crop cultivation

Managing Retractable Shade Curtains

Clemson University research shows how retractable shade curtains work differently in different situations.

By Jim Faust

Over the past decade, retractable shade curtains have become a regular feature of new greenhouse construction. The obvious benefit is that retractable curtains provide higher light levels during times of low light intensity (e.g., mornings, late afternoons and cloudy days). Retractable curtains also make an effective thermal blanket when used at night during cold weather.

With this said, we often observe growers not utilizing retractable curtains properly, so this project was undertaken with the support of the Fred C. Gleockner Foundation. Our goal was to develop strategies for managing retractable shade curtain systems.

Before we get started, we must first define terms. In this article, "uncovered" curtains refer to the situation when no shade is being provided, while "covered" curtains refer to the curtains providing shade. Also, please note that this discussion deals with retractable shade curtains positioned inside a greenhouse, which is not the same as a retractable roof greenhouse, although there are many similarities.

PROS AND CONS

Understanding the pros and cons of shading is at the heart of understanding how curtains are mismanaged and how curtains should be properly used. The first benefit of shade is reduced water use, thus irrigation management becomes easier. The second benefit is reduced plant temperatures, which reduces heat stress. The negative side effects of shade include reduced photosynthesis, which results in reduced growth and often results in lessened plant quality. Thus, we often use shade to 1) make our jobs easier and 2) reduce crop damage. The challenge growers face is that it is human nature to ease our work stress and minimize the chance of damaging a crop. The result is that growers often provide excess shade, which reduces quality and greenhouse productivity. The grower's goal should be to optimize photosynthesis while properly managing irrigation and greenhouse temperatures.

OPTIMIZING PHOTOSYNTHESIS

Understanding the effect of light and temperature on plant photosynthesis was essential for achieving our shade management goals. Figure 1, below, shows the photosynthetic response of red salvia to light. This figure suggests that photosynthesis is nearly saturated (97 percent of the maximum) at 4,000 foot-candles, and reducing the light to 3,000 foot-candles reduces photosynthesis by a mere 4 percent. At 2,000 foot-candles, the plants are operating at 82 percent of the maximum rate. Reducing light intensities below 2,000 foot-candles has a dramatic impact on photosynthesis. ➧

Figure 1. The effect of light intensity on photosynthesis. This figure demonstrates the effect shading has on reducing the rate of photosynthesis.

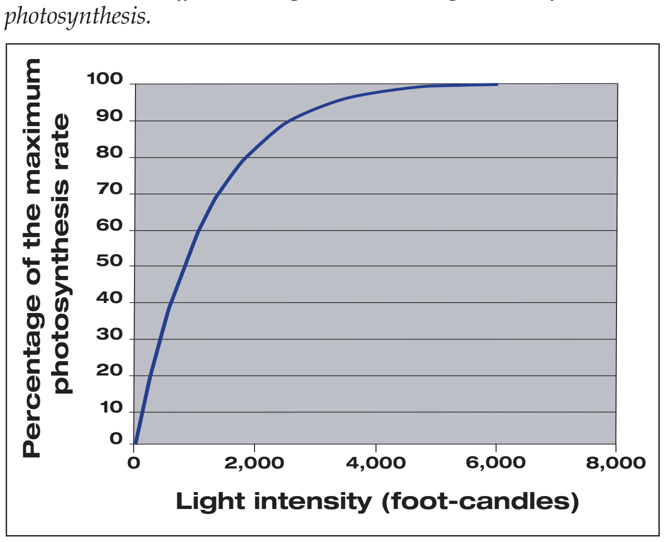
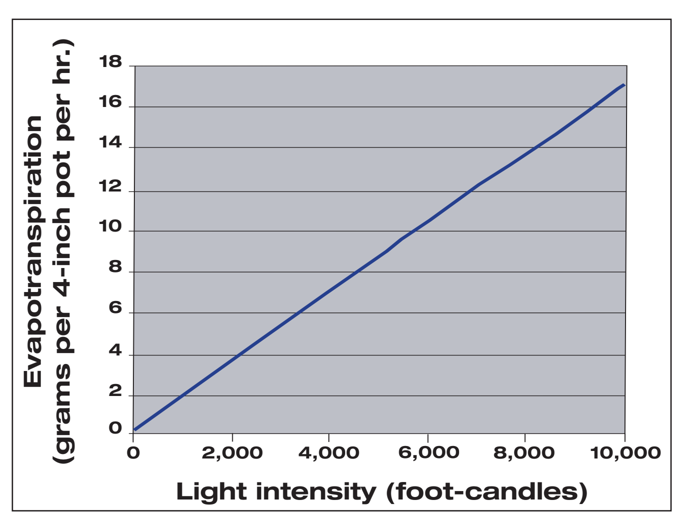


Figure 2. Evapotranspiration is closely correlated to the solar radiation; therefore, shade curtains are an important water



For example, at 1,500 foot-candles the plants are functioning at 72 percent of their capacity, while at 1,000 foot-candles, the plants are at only 57 percent of their photosynthetic capacity.

Figure 1 also demonstrates how applying shade affects plant growth. For example, if a plant that is receiving 6,000 foot-candles is shaded with a 50 percent cloth, so that the light intensity drops to 3,000 foot-candles, then growth is reduced by only 7 percent. In contrast, if a 65-percent shade curtain is pulled over plants receiving 4,000 foot-candles, the plants will only receive 1,400 foot-candles (70 percent of the maximum photosynthetic capacity).

Figure 3. The effect of average daily temperature on plant development. Heat stress occurs at temperatures slightly above the optimal temperature. For many greenhouse crops, symptoms are observed at average daily temperatures greater than 85° F.

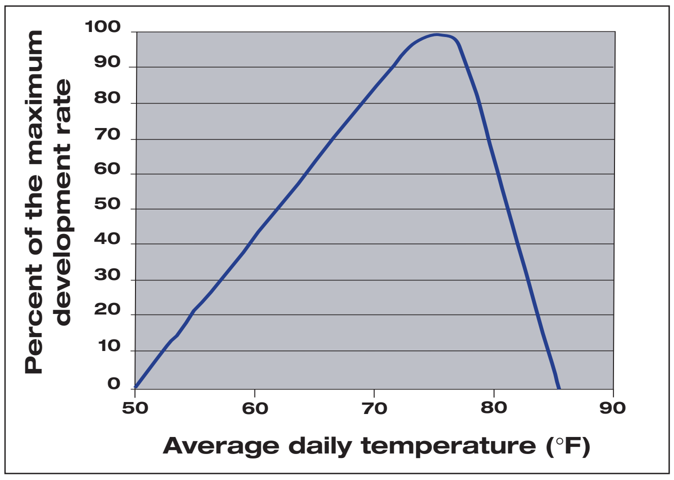
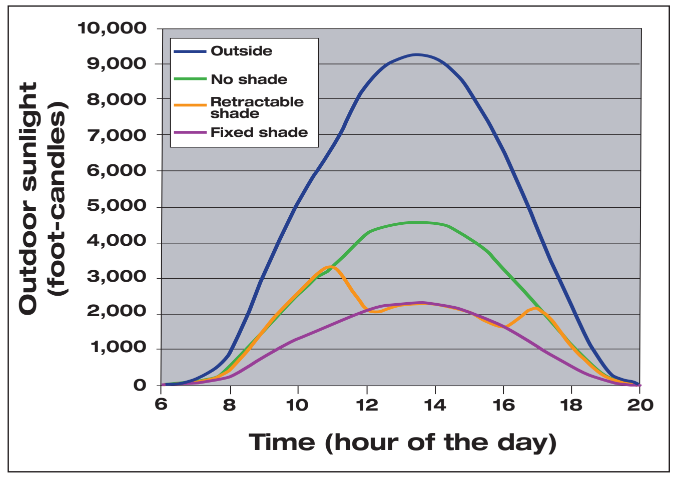


Figure 4. An example of the solar radiation delivered outside the greenhouse and inside a greenhouse with no shade, retractable shade and fixed shade.



How much shade does your curtain system provide? We often look at a curtain that has alternating strips of aluminum and open space and assume that we are getting 50 percent shade. This is not a safe assumption. You must make some measurements. In July, I walked through a greenhouse business that thought they had a 65-percent shade curtain. We set a light sensor on the bench, opened and closed the curtains and measured 82 percent shade. The maximum light intensity in that range with the curtains closed was only 1,400 foot-candles on a sunny, summer day.

This example strikes at the heart of any discussion about light in greenhouses. The fact of the matter is that our eyes are lousy light sensors. If we walk from the office to a shaded greenhouse, the light will seem relatively high whether it actually is or not. Real measurements must be made to get a handle on your greenhouse light environment. Accurate sensors are no longer cost prohibitive.

The plants also provide an indication of excessively high or low light conditions. Under low light plants will experience delayed flowering, lower flower number, poor lateral branching and thin stem caliper. Plants that receive excess light will often display cupping or folding or will orient themselves vertically. These adaptations are performed to reduce light interception and are more likely to be seen on smaller plants or on the most exposed leaves at the canopy.

IRRIGATION MANAGEMENT

Solar radiation is the greatest single factor that affects evaporation of water from the growing media and transpiration of water from leaves, i.e., evapotranspiration. Humidity, wind speed and temperature also affect evapotranspiration but to a much lesser extent. Figure 2, page 100, demonstrates how water use increases linearly as solar radiation increases. Knowing that a 4-inch pot holds approximately 240 grams of water, all the water would be used after 14 hours of exposure to full outdoor sunlight (10,000 foot-candles), while 45 hours of exposure to 3,000 foot-candles is necessary to use the same quantity of water. Therefore, shade curtains are an important tool for crop water management. However, growers must be careful not to provide excess shade just to make watering easy.

MINIMIZING HEAT STRESS

It should be recognized that many of our greenhouse crops perform exceptionally well in full outdoor sunlight; therefore, shade is usually provided for temperature control rather than for reducing the light delivered to the plants. Heat stress can cause acute or chronic damage to plants. Acute symptoms occur when a plant receives a very high temperature over a short period of time (less than one day). Most often, acute heat stress is associated with drought stress during high light. When the plant is drought stressed, the first response is to close the stomata (pores on the leaf), which shuts down transpiration. Transpiration keeps leaves cool on sunny days, so when transpiration ceases, plant temperatures increase dramatically. Acute heat stress symptoms include leaf or flower scald or burn. Roots can also be severely damaged when black pots are exposed to direct sunlight and the growing medium becomes extremely hot. Similarly, excessive leaf temperatures (usually greater than 95° F) can cause photosynthesis to be reduced. The photosynthetic apparatus may not immediately recover, so growth can be hindered for more than one day.

Chronic heat stress occurs when the average daily temperatures are too high for an extended number of days. For many greenhouse crops, the most rapid plant development occurs at 77° F, while heat stress occurs at 85° F or higher. These are the 24-hour average temperatures; so even though 85° F may not sound particularly high, those temperatures are not usually observed, since cool night temperatures usually drop the average daily temperatures to less than 80° F. The symptoms of chronic heat stress include: malformed leaves, leaf chlorosis, delayed flowering, small flower size, improper flower colors (reversion) and axillary bud abortion (no branching following a pinch). Cultivars within a species will vary in their susceptibility to heat stress. For example, 'Freedom Pink' is the first poinsettia cultivar to show signs of heat stress (leaf distortion), thus it serves as an indicator plant.

MANAGEMENT STRATEGIES

The goal for managing a shade curtain system is to keep photosynthesis operating near the maximum level (see Figure 1, page 100) while minimizing water stress (see Figure 2, page 100) and heat stress (see Figure 3, page 102). Retractable curtain systems are usually controlled with a computer that uses time of day, light and temperature measurements to decide whether the curtain should be deployed or not.

The first issue to address is the concept of partial closing of the curtains. Curtains can be programmed to provide incremental shading through a series of steps. Our opinion is that this is not a good strategy for production greenhouses. First, it creates an uneven distribution of light to the greenhouse crop, which creates irrigation challenges. This is particularly problematic if the greenhouse contains relatively small plants, such as plugs or cuttings in propagation. Second, it often causes the curtain system to frequently be in operation. This creates wear and tear on the system. A curtain system should be managed so that when shade is needed the curtain is fully deployed and when shade is deemed not necessary, the curtain is fully retracted. This results in relatively even light distribution, and the curtain moves a minimal number of times during the day.

The second issue is the response time or the number of consecutive minutes that a certain environmental condition must occur prior to the system responding. For example, a certain solar radiation level must be achieved for 10 consecutive minutes before the curtain moves. This is done to reduce the number of times a curtain moves during a fluctuating environment, such as a partly cloudy day. For tender plants the response may be relatively fast such as 5 minutes, while 10 to 15 minutes works well for more mature plants.

Computer systems vary, but there are several different curtain management techniques that can usually be employed. The following options are based on the time of day, outdoor light intensities and greenhouse temperatures:

Time Alone. The shade system is simply operated on a timeclock basis. A computer-controlled shade system seems to be overkill if it is simply controlled with a timeclock; however, this is occasionally observed. The obvious downside of this approach is that shade is provided regardless of the solar radiation. A time setting makes the most sense for situations where shade is likely to be needed daily regardless of the outdoor environment. This situation describes some propagation environments from spring to fall; however, excess shade may be provided if this setting is used throughout the winter.

Light Alone. The solar radiation measurements used in this discussion describe light with the unit: Watts per square meter ($W.m^{-2}$). Even if you are not familiar with this unit, it is easy to relate to, since the maximum summer outdoor solar radiation is ~1,000 $W.m^{-2}$; therefore, 500 $W.m^{-2}$ is ~50 percent of full sunlight and 300 $W.m^{-2}$ is ~30 percent of full sunlight. Also, note that 1 $W.m^{-2}$ = ~10 foot-candles

When an outside light level is reached, the greenhouse is covered with shade cloth (cover setpoint). The greenhouse is uncovered when a second (lower) light level is reached (uncover setpoint). If the uncover setpoint is set too close to the cover setpoint, the curtain may go through several uncover/cover cycles during a day, which is undesirable, as it causes additional wear on the system.

The light alone technique is useful for many situations. In the Southeast., a cover setpoint of 800 to 900 $W.m^{-2}$ will cause shade to cover around 11 a.m. to noon on sunny days from April through September. An uncover setpoint of 500 to 600 $W.m^{-2}$ allows for uncovering in the late afternoon when the greenhouse temperatures cease getting hotter. The light alone control option can be used in propagation if the response time is relatively fast, e.g., five minutes.

Figure 4, page 102 provides an example of the light alone technique. The figure shows the solar radiation delivered outside the greenhouse and inside a greenhouse with no shade, retractable shade and fixed shade. In this example, the retractable shade was covered when the outdoor solar radiation was 800 $W.m^{-2}$ (8,000 foot-candles) and was uncovered at a 500 $W.m^{-2}$ (5,000 foot-candles) setpoint. The daily light integral delivered was 34.2 moles/day outdoors, 17.1 moles/day in the greenhouse without shade, 11.5 moles/day in the greenhouse with retractable shade, and 8.5 moles/day in the greenhouse with fixed shade. Thus, retractable shade allowed for 35 percent more light to be delivered compared to the fixed shade greenhouse.

Light AND Time. This setting will usually deliver a higher light level to the bench crop since *both* light and time settings must be satisfied before the curtain will cover the greenhouse, i.e., the greenhouse will remain uncovered if either setting is not satisfied. Essentially, shade will only be provided during a portion of the day (midday and early afternoon) if the light level is high. This setting makes the most sense to use when trying to maximize light, while providing shade during the hottest hours of the day.

This approach can produce more consistent shading patterns over several months without having to regularly tweak the program settings. For example, from spring to summer to fall, the maximum solar radiation changes from 800 $W.m^{-2}$ to 1,000 $W.m^{-2}$ and back to 800 $W.m^{-2}$. If one is trying to provide minimal shade, then the cover setpoint may need to be adjusted each month in order for the curtain to cover just prior to midday on sunny days. For example, the cover setting, might be 700 $W.m^{-2}$ in April and September, 800 $W.m^{-2}$ in May and August, and 900 $W.m^{-2}$ in June and July. Also, the light and time option allows the curtains to remain open for a little longer in the morning and late afternoon, while still consistently shading in the afternoon. For example, a light alone setpoint of 700 W.m^{-2} will cause the curtains to cover on many sunny days from spring to fall; however, it may cover a little earlier and uncover a little later than desired in June and July. So, an additional timeframe of 11 a.m. to 4 p.m. may provide more light yet still provide a consistent shading pattern around noon.

Temperature override. A temperature override allows the shade curtain to cover the greenhouse when a maximum temperature is reached, regardless of the light or time. For example, when the greenhouse air temperature is 95-100° F, plant growth may be limited, regardless of light level. So, shade can protect plants from further heat or light stress. The combination of a light and time setting with a temperature override provides the ideal shade management strategy, i.e., shade is only provided when it is absolutely necessary — light levels are maximized and temperature stress minimized.

HOW MUCH SHADE?

What is the correct amount of shade to provide? The answer depends on the crop being grown, the light transmission of the greenhouse, and the geographic location. There is not one correct answer, but there are a few critical factors to consider .In many production systems 45-55 percent shade works well; 55-70 percent may be needed for propagation. Shade greater than 70 percent is not usually needed. Whitewash can always be added to reduce light levels for propagation or low light crops; however if the curtain provides excess shade, there is no easy way to provide higher light levels. Perhaps the most common mistake we observe is when a greenhouse has a relatively high percentage shade curtain and the shade curtain is covered for most of the day, e.g., 9:30 to 6:00 p.m. The result is relatively poor light levels even in midsummer.

The best shade system also depends on the cooling capacity of the greenhouse. If a greenhouse contains an evaporative cooling pad system, less shade is needed to provide equal greenhouse temperatures. The worst greenhouse environment for growing high quality plants is a high temperature and low light environment, yet this is the exact environment that is often produced when heavy shade is placed on a greenhouse during the summer months. Properly managed retractable shade curtain systems are a valuable tool for improving crop quality and greenhouse productivity. GPN

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Author's Note: This project was funded with a grant from the Fred C. Gloeckner Foundation.

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