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LIGHT REQUIREMENTS FOR FOLIAGE PLANTS

David E. Hartley[1]

Light is a major factor affecting foliage plant quality. Light requirements for foliage production and maintenance cannot be accurately determined without considering all external and internal factors contributing to the overall plant condition. Light is the major stimulant to the life cycle of a plant; however, a plant's response to light may be favorable or unfavorable according to the plant's age, previous history, genetic make-up, and interaction with environmental factors such as water, temperature, and nutrients. For a clearer understanding of the plant/light relationship, consideration should be given to the nature of light and its use by plants.

What is light?

Light is radiated in electromagnetic waves and also packets of electromagnetic waves called photons. The known distribution of electromagnetic energies arranged according to wavelengths, frequencies, or photon energies is called the electromagnetic spectrum. Wavelength, a common description of energy in horticulture, is the length of the energy wave between 2 identical points. The length of the wave is inversely proportional to the energy of each photon. Thus, short wavelengths have high energy while long wavelengths have low energy. Colors are representative of wavelengths. For example, a relatively short wave (360nm) produces a sensation of blue, while a relatively long wave (660nm) is visible as red. The nanometer (nm) is a useful unit for wavelength because the human eye can just about detect the difference in color of 2 sources that differ by 1 nanometer. Light is only that portion of the spectrum having wavelengths visible to the human eye (390-760nm).

Confusion arises when speaking of "light" in a horticultural context. The common usage of "light" in reference to all energy used by plants is widely accepted. Plants, however, do not utilize all of the visible portion of the electromagnetic spectrum. Technically, plants mainly respond to the blue and red bands of the spectrum. In contrast, human eyes are most responsive to the green-yellow bands. Plants respond to radiant energy measured in radiation units of calories, watts, ergs, Joules, or Langleys. Humans "see" light measured in illumination units of lux, footcandles, or lumens.

It is important that horticulturists understand the difference between "radiation" and "illumination", especially when measuring plant lighting. Due to their inexpensive simplicity, illumination meters have been traditionally used to measure plant lighting. A footcandle meter is a photosensitive cell that measures the amount of illumination at 520 nm (green-yellow) hitting the cell. The human eye is very responsive to green-yellow light; though this wavelength is of little value to plants. A footcandle is the measurement of one lumen per square foot; it is not an accurate reading of the radiant energy utilized by plants. Even though relatively inaccurate, the most commonly used unit of measurement for light recommendation is the footcandle.

A more accurate, yet complex and expensive, instrument for measurement of horticultural lighting is the plant-growth photometer. This instrument measures separately the blue (400-500nm), red (600-700nm), and far red (700-800nm) spectral bands hitting the leaf surface, corre-

[1]Associate Professor, Department of Horticulture, Colorado State University, Fort Collins, CO 80523.

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sponding to the spectral bands which are the most physiologically active for plants (1). The units of measurement are in micron watts per square centimeter per nanometer (μ W/cm²/nm). The photometer can also determine the transmission characteristics of glazing materials in natural lighting.

Why is light important?

Life could not exist on this earth without plants. Likewise, without light plants could not exist, for it is the force which stimulates all life processes of the plant. Large amounts of radiant energy are used in 2 major processes: transpiration and photosynthesis. Small amounts are used for flowering, seed germination, stomatal movements, and pigment production. The most important chemical process in the world is the transformation of energy from the sun into chemical energy. This process is photosynthesis. The unique anatomy of plants allows absorption of carbon dioxide and water into the leaf tissue where it is converted into complex sugar molecules and oxygen gas. This reaction can only occur in the presence of radiant energy. The importance of photosynthesis lies in the transformation of low energy compounds (carbon dioxide and water) into high energy compounds (sugars), as shown in the summary equation:

$$\underset{\text{carbon dioxide}}{6CO_2} + \underset{\text{water}}{6H_2O} \xrightarrow[\text{chloroplasts}]{\text{673 Kcal light energy}} \underset{\text{sugar molecule}}{C_6H_{12}O_6} + \underset{\text{oxygen gas}}{6O_2} \text{(1)}$$

Through photosynthesis, large amounts of energy from light can be used or stored for future use in the form of sugars. Energy stored as chemical energy is continually released in living cells during the process of respiration as shown in the following equation:

$$\underset{\text{sugar molecule}}{C_6H_{12}O_6} + \underset{\text{oxygen gas}}{6O_2} \longrightarrow \underset{\text{carbon dioxide}}{6CO_2} + \underset{\text{water}}{6H_2O} + \underset{\text{energy}}{\text{useful}}$$

When light of any significant intensity makes contact with the green pigment chlorophyll in the chloroplast, photosynthesis is instantaneous. The rate of photosynthesis (all other factors being equal) appears to be directly proportional to the intensity of light hitting the leaf surface, up to a saturation point for each species (2). The light intensity at which the rate of photosynthesis and respiration are exactly equal is the light compensation point. This point, at which the gaseous exchanges balance each other, is the dividing line of life and death for a plant. The actual minimum light intensity at which any species can survive has to be greater than the light compensation point (2). Only 0.5 to 3.5% of the total light energy is actually used in photosynthesis, although 80 to 85% is absorbed (3). The remaining energy is eliminated through reflection, transmission, convection, thermal reradiation, and evaporation (4).

Three interacting aspects of light affecting the life processes of plants are intensity (how much), duration (how long), and quality (what kind).

Light Intensity

Intensity is the amount of light falling at any instant upon a leaf surface. The intensity of solar radiation varies according to latitude, time of day, season of year, cloud density, elevation, and plane of exposure. The average solar radiation on a clear June day at noon in Colorado (40°N latitude) is 10,000 footcandles or greater. Most typical offices or home environments have an illumination of 20-100 footcandles. Accurate light intensity for foliage plants is dependent upon plant variety, age, general health, previous history, and the water, nutrient, and temperature regime. Over a period of time, plants can adjust to changes in light intensity; but, an abrupt change may cause severe damage. Light intensity recommendations are often described as low, medium, or high. Table 1 provides a more specific measurement for these terms.

Table 1. Recommended Lighting-Level Categories (based on a 12 hour lighting period per seven-day week.)

Low — minimum light level of 50 footcandles; recommended level of 75-150 footcandles.
Medium — minimum level of 75-100 footcandles; recommended level of 200 (plus) footcandles.
High — minimum level of 200 footcandles; recommended level of 500 footcandles.
Very High — minimum level of 500 footcandles; recommended level of over 1000 footcandles.

Light Duration

Duration is the length of exposure to light for a plant. Experimentation for folige plants has not yet proven that light/dark periods are critical. It is recommended that the lighting duration for most foliage plants be 12 to 14 hours per 24 hour day, 7 days per week. If the light intensity is lower than the recommended level, then the light duration should be increased to 18 to 20 hours per day (2). For increased foliage quality, the lighting period should be continuous and regular instead of sporadic.

Light Quality

Quality is the type or kind of radiant energy. The different types of radiant energy are discerned by numerous measurements. These include photon energy, wave number, wave frequency, wavelength, and color. In horticulture, wavelength and corresponding color are most commonly used. Light quality is less obvious than intensity or duration; therefore, it has often been disregarded. Quality is, in fact, an important aspect of the lighting requirement, because physiological responses are specific to distinct types of radiant energy.

Physiologically active irradiation (PAI) is a term applied to various effective wavelength regions ranging from 300 to 800nm which activate physiological reactions within a plant. PAI can be summarized as:

Physiological Response	Blue	Red
Photosynthesis	350-530nm	600-700nm
Chlorophyll synthesis	350-470nm	570-670nm
Phototropism	350-500nm	
Seed germination		
Seedling & vegetative growth		560-700nm
Photoperiodism	**Far Red**	680-780nm

The level of PAI determines the overall response, growth, and development of a plant throughout its life cycle (1). A balance of blue, red, and far red wavelengths are desirable for overall vigor, growth, and attractive appearance. Predominantly blue wavelengths produce short, stocky plants with dense green foliage. Predominantly red wavelengths produce elongated straggly plants with light green foliage.

The required lighting level for plant production and maintenance is contingent upon the desired growth response. Lighting levels can be divided into 3 general categories.

Pure Maintenance Level

A pure maintenance level supplies minimal light and moisture for photosynthesis and respiration, but at a very low rate. No new growth occurs; therefore, the plant dies at the end of the life span of the original foliage.

Sustained Maintenance Level

A sustained maintenance level supplies enough light and moisture to allow renewal of the senescent foliage, but prohibits free growth. Plants may live forever under this lighting level, although a high degree of care is required.

Full-Health Maintenance Level

Full-health maintenance level provides light and moisture for replacement of old foliage as well as additional growth. The plant may change in initial size, shape, and appearance. Little care is necessary at this lighting level because the plant is vigorous and healthy.

Damage From Incorrect Lighting

Excessive light will increase leaf temperature resulting in tissue damage and chlorophyll degradation. The symptoms of leaf browning and curling is called "sunscorch". Even after the plant has been removed from excessive light conditions, leaves may continue to yellow, exhibit black spots, or fall.

Inadequate light lowers photosynthesis resulting in weak, sparse foliage conducive to disease. Plants exhibit small, pale leaves and elongated, spindly stems.

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