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FLUORESCENT AND HIGH INTENSITY DISCHARGE LAMP USE IN CHAMBERS AND GREENHOUSES

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INTRODUCTION

Fluorescent and High Intensity Discharge lamps have opened up great opportunities for researchers to study plant growth under controlled environment conditions and for commercial growers to increase plant production during low/light periods. Specific technical qualities of fluorescent and HID lamps have been critically reviewed by Dr. James Dakin. I will direct my remarks to fluorescent and high intensity discharge (HID) lamps in growth chambers, growth rooms, and greenhouses. I will discuss the advantages and disadvantages of using each lamp in growth chambers, growth rooms and greenhouses.

Growth Chambers are small (3m x 4/m and smaller) walk-in or reach-in enclosures with programmable, accurate temperature, relative humidity (RH) and irradiance control over wide ranges. The intent of growth chambers was to replicate sunlight conditions and transfer research results directly to the greenhouse or outside. It was quickly realized sunlight and outside conditions could not be mimicked. We now appreciate most of the reasons, which include spectral quality, irradiation level and long wave differences. Today, it is recognized that it is of principal importance to provide radiation environments which can be repeated, so experimental plants can be compared over time, among chambers and among locations. Growth chambers are also used to study irradiance and spectral fluxes.

Growth Rooms are usually large rooms (larger than 3m x 4m) with only lamp irradiance, but providing relatively limited ranges of environmental control (i.e., 10 to 30 C temperature, 50 to 90% RH and ambient to 1000 ppm CO2), and commonly independent of outside conditions. The narrower range of environmental conditions (as compared to growth chambers) reduces construction costs without a great loss of accuracy of control. Irradiance requirements for growth rooms are similar to those of growth chambers, i.e. standardized spectral quality and uniform irradiance in the growing area. Growth rooms are also used for growing a large number of plants in a uniform standard environment condition, such as commonly required for Plant Science teaching, Plant Breeding, Entomology and Plant Pathology research. Growth rooms are also used in commercial horticulture for tissue culture, seed germination (plugs) and seedling growth.

Greenhouses are designed to allow maximum sunlight penetration through the structure. Initially greenhouses were used to extend the growing season. Then as heating systems, and cooling systems improved, they were used year round. Low light during the winter months reduced plant growth, but with the advent of efficient lamps (HID and fluorescent) it became possible to increase growth to rates close to that in summer months. Supplementary lighting is used during low light periods of the year and anytime to ensure consistent total daily irradiance for research plants.

FLUORESCENT-GROWTH CHAMBERS

Assets:

1. Cool White fluorescent (CWF) lamps have been and are the standard lamps used in growth chambers. Much of the experimental growth chamber results reported in the literature is based on CWF grown plants.
2. CWF lamps have the greatest moles of PPF output efficiency of all fluorescent lamps.
3. Spectral distribution of the CWF lamp is reasonable. Other fluorescent lamps warm white, daylight, etc. have different spectra and some of them have spectra closer to sunlight, but the total mole output of PPF is reduced.
4. Photon levels in chambers of up to 600 umol $m^{-2}s^{-1}$ can be achieved.

Liabilities:

1. CWF and most other fluorescent lamp are not identical to sunlight. One difficulty trying to mimic sunlight is the solar intensity varies from location to location and is constantly changing.
2. Fluorescent lamps have a relatively short lamp life (5,000 to 10,000 hrs.), compared to HID lamps.
3. Must use VHO fluorescent lamps to obtain useful levels of PPF.
4. Fluorescent lamps have a rather rapid decay rate. We have recorded a loss as much as 30 umol $m^{-2}s^{-1}$ in a week. The output of the lamp decays 75% over the life of the lamp. Replace 1/3 of the lamps every 3 or 4 months to maintain more uniform PPF.
5. The decay rate for new lamps is particularly rapid. Therefore, lamps should be operated for 100 hours before use in a research study.
6. PPF should be measured weekly.
7. The plant growing bench has to be adjusted up or down to maintain a desired PPF level at the top of the plant canopy.
8. Temperature of the lamp is critical to obtain maximum PPF output and longevity (an air temperature of 20° C is best, permitting optimum lamp bulb surface temperature of about 40° C). Therefore, the light cap area in a growth chamber should have good temperature control. If the temperature of the light cap varies, temperature of the lamp will vary and PPF output will vary.
9. Changes in line voltage will shorten lamp life.
10. PPF levels higher than 600 umol $m^{-2}s^{-1}$ are difficult to obtain.
11. Special plant grow lamps emit less PPF and are not recommended for use in growth chambers.
12. PPF levels close to the walls of the chamber are significantly lower than in the rest of the chambers. Each chamber should have PPF levels measured and plotted. Care should be taken to grow plants in known PPF locations. The growing area should be blocked to obtain effective experimental design.

FLUORESCENT - GROWTH ROOMS

Assets:

1. The assets are the same as for growth chambers.
2. If lack of height is a problem in the growth room, fluorescent lamps must be used to ensure uniform PPF. For example, rooms used for tissue culture or germination require fluorescent lamp, where the material is grown on closely-spaced shelves.

Liabilities:

1. Liabilities are the same as listed for the growth chambers.
2. For large rooms, fluorescent lamps may not be appropriate, because the installation of the barrier may be difficult. The barrier is needed to maintain the optimum temperature around the lamps.

FLUORESCENT - GREENHOUSES

Assets:

1. Assets are the same as for the growth chamber.
2. Lamps are easy to install.

Liabilities:

1. Most liabilities are the same as listed for the growth chambers.
2. Lamps cause excessive shade on a greenhouse bench.
3. Lamps need to be positioned close to the plant material (less than 1 meter) to provide useful levels of PPF.
4. Fixtures may be exposed to dripping water or water sprays and, therefore appropriate precautions should be taken (ground fault interrupters).

HID - GROWTH CHAMBERS

Assets:

1. HID lamps are required to attain PPF levels above 500 umol $m^{-2}s^{-1}$. Up to 1500 umol $m^{-2}s^{-1}$ can be achieved with HID lamps.
2. HID lamps have long lamp life. (30,000 hours for High Pressure Sodium lamps and 15,000 for Metal Halide lamps)
3. HID lamps have a high efficiency of PPF output, compared to other lamps.
4. Metal halide lamps have spectra satisfactory for plant growth without other sources.
5. Spectra from HPS lamps appear satisfactory at high PPF (>700 umol $m^{-2}s^{-1}$) but at lower

PPF the spectra from HPS lamps may be deficient in blue for many plant species.

6. Dimming ballasts can be used to change and control irradiance output. A 30% reduction can be used with HPS, without changing the spectra. Greater re-ductions may change spectral emissions and may turn the lamp off. There is up to a 10 minute delay in restarting of HID lamps. They can only be restarted at 100% of full power and then dimmed.

Liabilities:

1. Longwave radiation is a problem when HID lamps are installed to provide high PPF levels. Barriers and/or water can be used to reduce this long wave irradiance (3,000 nm and above). A barrier must be cooled with air and water passed through a heat exchanger, to remove the heat.
2. Plant material cannot be grown close to HID lamps, or heat damage will occur (no closer than 1 meter).
3. Uniform of PPF on the growing surface is difficult to obtain. Computer programs are available for HID lamp installations to insure uniform irradiance.

HID - GROWTH ROOMS

Assets:

1. Same assets as for growth chambers.
2. High irradiance levels are usually desired (500 to 1,000 umol $m^{-2}s^{-1}$) and can be achieved with HID lamps.
3. To produce a umol $m^{-2}s^{-1}$, it is more efficient to use HID lamps.
4. HPS lamps produce more mol m^{-2} per electric input than metal halide lamps. Metal halide has a better general spectra of PPF, than HPS which peaks at 550 to 660 nm.

Liabilities:

1. Same liabilities as for growth chambers.
2. Heat load from long wave radiation is high at high PPF and requires considerable cooling capacity.
3. Barriers to reduce long wave radiation may be difficult to install in large rooms. Water cooled lamps may be a better solution for heat removal, which in turn could reduce the size of the mechanical refrigeration.

HID - GREENHOUSES

Assets:

1. Same assets as for growth chambers.
2. HPS lamps are best, because of long lamp life, up to 30,000 hours, a small decrease in output of PPF over the life of the lamp, and the best efficiency of PPF for power used. (Low levels of blue wavelengths are satisfied by levels from sunlight).
3. Heat can be an asset during cold winter nights and on a normal winters night may supply 25% of the heating requirement.
4. With a supplemental lighting level of 200 umol $m^{-2}s^{-1}$, 26 mol m^{-2} day^{-1} can be achieved in most greenhouses in the US during the darkest months of the year by the combination of natural and supplementary light.
5. PPF uniformity (less than 15% variation) can be achieved with efficient luminaries and proper installation.
6. Computer programs are available to determine proper luminare installation for uniform irradiance.

Liabilities:

1. Same liabilities as for growth chambers.
2. Limit lamp installation to 200 umol $m^{-2}s^{-1}$ PPF or heat from the lamps and shade from the luminaries become too great.
3. Low levels of PPF (less than 50 umol $m^{-2}s^{-1}$) will present a problem to obtain uniform PPF.
4. Plants should be at least 1 meter below the lamps or long wave radiation will cause burn (heat) problems.
5. Ballasts (some models) can be remote from the lamps and luminaries to reduce the live load on the greenhouse structure and reduce shading of the plants.
6. Heat from the lamps can 'over heat' the greenhouses during mild outside temperature (above 0° C) and will cause exhaust fans to cool.