Principles of Light

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LIGHT SEEMS LIKE SUCH A SIMPLE phenomenon, yet it is deceivingly complex, especially with regard to its effects on plant growth and development. Light can influence essentially all aspects of orchid plant growth and flowering. First and foremost, it provides the energy for photosynthesis, or the conversion of carbon dioxide and water into sugars and oxygen. This article describes the three dimensions of light and the relevance of each to growing orchids.

LIGHT DURATION The duration of light in a 24-hour period is known as the daylength or photoperiod. Photoperiod changes throughout the year, and the magnitude of the change depends on the latitude. In equatorial regions, the photoperiod changes less than 30 or 40 minutes from winter to summer. As one moves farther away from the equator, the change in photoperiod during the year increases. For example, the natural photoperiod (the duration from when plants first perceive light before sunrise until when light is no longer perceived after sunset) in northern Florida (30°N latitude) ranges from approximately 11 hours in late December to 14.5 hours in late June. In northern Oregon, southern Minnesota and central New York (45°N latitude), the photoperiod varies from 9½ hours to just over 16 hours. These photoperiods are about 30 to 40 minutes longer than the period from sunrise to sunset, because there is enough light for plants to perceive for 15 to 20 minutes before sunrise and after sunset.

Photoperiod is one of the few consistent environmental parameters every year. Thus, it is no surprise that some plants use the change in photoperiod as a signal to induce flowering at a favorable time of the year. Numerous floriculture crops flower only when the day is sufficiently short (or more accurately, when the night period is sufficiently long). A few common examples are poinsettias and chrysanthemums. Some orchids also flower in response to short days, including some species and hybrids of *Cattleya*, *Dendrobium* and *Phalaenopsis*. However, there is relatively little research-based information on the effects of photoperiod on flowering of most orchid genera and their hybrids. The photoperiod can be readily manipulated by hobbyists and commercial growers. When the photoperiod is naturally long (from March to September in temperate regions of North America), short days can be created by covering plants with an opaque black cloth or plastic. When plants are not exposed to natural daylight, lamps can be set to be on for less than 12 hours per day. A word of warning: plants can perceive low levels of light — even sometimes one tenth of a foot-candle, which isn't enough for most people to read a book. Therefore, beware of light from adjacent rooms polluting your orchids if a short-day photoperiod is desired.

The photoperiod can more easily be extended by providing artificial lighting. To create a long day, a small amount of light (10 foot-candles or more) is required. This intensity can be delivered by one 60-watt incandescent or one 15-watt compact fluorescent lamp every 5 to 6 feet (1.5 to 1.8 m) apart. This amount is not enough to sustain plant growth, but is enough to create a long photoperiod if that is desired.

What photoperiod should you provide your orchids? There is not one correct answer, as it depends on what types of orchids are in your collections. For example, if some of your plants routinely flower during the winter when the natural day length is short, then you could inhibit flowering if you provided a long day. Growers primarily interested in increasing growth during nonflowering times may want to provide a long day (e.g., 16 hours of light). Continuous lighting can cause undesirable responses in some plants, so at least a six-hour dark period is recommended each day.

LIGHT QUALITY Light consists of individual particles of energy called photons. Each photon within the visible light spectrum has the potential to drive photosynthesis. Light quality refers to the spectral distribution of light, or the relative number of photons of blue, green, red, far-red and other portions of the light spectrum that is emitted from a light source. Some of these portions are visible, whereas others are not. The energy of each photon is dependent on its wavelength. Photons with a short wavelength, such

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as that of ultra-violet (UV), have more energy than photons with a longer wavelength, such as red light.

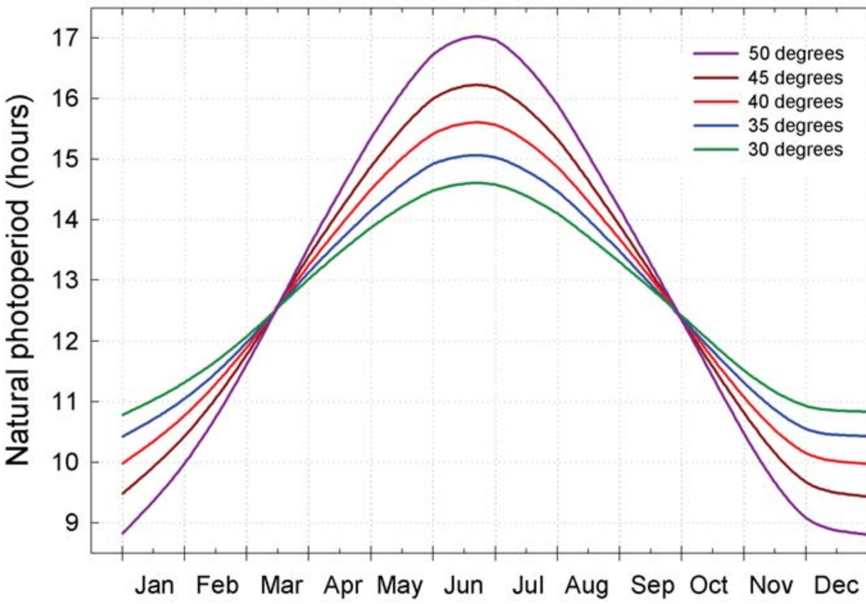
The wavelength of light is most commonly measured in nanometers (nm), which is one billionth of a meter. Blue light is generally considered to be the portion of light that has a wavelength between 400 and 500 nm. Blue light, green light (500 to 600 nm) and red light (600 to 700 nm) compose the spectrum of light that is primarily used for photosynthesis (400 to 700 nm). Approximately half of the energy that comes from the sun falls within the photosynthetic waveband. The remaining amount of energy has shorter wavelengths (such as UV light) or longer wavelengths (such as infra-red radiation).

The proportion of red light relative to the amount of far-red light (the red to far-red ratio) influences stem elongation, particularly in orchids that grow under high light. Lamps that emit large amounts of far-red relative to red light (such as incandescent lamps) promote plant elongation. In addition, plants are effective filters of red light, but transmit or reflect most far-red light. Therefore, in an environment shaded by plants (such as under a forest canopy), the red to far-red ratio decreases and extension growth of crops below is promoted.

Sophisticated devices called spectroradiometers, which measure light quality, are expensive ($4,000 or more). However, greenhouse growers and hobbyists usually don't need to measure light quality because it is

[1] High-pressure sodium lamps are the most common lamp type used in greenhouses because they are the most efficient at converting electricity into photosynthetic light.

[2] *Phalaenopsis* grown under excessively low light levels develop thin, narrow leaves.



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relatively fixed for each light source. The distribution of light for the most common light sources is summarized in Table 1. The radiant yield refers to the percentage of energy that is in the form of photosynthetic light. High-pressure sodium lamps for supplemental greenhouse lighting are used widely primarily because they have the highest radiant yield.

Fluorescent lamps are commonly used by orchid hobbyists to provide light to their plants. This lamp type is used primarily because it is much more efficient than incandescent lamps at converting electricity into light that can be used for plant growth. They also have a more balanced spectrum. In addition, fluorescent tubes are desirable because they more uniformly distribute light than lamps with a point source of light. Generally, fluorescent lamps are positioned so that they are 1 to 3 feet (30 to 90 cm) above a plant canopy because of their relatively low light output.

Metal halide and high-pressure sodium (HPS) lamps, also referred to as High Intensity Discharge (HID) lamps, are useful to provide significantly more light to plants. HPS lamps are more efficient, and therefore they are the primary lamp type used in greenhouses. However, HPS lamps emit a relatively small amount of blue light compared with metal halide lamps. Therefore, when there is no other light source for plants, metal halide lamps are desirable, either alone or in combination with HPS lamps. HPS lamps are usually used to supplement sunlight. Both lamps should be at least 5 feet (1.5 m) above the plant canopy to avoid excessive light levels and to help improve the uniformity of the lighting to plants. Hobbyists should generally use 400- or 600-watt fixtures; 1,000-watt lamps are practical only for large greenhouses where lamps can be hung at least 8 or 9 feet (2.4 to 2.75 m) above plants.

Private companies and researchers continue to advance the utility, performance and pricing of LEDs (light-emitting diodes). LEDs typically provide monochromatic light, but they can be mixed together in an array to provide a more balanced light spectrum. LEDs are desirable because they have a long life and are energy-efficient. The cost of LEDs continues to decrease but the economics are still less favorable than other common lamp types.

LIGHT QUANTITY Light quantity refers to the intensity of light that can be measured instantaneously or as a daily light sum. Plant growth is primarily influenced by the average amount of light received each day. In other words, plant growth is influenced by the number of hours of light and the intensity of light during the day. We refer to this value as the daily light integral.

When speaking of light, growers and hobbyists often use foot-candles, researchers commonly use $\mu mol \cdot m^{-2} \cdot s^{-1}$, and Europeans often use lux or klux (1 kilolux equals 1,000 lux). The $\mu mol \cdot m^{-2} \cdot s^{-1}$ unit refers to the number of photons (or particles) of light within the photosynthetic waveband that is received per second within 1 square meter of area. Watts per square meter ($W \cdot m^{-2}$) is used by greenhouse engineers and scientists when discussing units of energy. The foot-candle, $\mu mol \cdot m^{-2} \cdot s^{-1}$, and lux all describe the amount of light received at any one point in time. These can be measured instantaneously using a light meter and vary from one second to the next.

Why should we care about the different light units? Different light

Table 1. The percentage distribution of light within the photosynthetic waveband (blue, green, and red) and the radiant yield of common light sources. The radiant yield is the percentage of energy in the form of photosynthetic light.

Light source	Blue	Green	Red	Radiant yield
Cool-white fluorescent lamp	21	52	24	22–27%
High-pressure sodium lamp	5	51	38	29–31%*
Incandescent lamp	2	13	34	6–7%
Metal halide lamp	18	49	25	20–21%
Sun (direct sun and sky)	23	26	26	43%

*values are for 400-watt lamps; 600- or 1,000-watt lamps are usually more efficient.

Table 2. Common units used to quantify instantaneous light intensity and conversion factors for the most common sources of light.

Light source	$\mu mol \cdot m^{-2} \cdot s^{-1}$	Foot-candles	Lux	$W \cdot m^{-2}$ (total energy)
Sun	1	5.0	54	0.51
High-pressure sodium lamp	1	7.6	82	0.56
Metal halide lamp	1	6.6	71	0.59
Cool-white fluorescent lamp	1	6.9	74	0.54
Incandescent lamp	1	4.6	50	2.58


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units are similar to foreign languages. If we don't know how to translate units, they can be meaningless. For example, if a grower found an interesting orchid article that uses lux units for lighting, and the grower was familiar only with foot-candles, the information might not be useful.

Instantaneous light units can be converted easily using Table 2. For example, to convert 500 foot-candles of light from high-pressure sodium lamps into $\mu mol \cdot m^{-2} \cdot s^{-1}$, divide 500 by 7.6, which equals 66 $\mu mol \cdot m^{-2} \cdot s^{-1}$. The only way to measure light intensity is with a light meter, which can be purchased for about $100 to $300. For more information on light meters, a short article written by John Erwin may be helpful: www.greenhousegrower.com/grower_tools/200707_equipment_lightmeters.html.

Every orchid grower knows that light intensity needs to be carefully managed for good plant growth and flowering. If the light levels are too low, plants may not flower because there isn't enough energy to stimulate the flowering process. In addition, new leaves that develop can be undesirably thin and growth can be weak. In contrast, if light levels are too high on some orchids, leaves can become scorched, causing unsightly brown spots and reducing their capacity for photosynthesis. Excessive light can also cause spotting on flower buds and flower abnormalities, such as on *Zygopetalum*. Suggested maximum light intensities for some common orchid genera are 1,500 foot-candles for *Phalaenopsis* and *Paphiopedilum*, 2,500 foot-candles for *Miltoniopsis* and *Zygopetalum*, 3,000 foot-candles for *Cattleya*, and 5,000 foot-candles for *Brassia*, *Cymbidium*, *Degarmoara*, *Dendrobium* and *Oncidium*. Lower light intensities are suggested to prevent leaf scorch soon after transplanting and if root systems are poor.

Two general strategies are used to provide shading to greenhouses: (1) application of a shading compound such as whitewash and (2) use of a shade fabric to reflect light. Shading compounds are commonly used because they are relatively inexpensive to apply, can be used on any glazing material and structure, and reflect light outside the greenhouse before it enters and increases temperature. The major disadvantage of a shading compound is that the shading is somewhat constant and is present when shading is not needed, such as on cloudy days. In addition, the shading percentage of traditional whitewash products can decrease during the year as it slowly dissolves with rainfall.

Shade fabrics can either be manually placed above plants on a hoop-type structure or, in more sophisticated greenhouses, can be used with an automated retractable system. Although retractable shade curtains are relatively expensive to install, they allow light to be more controlled, which can improve plant quality. The ability to retract screens during periods of low light (cloudy weather) is an important attribute of this technology. Shade curtains can also function as an energy curtain at night. A good energy-saving curtain has a closed construction, meaning that air does not readily pass through. However, a curtain with a closed design can be undesirable when serving as a shade curtain because it does not allow warm air under the curtain to escape in the summer. A common shading factor for curtains used in greenhouses is 40 to 50 percent. However, higher shading factors may be needed when growing low-light orchids such as *Phalaenopsis* or *Paphiopedilum*.

[3] The variation in natural photoperiod depends on the time of year and latitude. The photoperiod that plants perceive is 30 to 40 minutes longer than from sunrise to sunset.

[4] Excessive light on *Zygopetalum* can cause black spots on flower buds and abnormal flower development.

[5] Leaf scorch on phalaenopsis, which can occur when a direct beam of light is greater than about 1,500 foot-candles.

[6] Aluminized retractable shade curtains are used by some commercial greenhouse growers to provide a reduced and more uniform light intensity to an orchid crop.

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