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The importance of the greenhouse environment to the successful growing and merchandising of plants

Plants have optimum requirements for successful growth and development and minimizing the environment for pest and diseases. The goal of growers and plant managers should be to improve production and the health of the plants for long term success. To achieve this, a multitude knowledge and management skills are required to fulfil markets and the consumer expectations for healthy plants.

Ultimately, optimal management of the total environment can equate to long terms profits and customer satisfaction for potential repeat business.

In this month's Nursery Paper, NGINA Industry Development Officer, Michael Danelon seeks to raise awareness of the importance of identifying and managing your greenhouse environment to the successful production and merchandising of plants and minimising the environment for plant pest and disease.

The importance of the greenhouse environment to the successful growing and merchandising of plants

The plant environment
Progressive growers seek to improve production by determining the optimum conditions for plant growth and providing these in the production facilities of the business. Those merchandising plants would be aware of the importance to manage the environment to maintain the optimal condition of the plants once they are received by the supplier, ie need for high light levels for seedlings and bedding plants or reduced humidity levels for plants subject to foliar diseases.

Plant production commences with some form of propagation, e.g. seed/ germination, division, striking of cuttings, layering, tissue culture etc. The growing on of a newly produced plant, e.g. seedling, tubestock, tissue culture into a larger container will differ to the environment in the propagation phase as will a larger more mature plant will again differ in its environmental conditions to the prior phase of growth and development.

The greenhouse environment
Growers need to consider the options available to them and provide a suitable greenhouse environment whilst managing the technology available but at a cost effective solution. Merchandisers need to strike a balance between a suitable environment for the plants they are managing and a comfortable environment for the buyer/shopper. Note – throughout this nursery paper, reference to greenhouse also implies glasshouse.

The challenge for growers and managers are:

- Which equipment and strategies should be used to achieve best crops from the greenhouse and environment the local climatic conditions
- What level of investment should be used in the greenhouse to achieve the best long term benefit with the least outlay and operational cost.

The key driver here is that the plant will be the product of the environment it has been subjected to. Growing and merchandising plants with different environmental requirements in the same conditions and management will ultimately mean a compromise and loss in quality and performance of the plants in the immediate and long term.

An example here is to consider the needs of a propagation greenhouse (temperature and relative humidity control and suitable light levels) to that of a display greenhouse for a retail garden centre which protects buyers and plants from rain and direct heat from sunlight.

The greenhouse
An examination of the greenhouse and climate is required to determine the potential and actual plant environment. Readers are directed to the *NGIA Nursery Paper "Greenhouse Design" 2005, February Issue 1* (1) for more detail regarding the type of greenhouse technology, structure, cladding and features referred to as low, medium and high technology greenhouses. The Governing factors of the greenhouse design relating to performance and the greenhouse environment are:

- size (height and surface/area)
- shape (gable roof, sawtooth, arched)
- style (covering and ventilation – sides and or roof, multispan)
- location (orientation, exterior shading, potential internal shading and slope).

The increasing trend in the nursery industry is to invest in high technology greenhouses (1) with computerised automation and the ability to manipulate the greenhouse environment to suit the plant requirements through ventilation, heating, cooling, internal screens, modification of light levels, irrigation and rolling benches to optimise the whole of the greenhouse.

Low technology greenhouses have limitations in their ability to modify the greenhouse environment for optimum production limiting their suitability

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for propagation where a higher level of management of the environmental conditions is required.
Not all greenhouses and plant situations can justify large investments to manipulate the greenhouse environment so planning is critical to get the best long term outcome for the grower and plant merchandiser.

In the greenhouse, the way irrigation is delivered (overhead – fogging/mist/droplets/drippers/hand watering, sub-irrigation – capillary, ebb and flow/flood floor) and moves within and out of the greenhouse, plant density, light levels and air movement within and out of the greenhouse will influence the plant environment.

Critical greenhouse factors
Within the greenhouse the key factors to influence how the plant will perform are:

- Light (visible light, photosynthetically active radiation [PAR] and thermal radiation)
- Air and root temperature (human comfort is different to the plant)
- Relative humidity (driving transpiration and disease potential)
- Concentrations of oxygen/carbon dioxide for fundamental plant process.

In the right climatic conditions, a simple low technology greenhouse can be used for propagation needs (bottom heat, relative humidity and light) until external factors limits its effectiveness.

Understanding the greenhouse and plant environment requires measurement and monitoring to be conducted. Basic measurement of temperature and at least on an annual basis assessment of the light quality within the greenhouse to determine if the greenhouse cladding either requires cleaning (glass) or replacement due to deterioration of the material through aging.

All too often a greenhouse roof covering if it fails from weather rather than optimised before light levels supplied to the plants are compromised.

With this information of the greenhouse conditions, adjustments to the greenhouse can be implemented which provide the basis of producing healthy and profitable crops.

Light – essential but be aware of too much of a good thing
Light is electromagnetic radiation within a certain portion of the electromagnetic spectrum. Humans refer to visible light (light) as electromagnetic radiation within a certain portion of the electromagnetic spectrum having a wavelength of 380 to 770 nanometers between the infrared and ultraviolet wavelength. For plants, the PAR is known to be 400 to 700 nanometers ([2]) with claimed peak of 435 to 675 nanometers.

The main source of light on Earth is the sun. Sunlight provides the energy that green plants use for photosynthesis. With the invention of electricity, electric lighting and advances in technology, artificial lighting has been used in greenhouse for many decades to either supplement or replace sunlight.

Manipulation of the colour spectrum (red, orange, yellow, green, blue, indigo, violet (ROYGBIV) have been claimed to allow photomorphogenesis (light mediated development) with new technology crop covers to improve stem length and produce larger leaves and phototropism (growth toward the light source) claimed to increase shoot tops and length of plant stems.

The quality and amount of light (photoperiod) and darkness is a critical factor for plants and needs to be considered for the type of plant. An example here is the mechanism for flower induction of Chrysanthemum by the duration of darkness required or elevated light duration to maintain vegetative growth.

Light is received as quanta/photons with photosynthetic photon flux density measured as watts per square metre (w/m^2). On a bright sunny day peak light levels will be around 1000 w/m^2 ([3]) and around 125 w/m^2 in an overcast day, whilst in comparison a bright winter day will be around 500 w/m^2 and an overcast day around 75 w/m^2.

The type of greenhouse covering (glass/polyethylene) will influence the type and amount of light which enters the

A specific greenhouse for orchid production which allows control over the light and temperatures through external and internal screening and forced ventilation for air exchange and cooling.

Modern greenhouses can perform well in hot summer conditions, provided ventilation (roof and sidewall) supports air exchange and the crop management applied meets the plant needs - NIASA accredited Howlong Nursery.

A modern greenhouse with high side walls, roof ventilation, internal screens and the ability to deliver good light levels for plant growth - NIASA accredited Alstonville Palms, NSW

structure. Glass is known to have the highest transmission around 90% whilst polyethylene cladding manufacturers claim up to 87% transmission with a diffused light offering a softer more appealing light for plant growth.

The orientation of the greenhouse (north/south or east west), the type of structure (height and roof type) and cladding will influence how much light enters the greenhouse. Always design the greenhouse for the worst case climatic conditions to provide sufficient natural light for successful production.

It is critical to optimize light levels in greenhouses for seedlings – particularly where the temperature threshold for growth has been achieved to avoid soft and "leggy" seedlings. Seedlings require exposure to the leaf layers and surface area of the growing media to optimize photosynthetic activity.

In propagation greenhouses which strike cuttings, light is important for photosynthesis (at least , however too much light without sufficient ventilation can cause temperatures to rise well beyond 25 degrees celcius (°C) and above the optimum basal rootzone temperatures of 22-24°C to exacerbate moisture loss of unrooted cuttings causing plant stress before roots are initiated and produced. The Cutting needs to be encouraged to put its limited energy into producing roots rather than more leaves so leaf temperature should a little lower than the root zone temperature - this is easier to do in winter, but not in summer in most parts of Australia. Mature plants have higher surface leaf area index and can intercept light more easily than seedlings. However, it is only the upper leaves which are exposed to the light with lower leaves potentially receiving 50% and the bottom leaves of larger trees and shrubs being 10% of the available light *– yes it is critical to look at plant density to avoid losing lower light*. It is also important to consider the needs of outdoor plants, those that grow in the rainforest understory and indoor plants.

Do not just assume a 30% shade cloth material equates to a reduction of 30% of the sunlight. Without an actual measurement of the light/photon you are potentially compromising crop health and productivity. Also consider the colour of the shade cloth/crop cover whereby darker materials are more able to absorb and retain the thermal radiation in comparison to white coverings which can deflect heat.

The plant response is the critical element within the greenhouse and the light saturation or that above the plant needs where a surplus can lead to higher greenhouse temperatures. Excess sunlight causes leaves to heat up potentially increasing water demand. Surfaces absorb the thermal energy (pots, benches, floors, steel) and are released as convection to heat the greenhouse environment. As the air heats up and if plants cannot transpire the relative humidity may drop and induce stress.

Internal screens used to reduce light and thermal energy (day) to modify the greenhouse environment and retracted at night for heat retention. NIASA accredited Alstonville Palms NSW.

Air and root temperature

Without good ventilation of the greenhouse (<2m high sidewalls and little to no roof ventilation) in high sunlight levels and ambient temperatures, the greenhouse can well exceed the outside temperatures to reduce plant growth or cause stress to the point damage occurs.

Irrigation can be used for evaporative cooling in certain situations, however it is important to provide passive ventilation and aiming to prevent the rise in temperature rather than dealing with high temperatures where the crop is. Irrigation is also used for plant cooling by transpiration, however if relative humidity is too high the ability of the plant to transpire may be compromised to allow for cooling.

External shading is an option if it can be removed when sunlight is limited or pulled across the greenhouse to reduce the thermal radiation when sunlight it adequate for crop needs. Some businesses apply a coating on the roof to reduce light levels, however this will compromise light when overcast conditions exist.
Subtle changes in the temperature are ideal to allow a more stable environment for the plants and not disrupt water uptake and transpiration. In addition, a rapid change in temperature changes the relative humidity (see below) and hence concentration of water within the air.

Relative humidity
Relative humidity is the ratio of the partial pressure of water vapour to the equilibrium vapour pressure of water at the same temperature. The relative humidity depends on temperature and the pressure of the system and is expressed as a percentage measure of the water vapour held in the air at a set temperature.

Plants will have an optimum relative humidity depending on the stage of development (propagation, transplant and mature) climate, and plant type, ie tropical, subtropical, temperature where they have adapted to certain climate zones.
Too high a relative humidity can result in reduced transpiration and poor water with reduced nutrient uptake and plant cooling.
For cutting propagation a general guide is 70 to 85% relative humidity to reduce transpiration loss from leaves which cannot be replaced until roots are present of cuttings. Similar applies to early stages for germination until roots are able to access water in the rootzone of the container.

To help manage relative humidity, air movement within the greenhouse and the consistency of the air movement is critical. Natural ventilation (typically through cross flow side ventilation and/or up to 25% of floor area as ventilation) with or without forced air ventilation may be required to have air movement within the greenhouse and throughout the plants. Subtle movement of air is the aim with 2 to 4km/hr to avoid condensation and a mixing of the greenhouse atmosphere.

Timing of irrigation can influence the immediate and short term relative humidity by charging the greenhouse with water which can add to the water vapour pressure. In general, aim to limit the amount of free water in the greenhouse when relative is >70% (unless propagation) and temperatures are declining toward the end of the day as relative humidity will increase as the temperature drops unless artificial heat (pipe heating) is supplied to dry the air whereas using natural or liquefied petroleum gas will produce water vapour as a byproduct.

Greenhouse drainage is critical to allow water movement and a residual bank of moisture which can elevate the water vapour. Having both floor drainage and drainage on benches to displace water out of the greenhouse are encouraged to allow a greater level of control.

To raise relative humidity, crude systems such as wetting the floor, plants and greenhouse surfaces have been used. For optimal control computer systems which deliver fog with relative humidity sensors reflective of the crop environment are recommended.

It is generally easier to increase relative humidity, however it can be difficult to remove if the ambient conditions have high relative humidity and high temperatures.

Think about progressively opening the greenhouse in stages to help lower rising temperatures and maintain humidity as ambient temperatures rise and closing the greenhouse progressively as ambient temperatures decline at the end of the day to help manage relative humidity levels to limit disease pressure and improve water uptake.

Concentrations of oxygen and carbon dioxide
Carbon dioxide is an essential plant food found within the earth's atmosphere. With evidence of global warming, so to is there evidence of increasing levels of carbon dioxide in the atmosphere.
The background level of carbon dioxide in 2015 has been measured at 400 parts per million (ppm) (4) whereas in the 1970's this was in the range of 330-340ppm.

In a well-sealed greenhouse fully occupied with plants where air exchange is restricted, the limiting factor to plant growth may be the carbon dioxide level. It is important to allow air exchange to introduce fresh supplies of carbon dioxide whilst allow potential manipulation of the temperature and relative humidity.

What can you do?
The information above endeavours to provide guidance and raise awareness of the importance of identifying plant needs and offering some simple tips for long term benefits to the grower and plant manager.

Assessing the existing performance of the greenhouse to suit your needs via a suitably well qualified greenhouse expert is often the first step. Air flow, peak temperatures, relative humidity and fit for purpose will drive any changes within your budget allow greater outlay subject to the plants and potential returns.

It should guide the reader to more specific information and encourage industry participants to review their management.

References and further reading

1. NGIA Nursery Paper - Greenhouse Design" 2005, February Issue 1
2. Photosynthetically Active Radiation – http://en.wikipedia.org/wiki/Photosynthetically_active_radiation
3. Light in Greenhouses - http://www.dpi.nsw.gov.au/agriculture/horticulture/greenhouse/structures/light
4. Climate Milestone: Earth CO^2 level passes 400ppm - http://news.nationalgeographic.com.au/news/energy/2013/05/130510-earth-co2-milestone-400-ppm

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