A New High-Tech Research Greenhouse©

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INTRODUCTION

This paper describes the design and environmental control features of a new research greenhouse built at the Gatton Campus of the University of Queensland (UQ). The greenhouse was funded by the University for the Centre for Native Floriculture, a research centre funded by the Queensland state government. Most University research greenhouses are designed for research on high light demanding agronomic crops such as sunflowers, sorghum, and wheat. This makes greenhouse design and environment control parameters relatively easy to deal with.

The nature of the research to be carried out in the UQ Gatton greenhouse involves studies of the floral physiology of a range of new native flowering plant species, and this requirement added a significant additional range of environment control parameters to this project. When the University of Queensland allocates funding for a project of this nature, an architect is appointed to manage the project. The architect has the final say on overall design of the structure. The University staff who are to use the facility form a "users' group" that determines the environmental parameters required of the facility. I was the Chair of the users' group for the development of this facility.

It was clear from the outset that the architect had no experience in designing research greenhouses. I spent a considerable amount of time stressing to him the interactions between light intensity, temperature, and humidity; their seasonal changes; and how they could be controlled. The final design proposed by the architect turned out to be stunning, and it integrated light intensity and temperature management very well with humidity management.

DESIGN PARAMETERS

The greenhouse structure is oriented east to west with a steeply sloping (45°) roof slope to the north (Southern Hemisphere conditions). This steep roof slope maximises winter light transmission into the greenhouse but causes significant summer light reflection, thus reducing internal summer light transmission and internal temperature during the hotter period of the year. This is an example of greenhouse design being used effectively to reduce the summer heat load. Southeast Queensland is not an ideal summer climate for greenhouse structures.

The structure has four greenhouse research bays facing north and most of the light entering is transmitted through the northern roof. At the southern side of the facility there is a laboratory area incorporated as an integral part of the facility. The doors into the greenhouse bays are inside the laboratory so the whole facility can be operated as a secure quarantine facility, if required.

THE GREENHOUSE COVERING MATERIAL

Clear, twin-wall polycarbonate sheeting with a 10-mm air gap was selected as the cladding material. This product was imported from Germany and is generally regarded as the most stable and long-lasting greenhouse covering material. The same product was used in a research greenhouse facility in Adelaide, and in a conversation with the manager of the facility I ascertained that light transmission through the polycarbonate sheeting had declined by 1% over the 10-year life.

Light is the environmental parameter that is most easily altered with different cladding materials and different screening materials creating significant differences in light entering the greenhouse and, in turn, affecting the internal light intensity and in turn the internal temperature and humidity. It is generally regarded that a minimum light intensity of 250 $W \cdot m^{-2}$ inside a research greenhouse is required for satisfactory plant growth. In southeast Queensland during summer the light intensity is frequently in excess of 500 $W \cdot m^{-2}$. This obviously leads to excessively hot temperatures so shading and ventilation become important in managing crop temperature.

Natural ventilation is an important feature of this structure with roof-mounted ventilators incorporated in the southern part of the roof structure. The temperature controller in each bay activates the roof ventilators.

ALUMINISED THERMAL SCREENS (50% SHADE DENSITY)

Retractable open-weave aluminised thermal screens were installed internally under the polycarbonate sheeting to provide additional light reduction (and associated temperature reduction) as required. There are two light sensors mounted on the roof of the facility feeding information on exterior light intensity levels to the environment control computer inside the facility. The retractable screens can be activated on a time basis such as screens moving into place at 7:00 AM and retracting out of use at dusk.

Alternatively, the screens can be activated and deactivated according to light intensity levels measured by the light sensors. For example, the settings in place when I retired at the end of 2006 moved the screens into place when the light sensors measured 250 $W \cdot m^{-2}$ and retracted the screens out of the way if the light intensity dropped to 200 $W \cdot m^{-2}$. This gives fantastic flexibility in accommodating the light requirements of different types of plants under research. The thermal screens in each of the four bays can be independently set to react to different levels of light so that research on the effects of light can be carried out.

Retractable aluminised thermal screens are becoming an industry standard for new greenhouse structures throughout the developed world. The screens can be open weave which allows air movement through the screens. Open weave screens are predominantly used for light reduction as warm air trapped under the screens can transmit through the screen and exit through the open roof ventilators. Closed screens are screens in which the aluminised weave in enclosed in a clear plastic layer. This type of screen is more useful for nighttime heat retention during winter because the plastic layer traps the heat underneath the screen.

TEMPERATURE MANAGEMENT

Each research bay has the capability of operating within the temperature range of 10 °C minimum and 35 °C maximum. Each of the four research bays can be individually controlled at different maximum and minimum operating temperatures. This requires the unit to be fitted with refrigerated cooling equipment and warm-air heating systems. The 35 °C daytime temperature may be required if research is being carried out on tropical native floriculture species from north Queensland. The 10 °C nighttime temperature may be required if research is being carried out on mechanisms to bring native floriculture species into flower outside of their normal flowering time, when vernalisation may be required.

The environment control computer is set with a temperature set point tolerance of ±1 °C. The system also programs daytime temperature within the range of 35 °C and a nighttime temperature of 10 °C. Daytime regime runs from 6:00 AM to 6:00 PM and at 6:00 P.M. the nighttime regime activates. The specification requires the nighttime set point temperature to be reached within 30 min of the change over. During the construction shake-down phase this aspect of control took a lot of engineering adjustments to get close to target.

The refrigerated cooling equipment operates using chilled water that is passed through cooling ducts into each research bay. Again, each research bay can have chilled water at different temperatures passing through, if required. Each research bay has an environmental sensing system that constantly logs temperature and humidity to a central computer in the laboratory area. This central computer is connected to the University network and research staff can log on externally from their offices to download environmental data, as required.

AUTOMATIC BLACKOUT SCREENS

Each of the four research bays has an internal blackout screen incorporated. These are activated by individually controllable time switches so that different blackout conditions can be set up in each bay. Flower initiation in short-day plants requires short day and long night conditions. If short day-plants are to be brought in to flower under long day conditions, blackout facilities to create artificial short-day conditions are required. They may also require artificially cool nighttime conditions to achieve this effect. That is why the specification requires that the facility can bring nighttime temperatures down to 10 °C, even in summer.

Blackout screens must create conditions of complete darkness if artificial short-day conditions are being created. Even small chinks (openings) of light entering through poorly fitted screens can prevent floral initiation. When the first blackout screen was installed in Bay 1 of the facility I could see daylight through it. I complained to the architect, and after investigations it was ascertained that the contractor had used the wrong blackout screens. Needless to say, the screen had to be changed.

PHOTOPERIODIC LIGHTING

Combinations of blackout screens and photoperiodic lighting are required depending on species and time of year that research is being carried out. Each bench in each bay of the facility has incandescent lighting mounted overhead. There are time switches in each bay to activate the lighting as required. The light intensity required for photoperiodic growth control is very much lower than that required for photosynthetic growth control. The lighting incorporated in this structure is required purely for photoperiodic control.

CONCLUSION

There is no doubt that this research greenhouse facility located at the Gatton Campus of the University of Queensland is the most sophisticated greenhouse facility built in Queensland. The tight operating specification gives it a level of environment control which had not been previously achieved in any research greenhouse in Queensland. I felt very privileged to be involved in its design and construction.