GREENHOUSE AND INDOOR PRODUCTION OF HORTICULTURAL CROPS

Detecting Crop Light Use from Normalized Difference Vegetation Index (NDVI)

Author: Krishna Nemali

ag.purdue.edu/HLA

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In northern parts of the United States, greenhouse crops usually receive less sunlight than they need during the winter. A lower solar angle, shorter day length, and cloudy days all contribute to the problem (Lopez and Runkle, 2008). For this reason, many growers use supplemental lighting to grow crops during the winter, but these lights substantially increase their operational costs. A commercial grower can spend up to $6,000 per month to provide 5 $mol \cdot m^{-2}$ of supplemental lighting for an acre of greenhouse.

Because supplemental lighting is expensive, it is important for greenhouse growers to ensure that plants are using the supplemental light with maximum efficiency. There are easy-to-use sensors (quantum sensors) that measure light intensity above plants, but there are no sensors to easily measure how much light the plants use.

In this publication, we will describe the importance of measuring plant light use, and then describe a study that offers some promise of helping greenhouse growers find an affordable way to measure plant light use.

Figure 1. This greenhouse uses high-pressure sodium lamps to provide supplemental lighting.

Plants Inefficient at Using Light

First, it's important to understand that plants are not efficient at using light. Under normal conditions, plants reflect 15-20 percent of the light they receive. While high-intensity supplemental lighting can add 100-150 $\mu mol \cdot m^{-2} \cdot s^{-1}$ of light, plants will still reflect 20-30 $\mu mol \cdot m^{-2} \cdot s^{-1}$ of this light and not use it.

Second, when plants experience mild or temporary stresses, they can reflect even more light they receive than normal (Ehleringer and Bjorkman, 1978). Because of intensive cultivation and difficulty with constantly monitoring plants in greenhouses, mild stress conditions during production are common. Some greenhouse growers intentionally expose plants to mild stress to control their growth. In other words, transient stress can further reduce a plant's light use efficiency.

For this reason, we recommend lowering light intensity when plants are not efficiently using light. This helps ensure that plants aren't reflecting away the added (and expensive) light. Currently, there are no simple and affordable ways to monitor how effectively greenhouse plants use supplemental light.

Normalized Difference Vegetation Index Sensors

However, one device may potentially help greenhouse growers detect supplemental light use in plants: a normalized difference vegetation index (NDVI) sensor. Chlorophyll pigment in the leaves (which give the leaves their green color) absorb light. The plant uses the absorbed light in photosynthesis. An NDVI sensor measures light reflection in two wavelengths: red and near-infrared.

Chlorophyll absorbs most of the red wavelength (or least reflectance) and reflects most of the near-infrared wavelength (or peak reflectance). Lower NDVI values suggest that the chlorophyll is absorbing relatively less red light (Aparicio et al., 2000; Asrar et al., 1984). Thus, taking NDVI measurements of plants in greenhouses with supplemental lighting can help identify whether plants are efficiently using that light. An NDVI sensor costs approximately $750 and is connected to a data logging device to continuously measure supplemental light use from a large area at a time (measurement area depends on the height of placement above plants).

Figure 2. A normalized difference vegetation index (NDVI) sensor.

Methods

Our research aimed to test how well NDVI sensors could continuously measure supplemental light use in greenhouse plants exposed to 1,000-watt HPS lamps using petunia plants. We purposefully exposed the plants to transient drought stress during growth, and then observed the changes in NDVI values. We supposed that the transient stress would lower the amount of supplemental light the plants used and result in lower NDVI values. Along with NDVI measurements, we also measured light intensity received by plants (photosynthetic photon flux, PPF) and photosynthesis rate of plants.

Results

Supplemental light provided a nearly constant PPF of 80 $\mu mol \cdot m^{-2} \cdot s^{-1}$ during the 14-hour nighttime period (Figure 3). The DLI or daily light integral (i.e., total light received by plants in a day) was 9.11 $mol \cdot m^{-2} \cdot d^{-1}$ (sunlight: 3.02 $mol \cdot m^{-2} \cdot d^{-1}$ and supplemental light: 6.09 $mol \cdot m^{-2} \cdot d^{-1}$).

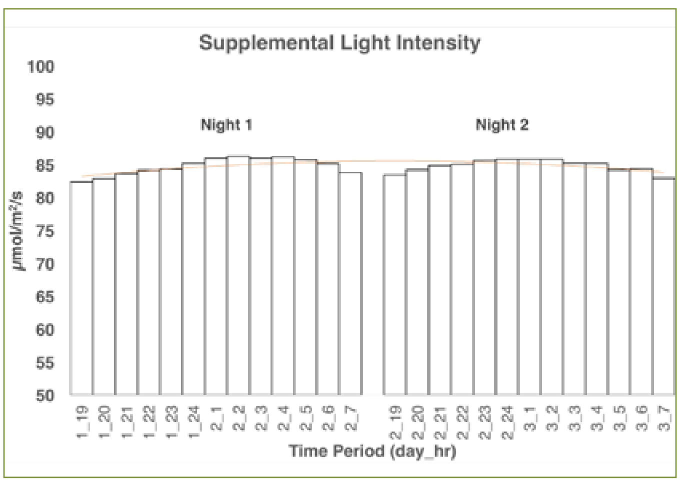

Figure 3. This graph shows the photosynthetic photon flux (PPF) from supplemental lighting at above plants in the greenhouse at night. Note that plants received both sunlight and supplemental light during the day and only supplemental light during the night. Supplemental lighting was nearly constant on both nights.

Plants use the light they absorb in photosynthesis, which produces carbohydrates for growth. When photosynthesis rates are lower, it is logical that plants require less light. Photosynthesis is lower in drought-stressed plants. Thus, drought-stressed plants use less light.

After withholding irrigation, the petunia photosynthesis rate declined during the second night (Figure 4). Because we didn't change the intensity of the supplemental light, the petunia plants likely used less of that supplemental light when their photosynthesis rate started to decline — starting from the second night after withholding irrigation.

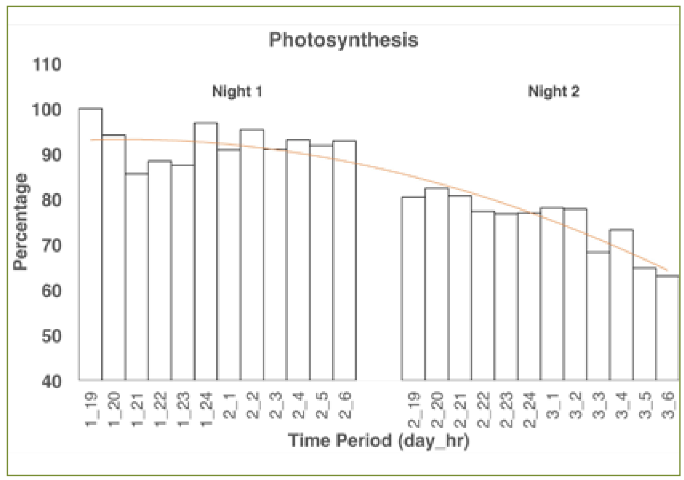

Figure 4. This graph shows percentage change in the leaf photosynthesis rate of petunia plants during two consecutive nights, when plants received supplemental lighting. Note that plants were exposed to drought stress at the start of the experiment, but plants started to experience stress from the second night after withholding irrigation, which is seen as decrease in photosynthesis.

As we hoped, we found that NDVI values were also lower during the second night (Figure 5). The decrease in NDVI values during the second night corresponds to decrease in photosynthesis rate or during the time when plants experienced drought stress and lowered light use. The lower NDVI value during the second night indicates that plant canopy reflected or wasted more of the supplemental light while under drought stress.

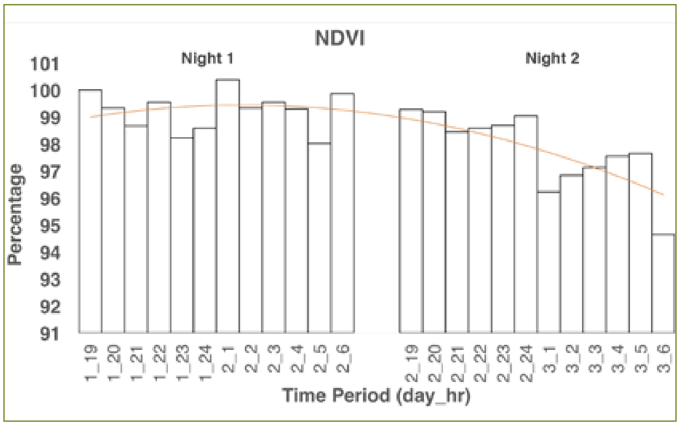

Figure 5. This graph shows percentage change in NDVI of petunia plants during two consecutive nights, when plants received supplemental lighting. Note that plants were exposed to drought stress at the start of the experiment, but plants started to experience stress from the second night after withholding irrigation. The decline in NDVI coincides with the time period when plant light use was low.

The results of our study indicate that NDVI measurements are sensitive enough to detect changes in supplemental light use. By using this sensor, growers can identify when their plants are using light less efficiently, and reduce light intensity. Doing so will likely reduce waste and increase profits.

References

Aparicio, N., D. Villegas, J. Casadesus, J.L. Araus, and C. Royo. 2000. Spectral vegetation indices as nondestructive tools for determining durum wheat yield. Agron. J. 92: 83-91.

Asrar, G., M. Fuchs, E.T. Kanemasu, and J.L. Hatfield. 1984. Estimating absorbed photosynthetic radiation and leaf area index from spectral reflectance in wheat. Agron. J. 76:300-306.

Ehleringer, J.R. and O. Bjorkman. 1978. Pubescence and leaf spectral characteristics in a desert shrub, *Encelia farinosa*. Oecologia. 36: 151-162.

Lopez, G. R. and E.S. Runkle. 2008. Photosynthetic daily light integral during propagation influences rooting and growth of cuttings and subsequent development of new guinea impatiens. HortSci. 43: 2052-2059.

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