LITERATURE CITED

McQuilken, M. 2001. Horticulture LINK project: Effect of different spectral filters on the incidence and severity of *Botrytis* on cuttings of *Calluna vulgaris*. <http://www.ost.gov.uk/link/>.

Morris, L. 2002. Effects of ultra-violet absorbing greenhouse plastic film on the flight behaviour of spring and summer forms of black bean aphid, *Aphis fabae scop*. Msc. Thesis, Writtle College, Essex.