The choice of spectrum of LED irradiators affect the life of lighting systems in horticulture

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Abstract. The article presents the results of experimental studies of LED degradation in greenhouse irradiators for horticulture. It was found that in the process of operation of the irradiators the emission spectrum changes. This is caused by different decrease rate of photosynthetic photon flux of different colored LEDs. For a longer service life it is recommended to use greenhouse irradiators with a large proportion of red LEDs.

1 Introduction

Light plays a huge role in vegetable production in greenhouses. The importance of light increases when growing vegetables in plant factories (vertical farms) without access to natural light. The most effective light sources are LEDs, the main advantage of which in horticulture is the ability to form the necessary spectrum of radiation for plants. In recent years, much attention has been paid to the influence of the level of photosynthetic photon flux and emission spectrum of LEDs on plants. In a study [1] it was found that the best lighting option in terms of total mass and beneficial substances for lettuce are LEDs with the ratio of red to blue light R:B=3. A study [2] found that the addition of far red FR light to the blue-red LEDs increased the yield of lettuce. Additional irradiation of green LEDs based on a combination of red and blue LEDs can also improve lettuce growth [3]. The light spectrum has a great influence on the yield and quality of microgreens. In [4], plants treated with light with a ratio of red to blue LEDs of 75/25 or 100% blue light had the highest raw and dry weight. The effectiveness of blue light for microgreens is confirmed in the cultivation of basil [5]. The highest raw and dry mass was obtained with 1R:2B illumination. In [6] the effect of spectrum on growth and photosynthetic characteristics of cherry tomato seedlings was investigated. In general, it was shown that blue-red and red-blue-green spectrum are favorable factors for growth and photosynthesis in cherry tomato seedlings.

It is known that with the first switching on of a light source its degradation begins - reduction of light (in the case of greenhouse irradiators photosynthetic photon flux). The complexity of greenhouse irradiators is the use of LEDs of different spectrum and power to create the most effective light for the plant. Therefore, an important task is to establish

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whether the emission spectrum of horticultural irradiators changes during operation and how this may affect the service life of lighting systems. This is the purpose of this study.

2 Materials and methods

Studies of degradation of LED lighting systems for horticulture during operation were carried out in closed boxes without access to ambient light. The objects of the study were LED irradiators for horticulture DSO-16 (Luch, Russia) and TL-PROM FITO VR 50 (Light Technologies, Russia). The former use SAMSUNG SMD2835 LEDs, the latter use Osram Oslon SSL LEDs. Measurements of photosynthetic photon flux density (PPFD) with spectral separation were performed by spectrophotometer TKA-spectrum (TKA, Russia). The baseline spectrum of illumination systems before the experiment is shown in figure. 1. PPFD measurement intervals were 1000, 2000, 4000, 6000, 8000, 10000 hours of operation.

Fig. 1. Spectrum of the DSO-16 LED illuminator (A) and TL-PROM FITO VR 50 (B) before the experiment.

To determine the service life of light sources, you can use the TM-21 standard "Method for Estimating the Service Life of LED Light Sources by Decreasing Luminous Efficiency". This standard was adopted in 2011. Illuminating Engineering Society (IES). TM-21 is a method for predicting the diminishing light output of LEDs, LED matrices and LED modules, based on data collected in accordance with the LM-80 methodology. It is a method for predicting the lifetime of LED products at real operating temperatures. According to the standard, an approximation curve is built based on the data collected over the last 5 thousand hours of LM-80 testing over 6-10 thousand hours. When collecting data for more than 10 thousand hours, TM-21 uses the other half of the data. Next, exponential least squares approximation is used:

\[
\Phi(t) = B \cdot e^{\alpha \cdot t}
\]  

\(t\) - operating time (h); \(\Phi(t)\) - averaged normalized light output at time \(t\); \(B\) - constant obtained by least-squares approximation of the curve; \(\alpha\) - coefficient of decline of the curve obtained by least-squares approximation of the curve.

Predicted stability interval of light output is determined by the expression:
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3 Results

The study showed that different LED irradiators for horticulture have different degradation rates. In general, the photon flux density under the DSO-16 and TL-PROM FITO VR 50 LED irradiators decreased by 18.3% and 10.6% respectively over 10,000 hours of operation (figure 2). A different degradation rate was obtained for each irradiation spectrum. Under the DSO-16 LED irradiator, blue, green, and red light decreased by 41.4%, 11.5%, and 2.9% (figure 3). Under the TL-PROM FITO VR 50 LED irradiator, blue, red, and far red light decreased by 10.7%, 10.0%, and 4.8%, respectively (figure 4).

\[ L_p = \frac{\ln\left(100 \cdot \frac{B}{p}\right)}{\alpha} \]  

\( L_p \) - is the duration of the stability period of the light output (h); \( p \) - is a given percentage of the initial light output.

Such approximation can be performed for any user-defined value of light output.

Fig. 2. Changes in photosynthetic photon flux density under the DSO-16 (A) and TL-PROM FITO VR 50 (B) LED irradiators during the experiment.
Fig. 3. Changes in photosynthetic photon flux density of different spectra of the DSO-16 LED irradiator during the experiment.

Fig. 4. Changes in the photosynthetic photon flux density of different spectra of the TL-PROM FITO VR 50 LED irradiator during the experiment.

4 Discussion

The study shows that changes in the spectrum of greenhouse irradiators for horticulture during operation are associated with different degradation rate of colored LEDs. At the same time, LEDs of the same range of different manufacturers and models have different degrees of reduction of photosynthetic photon flux (PPF). The difference of PPF reduction between blue LEDs SAMSUNG SMD2835 and Osram Oslon SSL used in different irradiators after 10000 hours was 30%. The difference of PPF reduction between red LEDs of the same manufacturers after 10,000 hours was 7%. This may be due to the different power of the LEDs used, because the degradation rate is greater the greater the current used [7]. At the same time the value of current has less effect on red LEDs than on blue LEDs. It can be seen that the blue-green light decreases and the red light increases during operation. Since red LEDs are energetically more efficient than blue LEDs [8], increasing red light can help reduce energy costs and energy intensity. The difference in the degradation rate of the LEDs has an effect, ultimately, on the lifetime of the lighting systems. Based on the
expressions obtained in the experiment according to the form (1), the irradiator lifetime was calculated according to the form (2). For a given light output of 70% of the initial value, the lifetime of the TL-PROM FITO VR 50 illuminator is 2 times longer (33600 hours) than that of the DSO-16 illuminator (16900 hours).

5 Conclusion

In the process of operation of LED lighting for horticulture, along with a decrease in photosynthetic photon flux, the emission spectrum changes. This is due to the different degradation rates of different colored LEDs. For a longer service life and lower operating costs of lighting in horticulture it is recommended to use greenhouse irradiators with a large proportion of red LEDs. In this case, to minimize changes in the emission spectrum, LEDs should be of the same manufacturer, the same model and unit power.

References

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