Fall 2010

ARGUS ADVISOR

Information for Argus Control System Owners

If you have ever looked at your crop and thought to yourself: "this crop is not performing to my expectations" you are not alone.

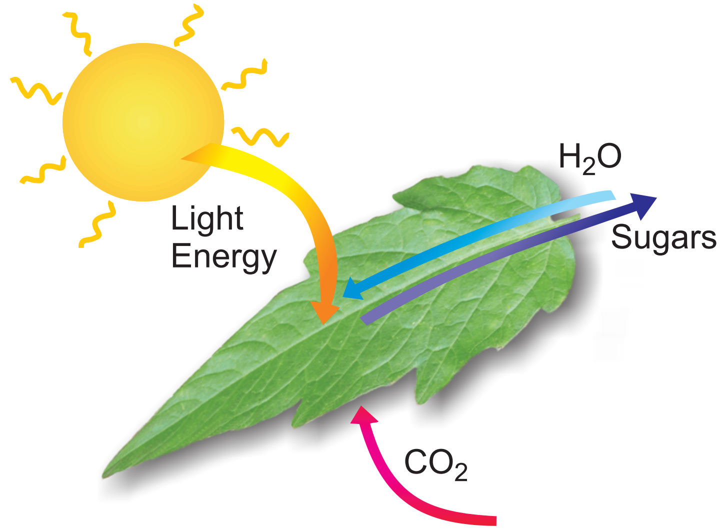
As winter approaches in the Northern Hemisphere, short days and prolonged cloudy weather can severely limit plant growth affecting both yields and quality. We often find ourselves struggling with the minimum conditions for acceptable growth. At such times, the more information you have about the plant climate the better equipped you are to make informed decisions.

In this issue of the Argus Advisor we take a look at a couple of things you can do to take back control of your crop - managing CO_2 and light levels.

We are also continuing our series on control concepts. This time we discuss PWM (Pulse Width Modulation), a relatively simple concept with a technical sounding name.

Alec Mackenzie

Managing CO_2 and Light



The importance of photosynthesis cannot be overstated. Plants use light energy to convert water and carbon dioxide into sugars. This process of carbon assimilation provides the fuel for all growth. Horticulture is all about facilitating photosynthesis for our own benefit.

In greenhouse production we are often more preoccupied with temperature and humidity control than CO_2 and light levels. Perhaps it is because both CO_2 and light occur naturally, although not always in the amounts needed. However, if we expect to achieve the highest production efficiency and crop quality it makes sense to monitor and manage these critical ingredients for photosynthesis.

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Take Control With Argus

CO_2

Surprisingly, the first thing you can do to combat low light levels is elevate the CO_2 concentration. For most crops it has been well documented that the natural CO_2 levels in greenhouses will actually limit plant growth. Increasing the CO_2 concentration can increase net photosynthesis at all light levels:

- It will help sustain and maintain plants when natural light levels are poor.
- It will ensure that you get the most value from expensive artificial light sources.
- It will help to maximize growth, yields, and crop quality when light is abundant.

In closed structures, CO_2 levels will often rise at night while the plants are respiring. However, this 'surplus' can be quickly used up in the morning as increasing light levels begin to drive photosynthesis. Daytime CO_2 levels are mostly affected by the rate of uptake by the plants and the amount of outdoor air exchange. The rate of uptake is in turn influenced by the total amount of leaf surface, the leaf temperature, and the intensity of photosynthetically active light radiation falling onto leaf surfaces. In some situations CO_2 levels can also be influenced by the release of CO_2 from decomposing organic materials in soils or composts.

Sensors

CO_2 sensors can be used for general monitoring and to help ensure correct CO_2 dosing rates. For greenhouse production, CO_2 sensors should be capable of measuring levels to within 70-100 ppm absolute accuracy. Better accuracy requires much more expensive monitoring equipment and the benefits are seldom justified.

High Light is Useless Without CO_2

Lower than ambient CO_2 levels can have a more pronounced effect on photosynthesis than elevated levels. For example, on a bright cold day in a tightly closed, plant-filled greenhouse, the CO_2 concentration may fall to below 200 ppm. This can result in a 20% decrease in net photosynthesis.

Upper Limits

Depending on the species, most plants reach a CO_2 saturation point when concentrations are between 600-1300 ppm. Increasing the concentration beyond these levels does not result in any further increases in net photosynthesis. For CO_2 enrichment, it is easier to maintain saturation levels under low ventilation conditions. As the ventilation rate increases it is often more practical and cost effective to maintain levels that are equal to or slightly above ambient (~400ppm).

Don't Ignore Air Circulation

Whether or not you provide CO_2 enrichment, it is important to maintain good air circulation through the leaf canopy to reduce any local CO_2 depletions occurring at the boundary layers of the leaves. This also helps to ensure even distribution of the CO_2 gas when dosing.

There are many equipment design and safety considerations to observe when managing CO_2 levels in enclosed structures. The Ontario Ministry of Agriculture and Rural Affairs has posted a detailed bulletin on their web site:

Carbon Dioxide In Greenhouses
www.omafra.gov.on.ca/english/crops/facts/00-077.htm

Light

The pyranometer light sensor mounted on the Argus weather station measures light in Watts per square meter (Wm^{-2}). It provides an excellent indication of the total solar energy falling onto your greenhouse. This information is very useful for energy balance calculations and climate control. However, a pyranometer does not directly measure the light that plants use for photosynthesis. For that you need a **PAR** light sensor.

PAR = Photosynthetically Active Radiation. This is light in the 400-700 nanometer wavelength range. PAR sensors are constructed to measure the light intensity only in these wavelengths. The readings are in micromoles per square meter per second ($\mu mol.m^{-2}.s^{-1}$).

PAR light values are most useful when they are measured at the crop. Outdoor PAR sensors do not provide an accurate indication of the light falling onto a greenhouse crop since much of the light energy can be lost as it either passes through or is reflected from greenhouse coverings, structural members, residual shading compounds, dirt and algae accumulations, curtain materials, and even other leaves higher in the plant canopy.

Measuring PAR light from a representative crop location provides an immediate indication of whether the current light levels are sufficient. While a short term light deficiency doesn't halt growth altogether, it does reduce the production of the sugars that are used to fuel plant growth. Many plants will also respond to sustained low light levels by stretching to try to find better light, shedding lower leaves, and delayed flowering. We usually want to avoid all of these in greenhouse production.

Since an in-zone PAR sensor 'sees' the effects of light and lighting control operations it is very useful for confirming the proper operation of any shade, thermal, or blackout curtains, as well as the effects of supplementary lighting equipment. It can also be used to measure and confirm the actual day lengths for crops with critical photoperiod requirements.

Daily Light Integral

If you measure PAR light with your Argus system you can also accumulate these values as a **Daily Light Integral (DLI)**. This provides an indication of the total amount of PAR light received each day. DLI is a great indicator of the potential energy available for growth. Each species has an optimal DLI range. For example, good crops of poinsettias can be produced with a DLI of 10-12 moles per day, while greenhouse tomatoes require an average of at least 25 moles per day for commercial yields.

Monitoring DLI can also help you to make better informed decisions regarding:

- Supplementary lighting and CO_2
- Shading
- Temperatures
- Pruning
- Plant Spacing

Suggested Reading:

Light and Lighting Control in Greenhouses
Argus Controls
www.arguscontrols.com

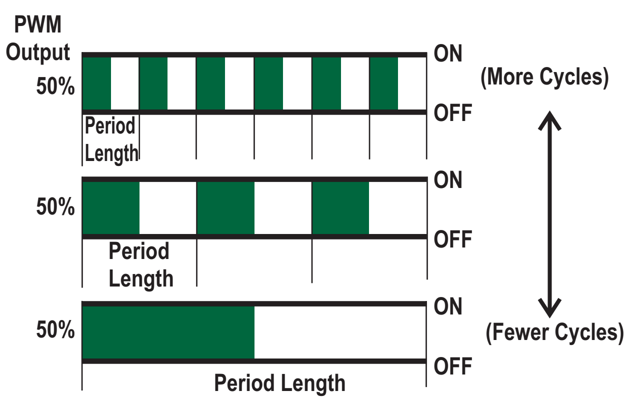
Supplemental Lighting for Greenhouse Crops
PL Light Systems
www.pllight.com./horticultural/publications.php

Control Concepts: Pulse Width Modulation (PWM)

PWM is a simple and effective control strategy for operating on/off equipment in a pulsed manner so that it produces results similar to fully modulating equipment. For example, single-speed greenhouse exhaust fans are sized to satisfy a maximum ventilation demand when they run continuously. For any demand less than this they must be operated intermittently. A fan that runs for 5 minutes and is off for five minutes will, on average deliver 50% of its maximum ventilating capacity. This is what a pulse width modulation strategy does: it divides the operation into timed on and off pulses to achieve an averaged output.

As a rule, shorter, more frequent pulses are more effective at smoothing out deviations in the controlled parameter (such as air temperature) but often at the expense of equipment life. Therefore, a happy balance must be found between the control objectives and the operating constraints of the controlled equipment.

For a PWM strategy, the overall period length (one off plus one on cycle) is matched to the natural cycle of the process. The longest period that produces acceptable control results requires the fewest equipment cycles. Higher equipment cycles tend to wear out equipment faster.



The effect of period length on equipment cycles.
All the above produce the same output (50%)

= ON Time

The minimum pulse time is the sum of:

1. The minimum time it takes to produce any output (a fan might take two or three seconds to reach a speed that actually moves air. A unit heater may take 90 seconds to complete a purge and light cycle before the main burners are lit and it produces heat)

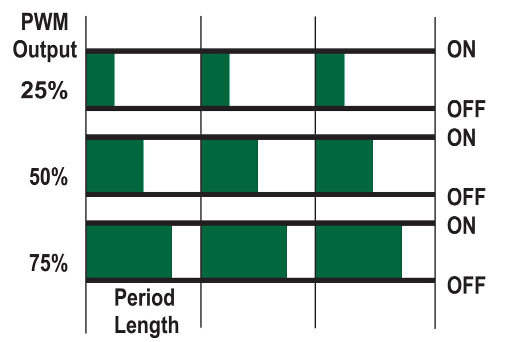
plus:

2. Any additional time it takes to reach a safe manufacturer approved equilibrium.

Some equipment is not suited for this type of control if it cannot be cycled off and on at the period (cycle time) required by the process (not designed for frequent starts) or if the minimum pulse time is too large for the acceptable pulse period.

PWM Alternatives

Fully modulating devices (typically using much more expensive equipment) are an alternative to PWM. Surprisingly, there are many situations where full modulation cannot provide as large a control range as PWM. For example, a single speed fan using PWM with an on time of 25 seconds out of 500 seconds (5%) will accurately move 5% of the continuous air flow. A variable speed fan (i.e. a variable frequency device or VFD) running continuously at 5% of full speed will not necessarily move 5% of the air, and at such low speeds, is overly susceptible to the influence of back pressure caused by wind or other factors.



PWM output is determined by the ON vs.OFF time

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