Kits to Demonstrate Light Quality Phenomena

Purpose: A demonstration in the back of the classroom can be paired with NGSS-associated lesson plans to show students how light quality affects plant growth and development.

Project Overview: Three light environments are provided with different lamps: broad spectral quality (control), high blue with UV spectral quality, and high red and far-red spectral quality. Red hydroponic lettuce is used to demonstrate how light quality affects anthocyanin development, and a grafting rootstock tomato variety is used to demonstrate occurrence of intumescence. A video overview of the demonstration set-up [https://www.youtube.com/watch?v=sUReExxG73U] (6 min) explains what equipment is needed and how to start plants.

Figure. 1. Stacked light demonstration.

Figure 2 (left): Linear light demonstration requires about 10’ x 2.5’wide.

Supplies List:

* 3 plant stands and height-adjustable T5 lamp fixtures with reflectors
* Control light: 1-T5 grow lamp with broad spectral quality (can be white LED or fluorescent)
* Hi Blue light: 1-T5 LED lamp with high blue and UV-A spectral quality; 1-10% UV-B bulb for desk lamp fixture
* Hi Red light: 1-T5 LED lamp with high red/far-red spectral quality; 1-red/far-red bulb for desk lamp fixture
* 6 black plastic half-flats
* 49 1-in and 300 ¾-in rockwool cubes
* complete, hydroponic fertilizer

* seeds of responsive lettuce and tomato varieties

* **Not provided: power strip, recycled gallon milk jug, two desk lamp fixtures**

Lamp Details:

* Control: Broad-spectrum grow light such as T5 Spectralux 24 W High output or white light LED

* Hi Blue: Grow light high in blue wavelengths with additional UV such as T5 AgroLED 21 W Sunlight Veg+UVA; desk lamp style is ReptiSun 10.0 UVB, which must be supplemented with other light for plant growth

* Hi Red: Grow light high in red and far-red wavelengths such as T5 ActiveGrow 12 W Red Bloom spectrum (Fig. 3); desk lamp style is GE Horticulture BR30 which must be supplemented with other light for adequate plant growth.

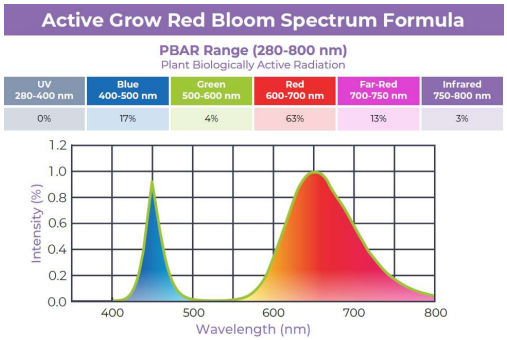

Figure 3. Spectral quality of ActiveGrow Red Bloom spectrum lamp.

Safety Considerations: While there is no reason to expect that the light sources used in this demonstration have any health risks associated with their use, human eyes and skin are damaged by excessive UV light, and especially the high-energy UVB. On the other end of the spectrum, while red light is sometimes used to treat degenerative eye disease, color sensitivity of human sight is accentuated under the red lamps and may result in visual disorientation. Therefore, safety awareness and precautions should be incorporated into teacher and student use of these materials.

OSHA (Occupational Safety and Health Administration) does not have any regulation for UV exposure in the workplace; it references guidelines established by ACGIH (American Conference of Governmental Industrial Hygienists). The ACGIH has established allowable UV threshold limit values for direct ocular and skin exposures to UV radiation and suggests that exposure not exceed 1 mW/cm^2 continuously. To put in perspective, the intensity of the sun on a clear day is ~3 to 5 mW/cm^2. In another comparison, the ReptiSun 10.0 UVB lamp emits 10% UVB radiation. In contrast, only 3.3% of the solar radiation that penetrates the atmosphere is UV, and only 5% of the solar UV energy that reaches the equator is UVB. So this lamp produces considerably higher levels of UVB than naturally occurs outdoors. Therefore, even though this product is used by herpetology hobbyists

in their homes, take care with its use in the classroom.

There are two ways to protect students and teachers from UV exposure: shield the people and/or shield the source lamp. Simple safety steps could/should include: 1) Set up the demonstration in the back or side of the classroom where the lamps won't be in direct line of vision. 2) Turn off the lamps when plants are being watered/fertigated or otherwise observed or handled, then turn them back on after plant evaluation/maintenance. This minimizes skin and eye exposure to the UVB radiation and/or visual disorientation from the red lights. 3) UVB rays do not penetrate glass (or UV-blocked polyethylene), so the UVB lamp could be set up in an aquarium or behind glass or plastic for added eye protection, or even in a back room or closet. 4) The UVB lamp could be placed on a timer to only emit light at night, as a boost to the high blue light treatment.

Plant Details and Sources: www.johnnyseeds.com

* Hydroponic butterhead and leaf lettuce types grow quickly. Use lettuce genotypes that can manufacture anthocyanins to demonstrate differences in red foliage coloration. Cultivar names often include 'red', such as 'Outredgeous', 'Salanova Red Butter', 'New Fire Red', and 'Rouxai'. To compare genotypes, green foliage hydroponic lettuce types, which will not produce anthocyanin under any light qualtiy but will differ in morphology, can include varieties such as 'Rex' and 'Salanova Green Sweetcrisp.'

* Tomato varieties that are used as grafting rootstocks are typically genotypes that will develop intumescence under *limited* UV light; that is, the plants grown with a boost of UV will be normal. A leading example is 'Maxifort.'

Growing Timeline:

Start seeds 10 to 14 days and set under control lighting before you want to begin lessons.

Lettuce: Sow seed, cotyledons emerge 3-4 days later

Tomato: Sow seed, cotyledons emerge 4-6 days later

Seedlings can be set under different treatment lamps at this point, but light quality will affect morphology of small plants (e.g. Fig. 4). If you allow 3 to 4 true leaves to develop before setting them under the light quality treatments, more normal lettuce will result. See Fig. 6 for lettuce size at different times.

Plant Care:

Fertilizer solution can be used for the entire production cycle. A rate of 125 ppm N from a hydroponic fertilizer that contains all macro- and micro- plant essential nutrients works well. For example, 16-4-17 Oasis Hydroponic Fertilizer: 3 g dry fertilizer diluted in 1 gallon is 125 ppm N (Figure

3). Wet up the rockwool with fertilizer and maintain about ¼-inch of fertilizer solution in the bottoms of the half-flats.

Sow one seed per moistened rockwool cube and set under the control lamp. Lower the full-spectrum control lamp fixture to within 8 inches of the germinating seeds so that as they emerge, they will be exposed to maximal light intensity to minimize stretch. Initially, grow all seedlings under the control lamp. This allows plants to have a strong, uniform start before being subjected to the light quality treatments.

Both lettuce and tomato seedlings will grow well with lights on 24 hours per day, though the UVB lamp can be turned on only at night.

If lettuce seedlings are placed under treatment lamps after the first true leaf has emerged, those under the high blue and high red lights will demonstrate differences quickly (Figure 4). You may prefer to allow the seedlings to develop until about the third or fourth true leaf stage under the full-spectrum control lamp, and then place these bulked-up plants under the high blue and red lamps. This will result in growth responses with larger plants that are more recognizable as lettuce.

Tomato seedlings can be placed under treatment lamps after just a couple true leaves have emerged. To ensure no intumescence, the boost of UVB will be necessary early in the growth cycle. To minimize student and teacher exposure specifically to UVB light, a timer could be used to turn this lamp on only at night.

The entire lettuce life cycle can be completed in the rockwool cubes, though the plants in the cubes can alternatively be potted up. The tomato plant gets larger more quickly and may need support beyond the rockwool cube.

Figure 4. Seedlings are started under broad-spectrum control lamps (left). If lettuce seedlings are moved to high blue (middle) and high red (right) lamps just after cotyledon emergence, seedlings show effects quickly.

Light Intensity Matters: In two ways, light intensity will affect the demonstration for your class: 1) enough light energy is needed to fuel rapid photosynthesis/plant growth (Fig. 5), and 2) uniform total

light intensity across spectral treatments results in a fair comparison of growth differences. Set the lamps up within 8-inches of the germinating seedlings to start, and raise as plant height increases needed.

Two lamps will give you more intensity, and thus faster growth, than one. The longer you can leave the lettuce in the system, the more dramatic the differences will be (Fig. 6).

Figure 5. Lettuce seedlings of same age, but grown under the desk lamp GE BR30 (left) vs. the higher-intensity T5 LED lamp Active Grow (right).

Figure 6. Lettuce grown under one lamp (left) and two lamps (right) for three weeks (left) and six weeks (right). Within each group, light quality treatments are high blue (left), control (center), and high red (right).

Your feedback is needed and welcome! Contact Kim Williams at kwilliam@ksu.edu with comments.

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