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How Much do Hanging Baskets Influence the Light Quality and Quantity for Crops Grown Below?

In this alert, learn how hanging baskets have both photosynthetic and photomorphogenic implications on the crops growing below by reducing the photosynthetically active radiation (PAR) and the red to far-red light ratio.

In order to maximize their production area, growers often place hanging baskets in one or more layers or tiers above their crops grown on the floor or benches. Ever wonder how much those hanging baskets influence the light environment for the crops growing below? On a recent greenhouse visit we took a spectrometer (instrument used to measure wavelengths of light spectra and light intensity) to two different greenhouse operations to find out (Figure 1). Before we tell you what we found out, we need to cover some light concepts so that we are all on the same page.

We are all aware that hanging baskets can reduce the overall plant quality for the plant grown below because the quantity of light [light in the spectrum from 400 to 700 nm, termed photosynthetically active radiation (PAR)] that is required for plants to photosynthesize and grow is greatly reduced. However, we often forget that light quality (color or spectral composition of light) is also greatly altered as well. Possibly the most

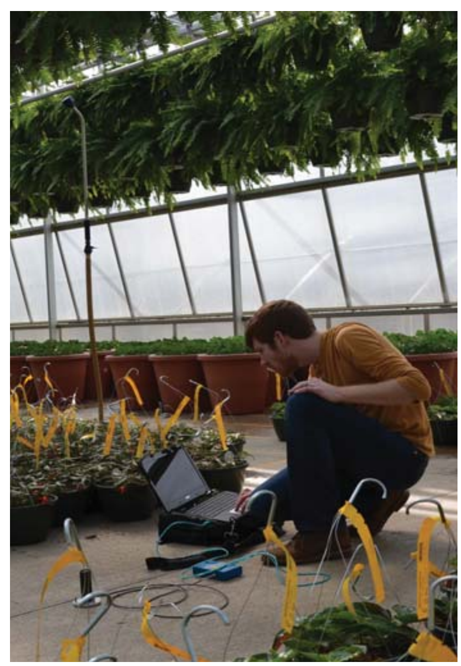

Figure 1. PhD student Joshua Craver is using a spectrometer to take light scans under a fern hanging basket crop.

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important relationship between plants and light quality is the response of plant growth to specific light spectra (color). While PAR is the primary driver of photosynthesis in plants, wavelengths (spectra) within and outside the 400 to 700 nm range have a major role in plant photomorphogenic responses such as germination, stem elongation, and flowering.

Sunlight provides almost equal amounts of blue (B; 400 to 500 nm), green (G; 500 to 600 nm), red (R; 600 to 700 nm) and far-red light [(FR; 700 to 800 nm) Table 1]. However, leaves in a tree canopy, tightly spaced bench, or hanging basket crop reflect, transmit, and absorb light of different wavelengths (Table 1). For example, only a small portion of far-red light is absorbed by the leaves of plants in the upper canopy or hanging basket crop and the vast majority is reflected or transmitted, while most of the red and blue light is absorbed and used for photosynthesis. An important light measurement correlated with plant morphology (architecture), growth, and development is the ratio of red to far-red light (R:FR ratio). Photoreceptors within plants function as light sensors that provide information on subtle changes in light composition within the growing environment. The plant photoreceptor phytochrome is known to control

Table 1. Proportion of total light (400-800 nm) within the blue, green, red, and far-red regions of the spectrum under full sunlight, a double polyethylene greenhouse or under one tier of fern hanging baskets at two different greenhouse facilities (GH 1 and GH 2) in March and the red to far-red ratio, phytochrome photostationary state (P_{FR}/P_{TOTAL}) and the photosynthetically active radiation (PAR) under each environment.

	Proportion of Total Light within each Waveband						
	Light Distribution (%)						
Environment	Blue (400-500 nm)	Green (500-600 nm)	Red (600-700 nm)	Far red (700-800 nm)	Red to far red ratio	P_{FR}/P_{TOTAL}	PAR ($\mu mol \cdot m^{-2} \cdot s^{-1}$)
Outside under full sun	23	26	26	25	1.1	0.72	1851.8
Under a double poly greenhouse	19	25	29	27	1.0	0.71	970.2
Under one tier of baskets (GH 1)	18	22	24	36	0.67	0.66	83.5
Under one tier of baskets (GH 2)	19	24	26	31	0.84	0.69	266.0

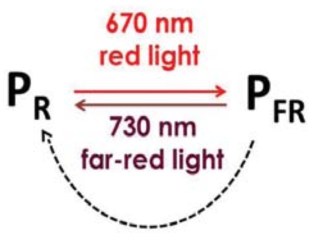

Figure 2. The biologically active from of phytochrome (PFR) can be converted to the inactive form PR under far-red light (700 to 800 nm) or darkness and the biologically inactive form of phytochrome (PR) can be converted to the biologically active form (PFR) when exposed to red light (600 to 700 nm).

photomorphogenic reactions by perceiving light in the red and far-red regions. It has a maximum absorption at peak wavelengths in the red (660 nm) and far-red (730 nm) light regions of the spectrum. Since the sun provides nearly equal amounts of red and far-red light, the R:FR ratio is between 1.1 to 1.2.

Phytochrome is a family of proteins with two interconvertible forms, the red light absorbing form (P_R) and the far-red light absorbing form (P_{FR}; Figure 2). The P_{FR} form is generally considered the active form and triggers phytochrome photomorphogenic responses. Depending on the light quality, these two phytochromes (P_{FR} and P_R) will reach an equilibrium mixture. Therefore, the relative proportion of the active form (P_{FR}) to the total phytochrome (P_{TOTAL}) is consider the phytochrome photostationary state (PSS; P_{FR}/P_{TOTAL}). The PSS can be estimated by multiplying the irradiance at each wavelength against the relative absorption at the wavelength for each form of phytochrome. Typical values of the PSS under ambient solar conditions are between 0.6 to 0.7 for full sun and 0.1 under dense canopy shade. Low PSS ratios of 0.10 to 0.50 represent a high far-red spectrum and high PSS ratios of 0.75 to 0.89 represent a high red spectrum.

Phytochrome plays an important role in seed germination, axillary bud development, stem elongation, leaf expansion, flowering, dormancy, and formation of reserve organs such as tubers. It is also the main mechanism that plants use to adjust their morphology (architecture) under shaded environments in nature and under hanging baskets and tight spacing in the greenhouse. When the plant density is high, individual plants will start competing for available light. Plants are capable of sensing neighboring plants by perceiving the light quality in their surrounding environment. As previously mentioned, plants in a greenhouse are exposed to somewhat equal amounts of blue, green, red, and far-red light from the sun. More blue and red light is absorbed by upper leaves or taller plants compared to green and far-red light, which in consequence delivers relatively more green and far-red light to the lower canopy or those growing on the bench or floor. A far-red rich environment generates a small P_{FR}/P_{TOTAL} that triggers the shade-avoidance responses such as an increase in stem and leaf extension.

Therefore, the combined effects of hanging baskets have both photosynthetic and photomorphogenic implications on the crops growing below. From Table 1, we can see that as we move from full sunlight outdoors in March and into a double-polyethylene greenhouse PAR is reduced by 48%. Under one tier of hanging baskets at greenhouse 1 (GH 1; Figure 3) and greenhouse 2 (GH 2; Figure 4), PAR is reduced by 95% and 85%, respectively, from outdoor values (Table 1; Figure 5). It is no surprise why we see lower crop quality (ie. increased stem elongation, larger leaves, weak stems, and reduced branching and flower buds) when the crops below receive such low light levels. The shade avoidance response from a reduced R:FR ratio only magnifies the stem elongation.

Research by Jim Faust at Clemson University has also shown that hanging basket color can also influence the percentage of light that is transmitted to the crop below as white and terra cotta colored baskets allow more light to pass through than green or black baskets (Figure 6).

As expected, we see a reduction in the percentage of red and blue light under the hanging baskets and an increase in far-red light (Table 1 and Figure 5). We can also see that the R:FR

Figure 3 (left) and Figure 4 (right) A fern hanging basket crop at greenhouse 1 and 2. Notice how a variety of crops are being grown under the heavily shaded fern crop in greenhouse 2.

ratio and PSS decreased under one tier of fern hanging baskets in the two greenhouses we visited. Although this decrease may appear low, it is enough to trigger the shade avoidance response and result in increased stem elongation, increased usage of plant growth regulators (PGRs) and even shrink.

Recent research has shown that even though outdoor solar DLIs increase during the spring due to longer days and higher solar angles, plants in hanging basket also increase in size; consequently, DLIs remain low for the crops growing below (Llewellyn et al., 2013). Additionally, it was reported that the R:FR ratio was also generally reduced as the season progressed. We hope that this e-GRO alert helps you make informed decisions about hanging basket placement.

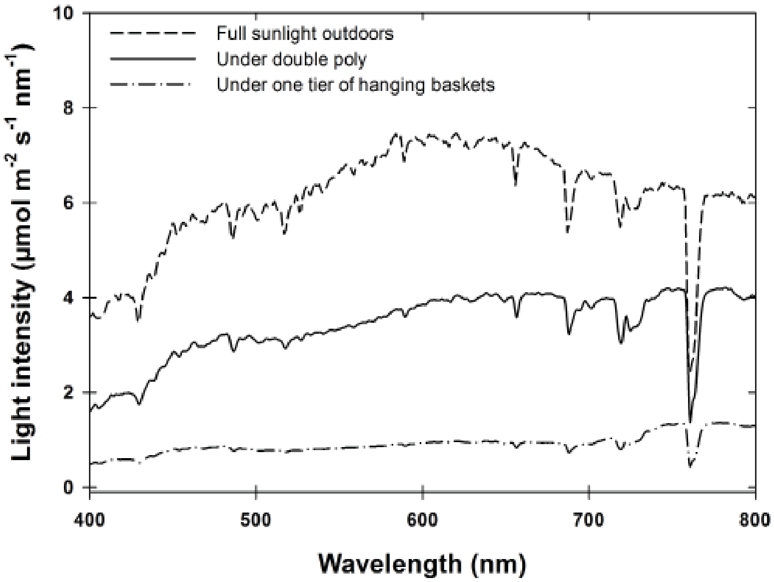

Figure 5 (left). Light spectra in March outdoors (full sunlight), under a double poly greenhouse, or under one tier of hanging baskets (greenhouse 1).

Figure 6 (right). Hanging basket color can also influence the percentage of light that is transmitted to the crop below as white and terra cotta colored baskets allow more light to pass through than green or black baskets (Photo courtesy of Jim Faust, Clemson, University).