Proceedings of the UK Controlled Environment Users' Group

2002 SCIENTIFIC MEETING

"THE GLASSHOUSE ENVIRONMENT"

Volume 13

Contents

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UK CONTROLLED ENVIRONMENT USERS' GROUP

2002 SCIENTIFIC MEETING

"THE GLASSHOUSE ENVIRONMENT"

The scientific part of the annual meeting consisted of five invited contributions. Summaries of these, supplied by the speakers, follow.

SUMMARIES OF PAPERS

B.J. Bailey (Silsoe Research Institute, Wrest Park, Silsoe MK45 4HS, UK) **Control and monitoring of glasshouses**

The most important variables that form the glasshouse environment are solar radiation, air temperature and the concentrations of water vapour and carbon dioxide (CO_2). Because of the high transparency and low thermal resistance of the glass cover, the internal environment is strongly influenced by solar radiation and external air temperature and the changes therein. Consequently, to produce commercial crops with acceptable yields and quality the internal conditions have to be controlled. The most important environmental variable is solar radiation which is frequently sub-optimal, however, as the cost of supplementary lighting is high, increasing the light intensity is limited to the production of some flower crops. Shade and day length control screens are used to reduce the intensity of solar radiation, again mainly for flower production. Consequently, the main controlled variables are air temperature, air humidity and CO_2 concentration. Temperature is raised by heating, generally by hot water circulated in ground level pipes, and lowered by opening roof ventilators. Humidity can generally be lowered by ventilation (which may also necessitate heating) and raised by the evaporation of water supplied from fogging nozzles. The CO_2 concentration is raised by the supply of either pure CO_2 or more likely the supply of CO_2-rich exhaust gases from boilers or CHP units fuelled by natural gas.

The conditions of the glasshouse air are measured in an aspirated screen, which is usually placed in the middle of the glasshouse in the upper part of the plant canopy. The aspirated screen has an outer surface reflective to solar radiation and ideally has insulating walls, a fan draws air over the sensors with a speed of at least 3 m s^{-1}. Wet and dry bulb thermometers, usually resistance elements, are used to determine the air temperature and humidity. The CO_2 concentration is determined by pumping a sample of the air to an infra red gas analyser. Because of the high analyser cost one is generally used for several glasshouses and the air from each is sampled in turn. Externally, solar radiation is measured using a black body detector (thermopile solarimeter) or by a photocell with appropriate filters, temperature is measured using a resistance thermometer, and wind speed and direction measured using a cup anemometer and wine vane.

Historically, control was aimed at maintaining essentially constant set-point values of the major environmental variables selected by the grower, using feedback controllers of the PID type that were widely used in process control. For use in glasshouses these controllers were designed to provide great flexibility of control and contained many control options e.g. the 24 hour period could be divided into multiple periods each with set point temperatures for heating and ventilation, the day temperature set point could be increased in response to solar radiation and the night set point by the radiation integral. However, it was not easy for growers to select meaningful values for the perhaps 100 set point values for each glasshouse.

Improvements to these types of controllers have been made to take account of the specific nature of the glasshouse environment. Two-stage control is used to control heating using hot water. The first stage determines the required water temperature based on the glasshouse air temperature set-point and the second stage controls the heating valve to ensure the required water temperature is obtained. Self-tuning controllers have been designed which are capable of changing their control parameters during commissioning to match the controller to the characteristics of controlled system. Adaptive control takes this a stage further by allowing the control parameters to be adjusted (adapted) continuously. This improves controller performance when the system response is non-linear as in the way the air exchange rate increases with the opening of roof ventilators. In feed-forward control, changes in the external conditions are measured and a glasshouse model is used to predict changes in the internal environment; thus control actions can be taken before the effects are detected inside the glasshouse, thus reducing deviations from the control set points. Currently, a single controller is used for each controlled variable, i.e. temperature, humidity and CO_2; thus no account can be taken of the interactions between the controlled variables e.g. the effect on temperature when controlling humidity. These interactions can be taken into account with multivariable control, which uses a model of the glasshouse environment to provide information on the interactions.

It is now common practice to control glasshouse humidity on the basis of vapour pressure deficit (vpd) instead of relative humidity. Unlike the latter, vpd is independent of temperature and is directly related to plant transpiration, which is now recognised to be important in ensuring good plant growth. Close control of the aerial environment does not necessarily mean that plants are not subject to conditions that produce stress or loss of quality. The physical state of plants such as temperature can be measured using infra red sensors and recent measurements have shown that there can be significant differences between the temperatures of plant organs and the surrounding air. The currently used air temperature set-points have been found to give acceptable plant performance, but there is no information on the resulting plant temperatures. Consequently, information will be required on the relationship between plant and air temperatures before the full benefits of controlling plant temperature directly can be realised. Also, large differences in temperature occur between transpiring (leaves) and non-transpiring organs (flowers, fruits) in a canopy.

The foregoing types of control require the grower to specify the control set point, which is then implemented by the controller and developments in controllers were aimed primarily at minimising deviations from the set points. However, in nature, plants do not experience a closely controlled environment and there is little evidence to suggest ever closer set point control will give an economic benefit. Consequently, recent developments in glasshouse environmental control have been aimed at assisting the grower in meeting specific goals in crop production. This has resulted in the introduction of a higher level of control, which adjusts the environmental set points 'on-line' to meet the goal. An example is the control of heating (and ventilation) to achieve a pre-set average temperature over a precept time period in order to minimise energy use without affecting crop performance. This makes use of the ability of some plant species to respond, within limits, to the average temperature they experience. The implementation of this form of control has been made possible by the availability of 'on-line' weather forecasts. Recent trials have shown energy savings of 10-15% with little influence on tomato, pepper or cucumber production. The benefits depend very much on the confidence the grower has in this form of control as the instantaneous temperature can be very different from the conventional value, and on the limits between which the temperature is allowed to vary.

Optimal control takes the concept of dynamic set-points a stage further. The aim here is to maximise the financial margin between the value of the crop and the cost of controlling a specific variable. An example is the optimal control of CO_2 enrichment for tomato production. This uses models to estimate how crop value is affected by CO_2 concentration via photosynthesis and fruit growth, and to estimate the cost of providing the CO_2, which depends on assimilation by the crop and the losses via ventilation. Using forecasts of solar radiation, temperature and wind speed, the CO_2 set point trajectory that maximises the financial margin is calculated and the set points are then implemented by a conventional CO_2 controller. This type of control has been shown to work on a research scale. However, the models are complex and a simpler robust statistical model more suitable for implementation by conventional controllers has been developed. This has been provided to growers, so they can compare the optimal CO_2 concentrations with the values currently used and so gain confidence in this form of control.

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P. Hadley and J.M. Fletcher (Centre for Horticulture and Landscape, School of Plant Science, University of Reading, PO Box 236, Reading RG6 6AS, UK) **Developments in novel plastic films designed for greenhouse cladding**

Film plastic technology for greenhouses has undergone something of a revolution over the last decade with a range of novel plastics either already commercially available or under development. Developments in film technology have led to improvements in light transmission, heat absorbing and reflecting films, growth control films and ultra-violet blocking films.

Fluorescent films

The growth of plants in greenhouses depends largely on the PAR transmission of such structures and of the cladding material in particular. Although the PAR transmission of many films used in greenhouses has increased, it is unlikely that there will be further significant improvements in the clarity of such films and other routes to improving light receipt need to be investigated. One possible route is through additives that enable films to absorb radiation outside the PAR range and fluoresce this as visible light. Films have been developed which include additives that absorb radiation strongly in the ultra-violet region and fluoresce this in the blue region of the spectrum. Such films show increased light transmission compared with conventional films, however, these improvements are inevitably small as the amount of energy available to be fluoresced is small and the process of fluorescence is not efficient. Moreover, light is fluoresced in both directions so that only half the potentially available light is fluoresced towards the plants. A further problem is that the additives used are degraded relatively quickly so that the fluorescent properties are relatively short-lived.

Light diffusing films
Another route to improving light receipt is to use diffusing additives in films. These convert direct beam light to diffuse light, which, at least theoretically, can be intercepted more efficiently by plants as diffuse light can penetrate more deeply into plant canopies. Diffusing agents can reduce the light transmission of the films, but trials on such films suggest definite benefits of incorporating diffusing agents with greenhouse cladding materials. Technologies are also being developed for introducing diffusive properties into films without using additives, giving the potential of introducing diffusing properties without the loss of light transmission.

Infra-red reflecting films
Although films with additives to reduce the long wave transmission of film plastics have been around for a decade or more, films have recently been developed which reflect infra-red radiation and so potentially reduce the heat load on greenhouses. This has been achieved by the use of additives, but other novel films have been developed using multi-layer technologies, which enable infra-red radiation to be reflected. Such films result in significantly reduced temperatures in summer with a consequent reduction in the need for greenhouse ventilation.

Far-red absorbing films
Plastics which block far-red radiation whilst maintaining a high transmission in the red region of the spectrum have been under development as growth control films. Films with a high red:far-red ratio reverse the typical stretching effect, which is seen when growing plants naturally under the shade of other plants which absorb red light but transmit far-red light creating low red:far-red ratio light conditions beneath. Considerable quantities of plant growth regulators are used by the ornamentals industry to maintain the compact growth habit required by the market. These films show great promise in reducing the need for chemical growth regulators in the ornamentals industry; however, new additives are required, which are more long lasting in their effects.

Ultra-violet blocking films
Perhaps some of the most exciting applications of spectral filters appear to be in the area of pest and disease management in protected structures. It is known that the sporulation of many strains of fungal pathogens, such as *Botrytis*, only occurs in the presence of ultra-violet radiation. In addition, a number of insect pests use ultra-violet radiation as part of their foraging behaviour. In the case of fungal pathogens, the use of ultra-violet blocking films has significantly reduced the rate of spread of *Botrytis* disease and could help dramatically in the control of this disease in many protected crops. Similarly, the use of ultra-violet blocking films significantly reduces the spread of whitefly, again suggesting that the ultra-violet blocking films may have significant anti-insect characteristics.

Developments in film plastic technology have also been accompanied by the development of novel greenhouse structures. These include, for example, roll-off roof designs for plastic film structures and other similar systems to provide high ventilation structures, which are of value to growers of protected ornamentals. However, film plastics, because of their light weight and high light transmission, offer opportunities for novel greenhouse designs with high light transmission and energy saving being some of the potential features.

In conclusion, novel film plastics can improve light receipt and growth control of protected crops combined with improved pest and disease suppression. Other features can lead to reduced heat accumulation and energy saving. When combined with developments in greenhouse structures, these have the potential to provide a new generation of high performance greenhouses.

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Why screens?

Optimising the glasshouse climate is an objective every grower should aim for to make sure that both production per m² and quality are high. This is the only way to make the investment in expensive greenhouse structures profitable today. Movable thermal screens have already been used for many years in greenhouses to achieve this target. And they are also used to reduce heating costs.

In this paper we would like to update the current situation regarding the use of screens as well as consider some possible future developments.

A movable environmental screen: a multipurpose vehicle

The way environmental screens are constructed today makes them suitable for several important tasks. This was quite different at the time that screens were introduced in greenhouses at the end of the seventies. At that time the main function was energy saving, in response to the strongly rising energy prices. Most of the time screens were made of simple materials like polyethylene (PE) foil or non-woven fabrics, used for other purposes as well. No specially designed materials were available at that time. One of the consequences was that the use of those screens had a negative effect on the greenhouse climate, especially on the air humidity. It gave screens the bad reputation of lowering production, especially in the case of tomato crops.

Quickly, after these first experiences with screens, several textile manufacturers came up with more specialised fabrics, culminating in the introduction of the well-known LS-screens at the beginning of the nineteen eighties. These screens were a kind of a hybrid between a foil and a textile: small, 4-mm-wide foil strips, knitted together with fine, capillary yarns. These screens combined a high energy saving effect with a good vapour transmission, taking away most of the humidity problems related to other materials. The application of aluminium strips in these screens was really revolutionary. Aluminium increases the energy saving of the screen considerably and at the same time makes the screen suitable for shading in the summer.

Present situation

Today screens are available in many different designs. Specific screen types have been developed for specific purposes. Most ornamental growers now use screens, both for energy saving as well as for improving climate. Quite often those growers even use more than one screen to make sure that all objectives are fulfilled as well as possible. Among vegetable growers, the application of screens is also on the increase, partly because of higher energy prices, partly due to better, more transparent screen types.

Within the vast assortment of screen types we can distinguish the following groups:

- Transparent screens, mainly for energy saving
- Partly aluminised screens, both for energy saving and shading
- Aluminised screens with an open structure, mainly for shading
- Blackout screens, for daylength control

Of course there are many aspects to be considered for a grower before making a choice. First one should know what is most important: shading, energy saving or both. Apart from this, it makes sense to investigate the quality aspects of the screen to be chosen. Normally the screen will be in the greenhouse for at least 7 years before it should be replaced. So to get the best out of the investment one should know what one is getting. In the next section we'll discuss the different quality aspects.

Quality aspects of screens

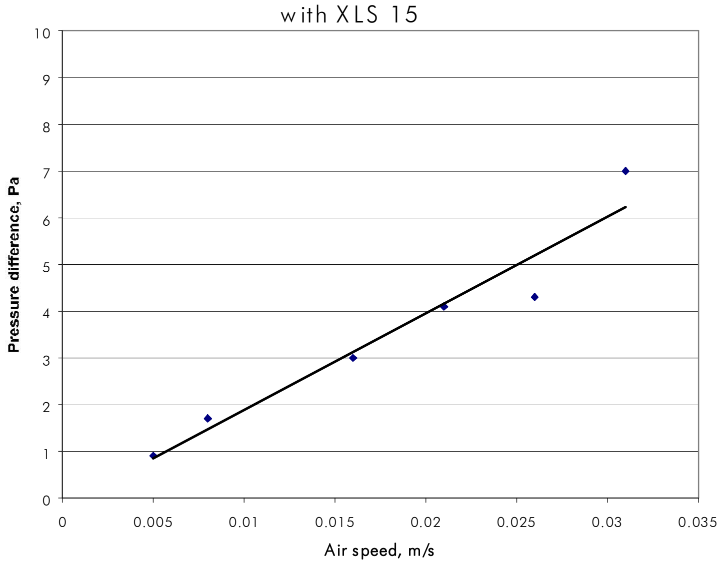
Energy saving

For a high energy saving it is important that a screen stops both radiative and convective heat. Thermal radiation (IR) has a wavelength roughly between 3 and 20 µm, so the materials used in screens should have a low transmission for this waveband. Let us take, for example, XLS 15; this screen is made of transparent, polyester strips in combination with strips with an aluminium laminate on the top. Polyester has a high IR absorption as opposed to regular polyethylene, 60% versus 20%. The aluminium-laminated strips are even more effective, due to the low emission of only 8%. As a result, XLS 15 has following characteristics with respect to IR radiation (source: IMAG, Wageningen)

	Bottom	*Top*
Transmission 3-20 μm	0.24	
Reflection 3-20 μm	0.138	0.395
Emission 3-20 μm	0.619	0.362

Limiting the porosity of the screen as much as possible should minimise the convective heat losses, keeping in mind that the screen should still transmit sufficient vapour. A way to determine the screen's porosity is to measure the air speed at different pressure differences. Typical values for XLS 15 are shown in Figure 1 (source: IMAG, Wageningen):

Fig. 1 Relation between pressure difference and air speed with XLS 15



Temperature differences over screens create pressure differences, which cause air to stream through the screen.

The sum of the phenomena, radiation and convection, results in a reduced U value of the greenhouse. For XLS 15 it has been calculated, based on the above results, that the U value will drop from 6.2 to 2.7 W/(m²·K). This can be translated into an energy saving of 56.5%.

Shading and cooling

The temperatures of the crop and the greenhouse air sometimes reach undesired high values. For counteracting this, screens can be used successfully. They stop a certain percentage of the incoming solar radiation, so that less heat accumulates.

Two elements determine the effectiveness of a screen:

1. The openness of the fabric. The more open it is the more easy air exchange will take place through the screen. This is an advantage in greenhouses with roof vents, which is the situation in most cases.
2. The degree to which the superfluous radiation is reflected or absorbed. Reflection is much better than absorption, as it prevents unwanted heat accumulating in the screen and in the air underneath the screen. The best screens absorb little and reflect a lot.

To illustrate the second point we have made a calculation, comparing an ancient model we produced with a current one, ULS 15 and XLS 15, respectively. Shading of both screens is 55 and 54%, respectively, however the surface area of reflective aluminium strips differs: 38% for ULS 15 and 49% for XLS 15. The reason for this is the different yarns used in the screens: black and 'branched' for the ULS, opposed to transparent and flat for XLS. As a result ULS absorbs 14% of the solar radiation, while XLS only absorbs 4%.

The consequence of this is not something to be neglected. With radiation of 700 W/m² we have calculated that the overall effect can be a temperature as much as 2.6 °C lower under the XLS 15 screen in comparison with that under the ULS 15!

Humidity

When a screen is closed there will always be an effect on the humidity and the transpiration of the crop. The degree to which this will happen is dependent on:

1. How easily will water vapour pass through?
2. What is the outside temperature?
3. What is the phase of the crop, just planted or mature?

The net effect is not easily to predict. It is important that the screen does not increase the humidity too much especially for tomato growers. And of course no condensation should take place on the bottom of the screen.

Lifetime

The greenhouse climate could be considered to be quite aggressive with respect to screen fabrics. UV, heat and chemicals are all ready to destroy the strength and properties of screens. So it is important that the right raw materials, both strips and yarns, are selected to ensure a sufficient lifetime of the screen. Most applied materials in screens are:

- Polyethylene (PE) film: can be stabilised against UV, however it is sensitive to the combination of UV and sulphur; not so strong against heat.
- Polyester (PET) film: strong resistance against heat and chemicals; from nature not so good against UV; at Svensson a method to tackle this has been developed
- Polyester yarn: see PET film.
- Acrylic yarn: good against UV, bad against heat.

Overall at Svensson we prefer to use polyester for both strips and yarns, UV stabilised according to our formulation.

The future

There are several developments with respect to glasshouse cultivation, which are important for the use of screens. We mention a few of them:

Environmental legislation: There will be laws with respect to the use of energy and pesticides per m². This will stimulate greater use of screens.

Light pollution: In certain areas there will be a ban on unlimited lighting. This is already the case in The Netherlands where lighting is forbidden between 20:00 and 24:00 unless screens are used.

Apart from the above 'external' factors there will be the increased wish of growers to improve the profitability of their screening system. For vegetable growers this means higher light transmission, even better energy saving values, humidity neutral use. For flower growers we expect an increase in the use of double screens: one open screen for shading, one closed screen for energy saving.

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S. Pot (Philips Nederland BV, Horticultural Lighting, Postbus 90050, 5600 PB Eindhoven, The Netherlands) **Developments in Dutch energy management and glasshouse lighting**

Energy management

At the moment a great concern in the horticulture industry is its relatively high demand for energy. According to the Kyoto Treaty, the Dutch horticulture industry has to reduce its energy consumption to a large extent. A special Dutch convention for horticulture and environment has a target to increase the energy efficiency in 2010 by 65% compared to 1980. At this moment, a lot of effort is being put into increasing the efficiency of energy use. Most of the energy is needed as electricity for artificial lighting and as heat for climate control. Many growers use generators (gas turbines) to produce their own electricity. The released heat and CO_2 is used for optimal climate control and plant growth. When the demand for electricity is higher than the demand for heat, the surplus heat is stored in very large water buffers. This stored energy is drawn on when more heat is needed in the greenhouse than the generator can deliver. Latest developments are the use of the storage capacity of the soil for heat and the use of highly efficient heat exchangers for better humidity and temperature control. The CO_2 from the generators is purified from NO_x and released in the greenhouse to control the CO_2 concentration. The desired CO_2 concentration is approximately 1000 µmol mol^{-1} (1000 vpm) for most crops. This concentration is not reached in most cases, because of the necessity of ventilation for good temperature and humidity control.

The challenge for the grower is to find a good balance for optimal growth. Computer software models based on measured climate inside or outside the glasshouse, are being used more often for optimal energy management. The latest development is the incorporation of plant physiological parameters in these models. A number of practical sensors have become available for measuring these parameters e.g. for leaf temperature, water uptake and chlorophyll fluorescence.

At the Dutch Floriade this year, the greenhouse of the future was presented. Greenhouse cladding, which lowers heat loss by 45% while maintaining light transmittance, compared to standard, was fitted to one compartment. Another compartment had special hardened glass with anti-reflection coating to increase light transmittance by 2%. By applying clamped glass roofing panels, larger glass sizes (2.40 m x 2.57 m) were combined with improved repairability. There were structural improvements proposed as well; an improved metal structure with reduced light intercepting profile while still supporting repair, roof washing and glazing machines; integration of insect nets into the support profile; and integrated girders combining gutter, storage space for the energy screen and track for repair machines.

Artificial lighting

In spite of the target for reducing energy consumption, the use of artificial light as supplementary light in greenhouses, is increasing. The main reasons for the use of artificial light are not just to increase crop production and product quality, especially in winter time, but more and more also to ensure, all year round, a production and quality of product which meets the market demands. Nowadays the use of artificial light is very common for ornamental crops (roses, chrysanthemums, lily, pot plants etc.). More and more growers of vegetables are starting to use artificial light as well, as it turns out to be profitable.

A continuous search is going on to increase the efficiency of artificial light sources. At present the high-pressure sodium lamp (HPS) is the most efficient light source for converting electrical energy into growth light (µmol/s). Recently a 400-volt system has been introduced which gives an increase of 8-10% in efficiency (µmol/s per watt). The heat output of the lamp is used for warming up the greenhouse. However at high light (for roses circa 100-120 µmol $m^{-2}s^{-1}$), too much heat might be generated for maintaining optimal temperature in the greenhouse; an extra 10 µmol $m^{-2}s^{-1}$ can increase temperature in a glasshouse by 0.6°C. In future light sources with less heat output are needed. To increase efficiency of light sources for plant growth is an ongoing process within Philips. The spectral composition and plant sensitivity to light is under investigation. A lot is known about the effect that the spectral composition (red/far red ratio, blue/red ratio, UV) has on plant morphology. Nowadays a number of chemicals are still used to control morphology. There is an increasing pressure from society to minimise the use of chemicals. The use of artificial light may become a good alternative to chemicals for increasing product quality.

As important as the efficiency of a light source is how the light will be distributed to the plants. For tall crops with high plant density, intra-canopy lighting will be investigated. Also the use of movable lamps that create high light intensities over a small area is an interesting development. Both these systems still need a lot of research before their usefulness is proven.

Reference

http://www.horticultural.lighting.philips.com (This site requires a minimum browser of Nestcape 4.79 or Internet Explorer 5.5.)

G. Evans (Cambridge Scientific UK Ltd, Wallingfen Park, 326 Main Road, Newport, East Yorkshire HU15 2RH, UK) **Structures, cladding and related health and safety issues**

The objective of this summary is to inform you of the procedures and documentation necessary to ensure the minimisation of risk when working with glasshouses. It is divided into three main areas: -

- New structures
- Maintenance and structural hazards
- Other hazards

New structures
Generally contractors will build new structures. The emphasis here is on your organisation's responsibilities in this situation.

The first step is planning. Who is going to have overall responsibility for health and safety? What are the operational requirements for the glasshouse and what locations are available? Check the design and location for potential hazards.

There are a number of documents, which you will need in order to demonstrate that you have safe working systems:
For construction and design management (CDM) which will include
- a design risk assessment,
- a construction risk assessment,
- method statements for construction and glazing and possibly
- COSHH risk assessments (control of substances hazardous to health regulations).

Your contractor may well write some of this documentation, but you need to have copies that are appropriate to the project.

The best time to reduce hazards is during the design stage. Carry out an assessment of potential hazards and if possible design them out. Falls are a major hazard – design the project so that work does not have to be carried out at height, or alternatively, build in appropriate means of access. At this stage also check that there will be adequate monitoring of hazardous environments, fire precautions, means of escape, containment and alarm systems.

Before work starts on site ensure that contractors are issued with site safety rules, have good safety management systems, suitably qualified staff and once work has started that they actually comply with the procedures.

Choice of glazing material
Different glazing materials have markedly different hazards; horticultural glass is fragile and breaks into heavy, knife-like shards. Toughened glass is very similar except that fragments are more rounded and very small, usually less than a gram. Laminated glass and polycarbonate (and similar plastics) are very strong and lightweight, but check plastics for flammability. Also bear in mind that light transmission and heat loss also vary – the chosen material must be suitable for your research.

Maintenance and structural hazards
In most cases your staff will carry out maintenance. Where contractors are involved your responsibilities are largely similar to new structures, except that maintenance is often carried out in operational areas.

In the planning stage identify health and safety responsibilities – who is in charge, what is each individual's responsibility. Specify the job, equipment and procedures, carry out a risk assessment on these and modify as required. Arrange training for maintenance operatives as well as any individuals who will interact in any way. Get expert help if necessary.

The most hazardous greenhouse work is that which takes place on the roof. Particular risks are slipping ladders, falling while moving between ladder and gutter, overbalancing while moving along the gutter and falling through, or being hit by broken glass. Before carrying out roof work ensure that you have read the HSE information sheet "Safe working on glasshouse roofs" (1996).

The hazards of working on the roof can be reduced by use of tougher glazing materials, mechanical washing systems or sprinklers, walking frames or work platforms. Personnel involved in maintenance should always wear the proper protective clothing and work should not be carried out in adverse weather conditions.

Training
Use hazard assessments to identify training needs for maintenance staff, users and visitors. Ensure that all relevant people are aware of the risks and are trained as appropriate.

Other hazards
Wind is a potential hazard at any time in a glasshouse. For the safety of those working inside an alarm can be set to sound if the wind speed approaches dangerous velocities so that staff can evacuate. Loose objects that can be blown against the glasshouse (e.g. plastic crates, roofing sheets) should be battened down as these present a hazard at wind speeds well below those, which will cause structural damage.

Working on the roof in wind is also a problem. Consider temporary repair sheets which can be installed from inside to repair damage until it is safe to go on the roof.

Hail and heavy snow have also been known to damage glasshouses.

The glasshouse environment itself may also pose a risk at times, particularly to some individuals, or where protective clothing is necessary to carry out work. Consider carrying out some jobs (like pesticide application) early or late in the day when temperatures are more moderate.

Because of the varied nature of glasshouses, their locations and purposes, it is not possible to be prescriptive about health and safety procedures. Using these guidelines and a good dose of common sense it should be possible to devise safe working practices for most situations. Guidance is also available from HSE, glasshouse manufacturers and insurers.

Useful information

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6) Construction and Design Management web site (CDM): http://www.cdm.com