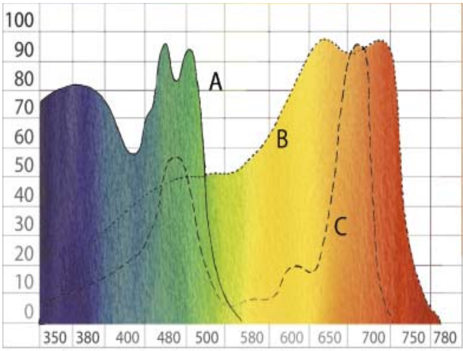
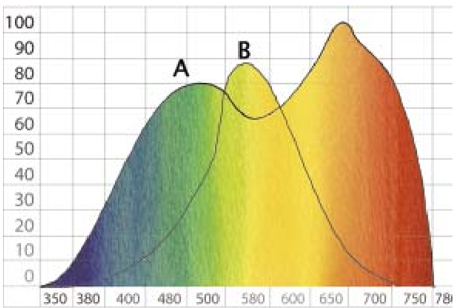
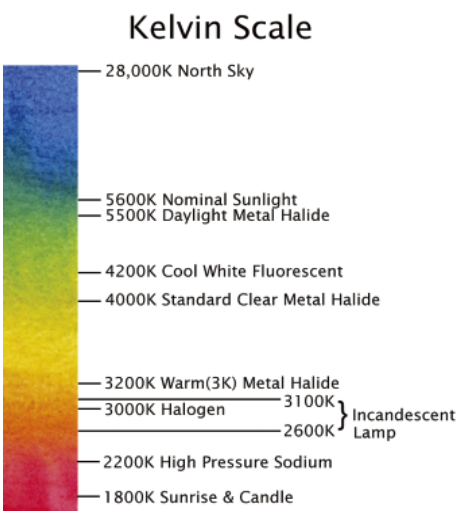
These pepper plants are thriving indoors under artificial light and are growing in expanded hydroclay hydroponically.



This graph shows the exact level at which A. Phototropic response, B. Photosynthetic response, and C. Chlorophyll synthesis take place.



The single-humped line in the center of the graph represents the visible light spectrum humans see. The dual-humped line represents the spectrum plants need to grow.



Introduction

Until the 1980s, light was the limiting factor for indoor growing of plants requiring medium or high light levels. Until that time, only a few dedicated gardeners grew indoors, mainly African violet and orchid enthusiasts who used fluorescent lamps. Over the last twenty-five years, indoor gardening and horticulture have been revolutionized by advances in lighting technology. By understanding how plants use light, indoor gardeners can use High Intensity Discharge (HID) lamps to grow spectacular flowers, nutritious vegetables, and ornamental plants indoors.

Light, Spectrum, and Photoperiod

Plants need light to grow. The light must have the proper spectrum and intensity to ensure rapid growth. Light is comprised of separate bands of colors. Each color in the spectrum sends the plant a separate signal. Each color in the spectrum promotes a different type of growth.

PAR and Light Spectrum

Plants need and use only certain portions of the light spectrum. The most important colors in the spectrum for maximum chlo-

Bulb Rating	CCT Rating in degrees Kelvin
Warm	3000
Neutral	4000

Bulb	Kelvin Temp	CRI
Cool White	4150 K	62
Lite White	4150 K	62
Warm White	300 K	52
Deluxe Daylight	8500 K	84
Vitalight	5500 K	96
Noon Sunlight	5300 K	100

rophyll production and photosynthetic response are in the blue and red range. The main portion of light used by plants is between 400 and 700 nanometers (nm).* This region is called the Photosynthetically Active Radiation (PAR) zone.**

“PAR watts” is the measure of the actual amount of specific photons a plant needs to grow. Photons are a measure of light energy. Light energy is radiated and assimilated in photons. Photosynthesis is necessary for plants to grow and is activated by the assimilation of photons. Blue photons are worth more PAR watts than red photons, but scientists have difficulty measuring the exact difference.

Each color of light activates different plant functions. Positive tropism, the plant’s ability to orient leaves toward light, is controlled by spectrum. Lightbulbs deliver only a part of the necessary light plants need to grow. However, they deliver enough! Most plants’ light needs can be met by artificial means.

*One nanometer (nm) = one billionth (10_{-9}) of a meter. Light is measured in wavelengths; the wavelengths are measured in nanometers.

**Some scientists still disagree as to the exact PAR zone and make their calculations based on 350 to 750 nanometers. PAR watts measured with this scale will be a little higher.

Measuring Light

Virtually all light is measured in foot-candles, lux, or lumens. Foot-candles and lux measure light visible to the human eye. The human eye sees much less of the light spectrum than plants “see.” The eye is most sensitive to light between 525 and 625 nanometers. The importance of the blue and red portions in the spectrum is diminished greatly when light is measured in foot-candles, lux, or lumens. A foot-candle is a unit of illumination equal to the intensity of one candle at a distance of one foot. The lux scale is similar to that of the foot-candle; one foot-candle is equal to 10.76 lux.

Although this simple light meter measures light in foot-candles rather than PAR, it still gives an accurate idea of light distribution.

Humans see light differently than plants do. Compare the graphs above to see how the light you see differs from the light a plant uses to grow. Plants use the photosynthetically active response (PAR) portion of the spectrum. Humans use the central portion of the spectrum, while plants are able to use large portions of the spectrum not measured by light meters that record foot-candles, lux, and lumens.

Light is also measured in spectrum with kelvin temperature which expresses the exact color a bulb emits. Bulbs with a kelvin temperature from 3000 to 6500 are best for growing plants indoors. The PAR section above explains that plants use specific portions of the spectrum—a complete range from blues to reds. Lamps with a spectrum similar to PAR-rated bulbs can use kelvin temperature of a bulb to ascertain the approximate PAR rating of the lamp. Color spectrum results from a specific mix of different colors. High intensity discharge bulbs are very similar in spectrum. Making these safe assumptions, a rough PAR rating could be extrapolated from a kelvin temperature rating.

The Color Corrected Temperature (CCT) of a bulb is the peak kelvin temperature at which the colors in a bulb are stable. We can classify bulbs by their CCT rating which tells us the overall color of the light emitted. It does not tell us the concentration of the combination of colors emitted. Companies use a Color Rendering Index (CRI). The higher the CRI, the better the bulb is for growing.

Light Meters

Most commercial light meters measure light in foot-candles or lux. Both scales measure light to which the human eye reacts to "see." They do not measure photosynthetic response to light in PAR watts.

Light measurements in this book are made in foot-candles and lux. This information is still valuable, because it records the amount of light spread over a specific surface. The information is then coupled with the PAR rating of different bulbs. Regardless of the lamp, the amount of light emitted is constant. It only makes sense to use the proper reflective hood with a high PAR-rated bulb to grow the best garden.

After all the talk about PAR watts, industry officials are unable to agree on a common scale of measurement. For this reason, we have decided to rely on kelvin color temperature to measure lamp spectrum.

Turn on a green light bulb to work in the indoor garden at night. Green light will not affect the photoperiod of flowering plants.

Photoperiod

The photoperiod is the relationship between the duration of the light period and dark period. Many plants will stay in the vegetative growth stage as long as an 18- to 24-hour light and a six- to zero-hour dark photoperiod are maintained. However, there are exceptions. Eighteen hours of light per day will give plants all the light they need to sustain vegetative growth.

In short-day plants, flowering is most efficiently induced with 12 hours of uninterrupted darkness in a 24-hour photoperiod. When plants are at least two months old—after they have developed sexual characteristics—altering the photoperiod to an even 12 hours, day and night, will induce visible signs of flowering in one to three weeks. Older plants tend to show signs of flowering sooner. Varieties originating in the tropics generally mature later. The 12-hour photoperiod represents the classic equinox and is the optimum daylight-to-dark relationship for flowering in short-day plants.