Minnesota Commercial Flower Growers Association Bulletin

Serving the Floriculture Industry in the Upper Midwest

January, 1993 Volume 42, Number 1

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LIGHT QUALITY: A BRIEF OVERVIEW

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Introduction

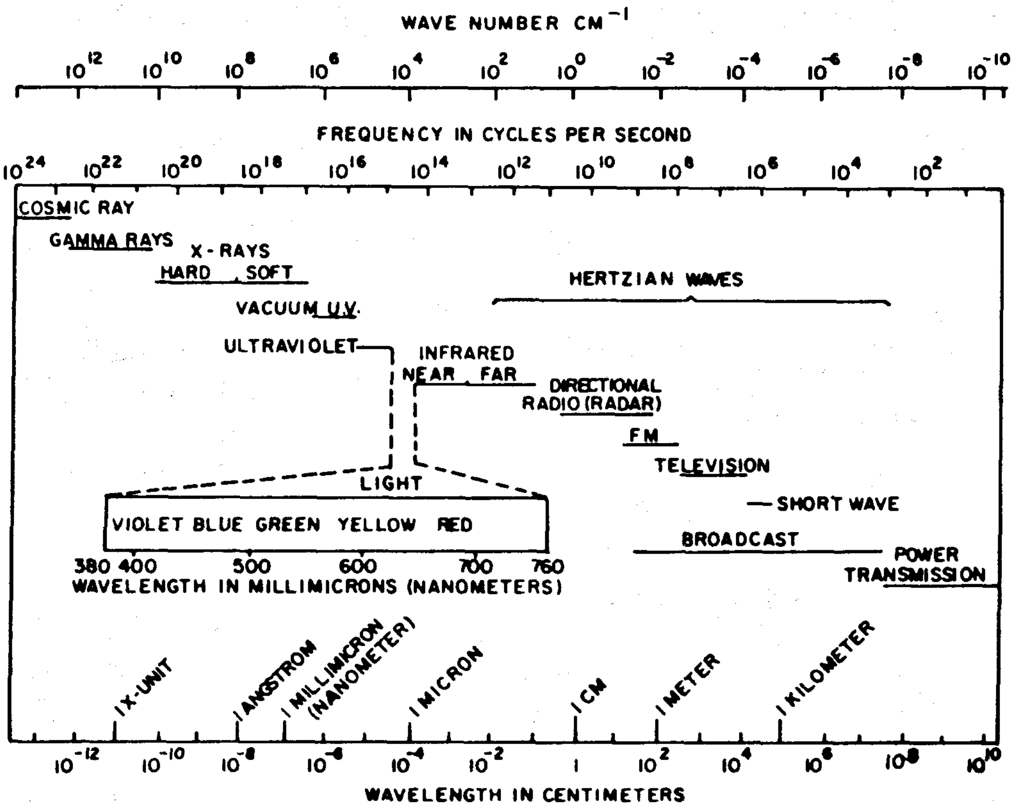
Light quality or color can have a dramatic impact on the appearance of a plant. Light quality affects plant height, color, leaf size, leaf orientation and sometimes whether or not a plant flowers. We, as growers, are regularly altering the color of light which our crops are exposed to. We change the light color which plants are exposed to whenever we turn lights on in the greenhouse, space plants or move plants among greenhouses which may have different coverings. In addition, the color which plants are exposed to on a bench changes as the plants grow together on a bench.

Not only the color of light, but when plants are exposed to different colors of light during a day/night cycle is important. Exposing plants to red light in the morning can have a very different effect on plant growth than if plants are exposed to red light at the end of the day. This article will review how light color affects plant growth, how timing of lighting can affect plant growth and how we can use this knowledge in greenhouse production to our benefit.

What is Light?

Light is radiant energy. Just like a radiowave, light has a wavelength and a frequency. Light travels at a speed of 186,300 miles per second. For our purposes, the speed of light is instantaneous. As a side note, we can use this information to calculate the distance of an approaching thunderstorm from us. Sound travels at a speed of .21 miles per second. Therefore, if we count the number of seconds from the time we see a lightening bolt till the time we

Figure 1. *Radiant energy of the electromagnetic spectrum (adapted from IES Lighting Handbook, 1959).*



The wavelength of light determines the color of the light.

hear thunder, we can calculate the distance of the storm from us. Simply multiply the number of seconds by the speed of sound per second.

Light Color

The wavelength of light determines the color of the light. For instance, light with a 440-450 nanometer wavelength is blue in color. In contrast, light which has a 675 nm wavelength is red in color (Figure 1). White light is actually composed of many of the colors visible to our eye. The best example of this is to take a prism and pass light through it. What we see is a rainbow of colors as the prism separates white light into its different components. Light can appear white to us if it contains equal proportions of blue, green and red light. The best example of this is apparent on a typical color television. If you look very closely at a color TV screen you see pixels which are only 3 colors, blue, green and red. By differentially altering the intensity of light emission from each of these different colors within a TV screen we can see a variety of colors including white.

It is important to realize that there are many different types or colors of light which we cannot see with our eyes because our eyes are not sensitive to them.

When we 'see' an object, we are actually 'seeing' what colors that object is tranmitting or reflecting. For instance when we hold a red piece of transparent plastic up to sunlight, the plastic appears red to us because it is filtering all other colors of light out except red. Similarly, a yellow car appears yellow to use because the paint on the car is absorbing all of the colors of sunlight except yellow.

It is important to realize that there are many different types or colors of light which we cannot see with our eyes because our eyes are not sensitive to them. For instance, honeybees can see light which has shorter wavelengths than we can see. In other words, they can see light colors which are on the upper end of the ultra-violet spectrum. Plants which depend on bees for pollination have evolved to have flowers which are colors which bees can see. Our eyes cannot always see the 'true' colors of many flowers. Bees cannot see red colors, or colors with longer wavelengths as humans can. This is the reason why most flowers which are pollenated by bees are blue, pink and/or violet in color to our eyes. Interestingly, flowers which are pollenated by butterflies (which are the only insects which can see red) or birds (which can see red) are almost exclusively red in color.

What colors which are visible to a bee, a human, or a plant depend on what is 'seeing' the light, or the light receptor. A receptor in a bee eye is different from a receptor in a human eye. Plants have receptors which utilize light for energy and gathering information about the environment around them which are different from the receptors in bee or human eyes.

Biological Significance of Light in Plants

Light essentially results in 2 biologically significant purposes in plants: the use of light for chemical reducing or oxidizing power (photosynthesis) or as a trigger effect to release a large amount of stored energy (photo- or light perception). Photosynthesis uses light to create energy for life, whereas photo- or light perception is a process where an organism obtains information about the environment surrounding it.

Photoreceptors

Plants have 4 primary light receptors: chlorophyll, carotenoids, phytochrome and cryptochrome. Chlorophyll is the photoreceptor which uses light to drive chemical reactions, or specifically, photosynthesis. Chlorophyll and carotenoids utilize light to produce energy. In contrast, phytochrome and cryptochrome utilize light to direct growth.

Light Harvesting

Photosynthesis is the most important chemical process in the world. Photosynthesis essentially supplies all life on earth with energy. Chlorophyll utilizes sunlight to generate carbohydrates and sugars which are the basic sources of energy for both plant and animal life. Chlorophyll absorbs blue and red light. It does not absorb in the green or yellow region of the spectra. That is why plants appear green to us.

Carotenoids are pigments, which are more stable than chlorophyll, which also contribute to photosynthesis. They are generally yellow to orange in color. We often are not aware that carotenoids are even in plants until the fall of each year (for those of us in the northern climates). Because carotenoids are more stable than chlorophyll, they become visible when the chlorophyll in a leaf is broken down. Carotenoids are responsible for the fall leaf colors of yellow, orange and red. Carotenoids are important to humans in that they are broken down by our bodies to form vitamin A_1. Carrots are very high in carotenoids and are, therefore, an excellent source of vitamin A_1.

Phytochrome

Phytochrome is a pigment which a plant uses to gather information about its surrounding environment. It exists in 2 forms: P_r and P_{fr}. P_r absorbs light which is red (660 nm) and to a lesser extent blue light (440 nm). P_{fr} absorbs far red light with a peak at 730 nm. Absorption of light in either form converts it to the other form (Figure 2). In other words red light converts P_r to P_{fr} and vis

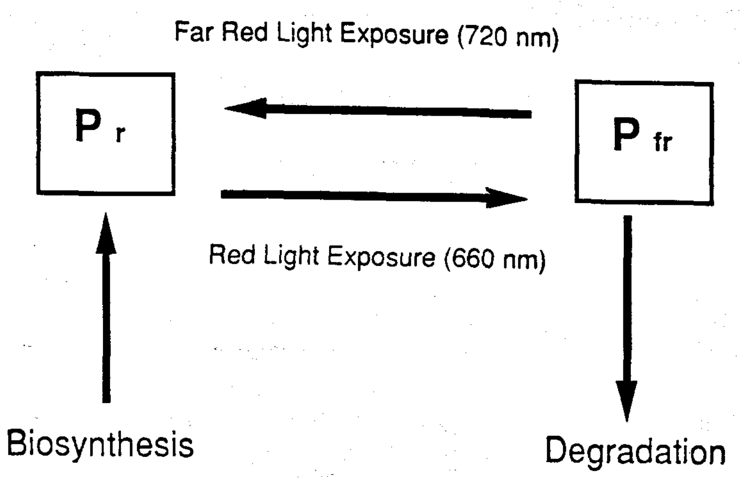


Figure 2. *Effects of red and far red light on phytochrome (P) form.*

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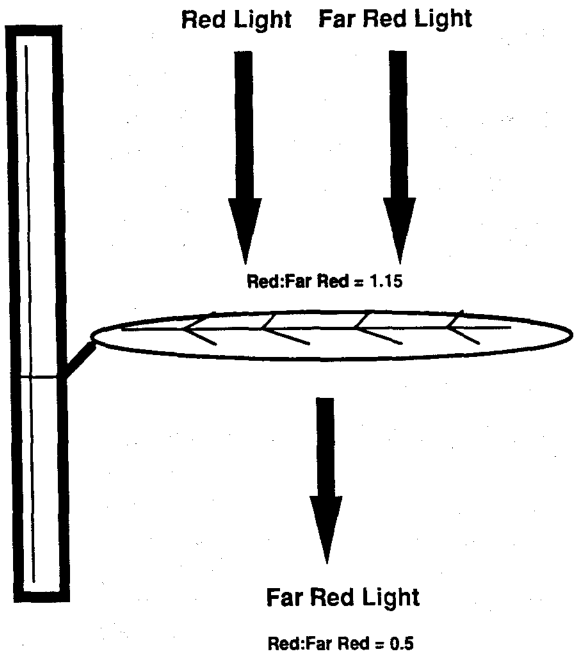
Plants have 4 primary light receptors: chlorophyll, carotenoids, phytochrome and cryptochrome.

Photosynthesis is the most important chemical process in the world.

Phytochrome is a pigment which a plant uses to gather information about its surrounding environment.

Figure 3. *Leaves act as preferential filters. Green leaves absorb red light and allow far red light to pass through.*



Phytochrome allows a plant to perceive if other plants are near or shading it.

Leaves are preferential filters. In other words, they absorb some light and let some light pass through.

A plant will respond the the ratio of red light: far red light.

The degree of responsiveness of a plant depends on what type of environment the plant evolved in.

versa. In darkness it is also important to note that P_{fr} naturally degrades or reverts back to P_r.

Phytochrome allows a plant to perceive if other plants are near or shading it. Phytochrome allows a seed to determine if the time is right to attempt germination. Phytochrome is also involved in the ability of a plant to perceive short days versus long days, i.e. phytochrome is involved in photoperiodism. How does this unique pigment direct all of these such widely varying processes?

Leaves are preferential filters. In other words, they absorb some light and let some light pass through (Figure 3). Specifically, green leaves absorb more red light than far red light. Therefore, plants growing under a canopy or in a canopy are exposed to a greater proportion of far red light than red light than if they were growing in open sunlight. Plants utilize this information.

A plant will respond the the ratio of red light: far red light. As this ratio of red to far red light changes, a plant will act accordingly to try to survive. Factors which are greatly influenced by the ratio of red:far red light are shown in Table 1.

You can see from Table 1, that when a plant is shaded it applies its resources to growing above a canopy: stem elongation increases, branching decreases and energy is directed from the roots to the shoots. Similarly, the plant tries to capture as much light as possible when plants are in a canopy: leaf size increases and leaf orientation increases. We see this phenomenon almost every day but don't realize it. You may notice that plants on the edge of a forest or flower bed tend to be shorter and more well branched than plants which are in the middle of a forest or flower bed. This occurs because the red:far red ratio of light decreases as you move from the edge into the middle. This is the same concept which is responsible for why plants on the edges of our beches in greenhouses are shorter than those in the middle.

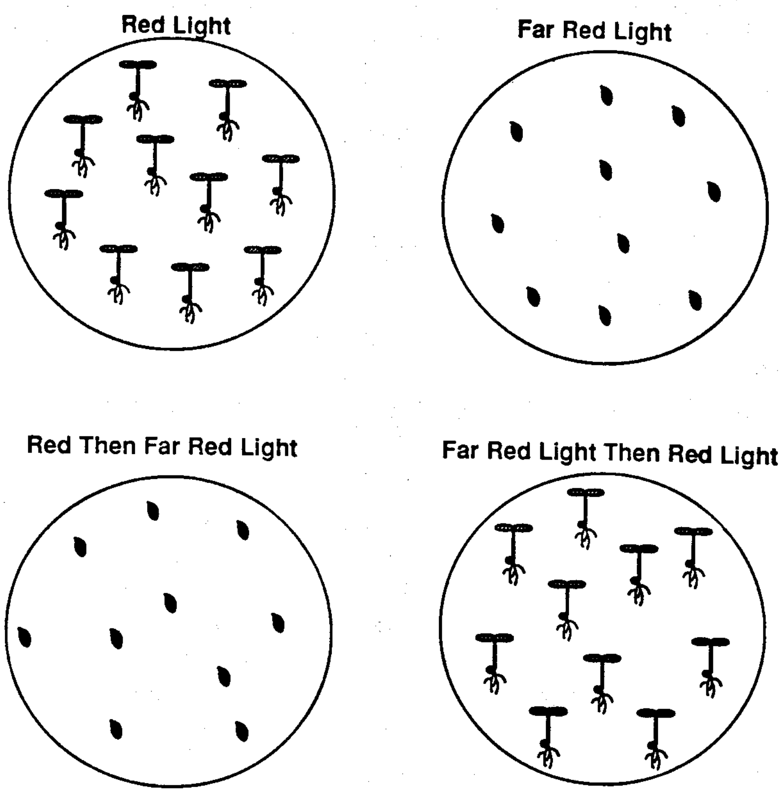
The degree of responsiveness of a plant depends on what type of environment the plant evolved in. Plants which evolved in an open field environment are very sensitive to changes

Table 1. *The effect of low red:far red ratio versus a high red: far red ratio on plant growth. A '+' denotes promotion and a '-' denotes inhibition.*

Characteristic	Low red:far red ratio (within a canopy)	High red:far red ratio (full sunlight)
Stem elongation	+	-
Petiole and peduncle elongation	+	-
Branching	-	+
Leaf Size	+	-
Leaf Color	-	+
Shoot/root ratio	+	-
Leaf Orientation	+	-

in light quality or color. In contrast, plants which evolved in the shade do not respond to light quality as much. Lamb's quarters or *Chenopodium* (evolved in an open field type environment) is extremely sensitive to any shading. In contrast, impatiens (evolved in a canopy type environment) is not very sensitive to changes in light quality.

Figure 4. *The effects of red and far red light on lettuce seed germination.*



Some seed germination is inhibited by far red light and promoted by red light.

Some seed germination is inhibited by far red light and promoted by red light (Figure 4). Lots of far red light tells a seed that it is being shaded by a canopy. Therefore, seed germination at that time may not be ideal. When the proportion of red:far red light increases, i.e. in open sunlight or when a tree falls, seed germination of many of these species is promoted.

In contrast, some seed germination may be inhibited by exposure to light. In most cases this is a mechanism to insure that seed do not germinate on top of the soil but only when they are covered.

Light quality is an important factor in photoperiodism.

Light quality is an important factor in photoperiodism. For many short day plants, such as chrysanthemum and poinsettia, we interrupt the night to inhibit flowering until we want plants to flower. The most effective light color for inhibition of flowering of many short day plants is red. In contrast to short day plants, a night interruption using red lighting promotes flowering in long day plants more than any other color of light.

Blue light receptors

Irradiation of plants with blue light results in a number of morphological responses in plant growth.

Irradiation of plants with blue light results in a number of morphological responses in plant growth. The most prominant among them is phototropism. Phototropism is the ability of a plant to move in the direction of light. Irradiation of a stem on one side but not the other will cause a plant to bend towards the light. The bending response will not occur unless the light source contains blue light (approximately 440 nm). Additionally, irradiation with blue light tends to reduce stem elongation, stimulates germination of some fern spores, carotenoid and chlorophyll synthesis. The primary receptor responsible for blue light perception is cryptochrome.