Highly Efficient Phytoradiator Development for Plant Photoculture Based on Combined Spectrum

Alexandr E. Kurshev, Sergey D. Bogatyrev, Olga E. Zheleznikova, Lyudmila V. Sinitsyna

Abstract: They presented the results of photobiological studies, the purpose of which was to determine the preferred requirements for the spectrum of phytoradiators in experimental research hydroponic device for plant photoculture based on combined-spectrum light emitting diodes taking into account the specific features of specific crops and growing tasks. They presented the results and the assessment of phytoradiator spectral composition effect based on LEDs and the productivity (biomass) of green culture (Starfighter salad). They showed that the results of photobiological research will create a scientific basis for phytoradiator production organization based on LEDs at OJSC "Ardatovsky Lighting Engineering Plant", the spectral density of the radiation flux of which takes into account the "preferences" of green salad crops as much as possible.

Key words: light crops, phytoradiator with LEDs, spectral composition, irradiance, experimental hydroponic research device, photobiological studies, biomass.

I. INTRODUCTION

The goal of the Long-term Socio-Economic Development Concept of the Agro-Industrial Complex until 2020 adopted in the Russian Federation is to provide the population with high-quality agricultural products and food of Russian production, including vegetables, during the off-season period. This goal achievement is carried out through the Russian vegetable-growing industry competitiveness increase by protected ground [1]. The implementation of this Concept is accompanied by the active construction of new and reconstruction of existing winter greenhouse complexes.

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Despite the rapid development of LED light sources, the irradiators with high-pressure sodium lamps (HPSL) with a phytospectrum are traditionally used in greenhouses and plant factories. The transition to LED lighting will reduce up to 50% of the electricity consumption for the light culture, the cost of which is about 20% of the total cost. Having reached and surpassed the level of irradiators with phyto-HPSL in terms of energy efficiency, LED phytoradiators also surpass them by the possibility of radiation spectral characteristic optimization, taking into account the species characteristics of specific crops and growing tasks. On the basis of LEDs, it is currently possible to create phyto-radiators with the spectrum necessary for a particular culture [2-5].

Photobiological studies carried out in [3, 6] show convincingly that the reaction of plants (their productivity) is non-additively dependent on the spectral composition and irradiation, and the search for universal spectra of effects on the productivity of plants is unpromising. That is, there is no alternative to experimental methods for plant photoculture parameter optimization.

In this regard, FSBEI of HE "MSU named after N.P. Ogarev" together with OJSC "Ardatovsky Lighting Plant" carried out photobiological studies, the purpose of which was to determine the preferred requirements for the spectrum of phytoradiators in an experimental device for plant photo-culture based on combined-spectrum LEDs and cultivation tasks taking into account specific crop peculiarities. As a research object, the group of green vegetable crops was chosen, in particular, Starfighter salad, which is a promising crop for economic cultivation in winter greenhouse complexes.

II. METHODS

During the conduct of photobiological studies, they used the method of lettuce-green plant growing according to the light culture technology, developed by the agrotechnical complex of the State Unitary Enterprise RM "Teplichnoye".

On December 11, 2018, "Starfighter" salad seeds were sown without irradiation. From December 13 to December 23, 2018, the experiments were carried out at 24-hour photoperiod (the irradiance level is 115 - 120 μmol/c·m2). Since December 24, 2018, the photoperiod was 16 hours.

III. MAIN PART

To conduct photobiological studies OJSC “Ardatovsky Lighting Engineering Plant” developed the series of phytoradiators with LEDs in accordance with the requirements of [7]. The emission spectra of phyto-radiators are presented on Figures 1 - 3.

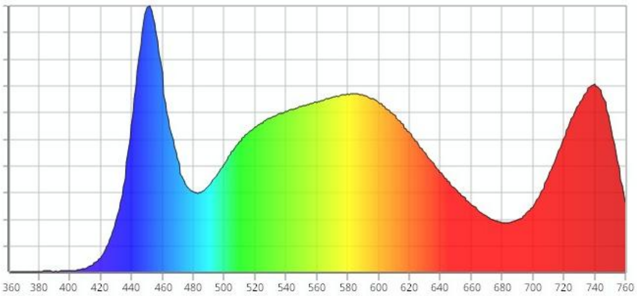

Figure 1. The radiation spectrum of the phytoradiator FO1.

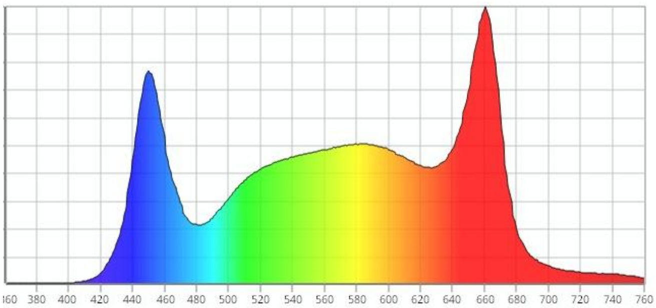

Figure 2. The radiation spectrum of the phytoradiator FO2.

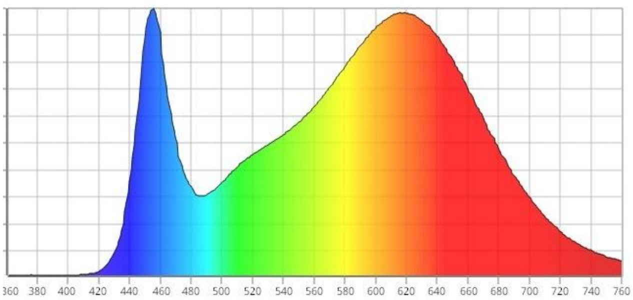

Figure 3. The radiation spectrum of the phytoradiator FO3.

IV. RESULTS AND DISCUSSIONS

The design of phytoradiators involved the installation of four LED modules. Depending on the required spectrum, appropriate types of LEDs were used on each module to create a continuous spectrum and quasimonochromatic sections, for example, in the area of 660 nm, 730 nm.

Each module of the FO1 phytoradiator included the LEDs of FM-P3528WNS-460W-R80 type by NationStar company with the color temperature ($T_{ц}$), equal to 6500 K, and Cherry Red LEDs of FX1 group with the peak wavelength λ = 730 nm by Edison company. FO2 phytoradiator is assembled on the basis of modules with the LEDs of FM-P3528WNS-460W-R80 type with $T_{ц}$ = 6500 K and Deep Red LED’s of EX0 group with the peak wavelength λ = 660 nm by Edison company. FO3 phytoradiator module included FM-CP3030WDS-460W-R80 LEDs with $T_{ц}$ = 4000 K and the LEDs L1SP-PRP1003500000 Purple (12,5 % Blue) by Lumileds company [8-10].

For photobiological studies during the cultivation of lettuce, the experimental research hydroponic device (ERHD) was used, which consisted of 3 tiers. The area of the working zone of each tier was 0.91 m^2. Three phyto-radiators were attached above each tier (Fig. 4).

Figure 4. Experimental hydroponic research device.

ERHD was mounted in the laboratory of artificial climate at FSBEI HE "MSU. named after N.P. Ogarev". The experimental conditions met the requirements of phytotron lettuce growing technology. The air temperature during the day was 22 °C, and 18 °C at night. Watering was carried out every 2 hours for 15 minutes. The salad was grown in pots filled with IZOVOL AGRO Universal substrate. The nutrient solution contained the following mineral fertilizers: KH_2PO_4, K_2SO_4, $MgSO_4$, $Ca(NO_3)_2$, KNO_3, Helftem Fe 13%. The maintained air humidity was 70%.

FO1 phyto-radiators were used to irradiate ERHD upper tier, FO2 - for middle tier, and FO3 for low tier.

Photobiological studies were conducted from December 11, 2018 to January 14, 2019. The results of salad biomass calculation are given in table 1.

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Table 1. Estimation of "Starfighter" salad biomass.

Date	27.12.2018	04.01.2019	09.01.2019	14.01.2019
Phyto-irradiator	Salad weight, g.			
FO1	61,5	94,5	103,5	120,5
FO2	58	114	150,5	214
FO3	83,5	132,5	161	219

The salad on the upper tier under FO1 phyto-radiators has the lowest weight and a very fragile stem. The root system is underdeveloped. The salad on the middle tier under FO2 phyto-radiators turned out with bulky foliage and dense stem. The height of the leaves was 27 cm on average. The root system is moderately developed. The lower tier salad irradiated with FO3 phytoradiators differs from the samples on other tiers by its bulk foliage and dense stem. The average leaf height was 24 cm. The root system is better developed than among other samples.

The nitrate content was determined in the laboratory of SUE RM "Teplichnoye". Nitrates are an intermediate product of photosynthesis, the smaller they are, the more glucose and vitamin C in products, which affects its organoleptic properties. The research results showed that this indicator is below the maximum permissible concentration for all options (2000 mg/kg).

V. SUMMARY

Thus, it should be emphasized that the work on the development and creation of highly efficient phytoradiators of various capacities based on energy-efficient LEDs with an optimum spectrum of phyto-irradiation require continuation, in particular for such vegetable crops as tomatoes and cucumbers during different vegetation periods. When they use such phytoradiators, it is possible to increase the efficiency of light energy absorption by cultivated plants, which will reduce the duration of the growing season before fruiting, increase the productivity of plants, as well as improve the commercial quality of products.

V1. CONCLUSIONS

It was found that the radiation spectrum of FO3 phytoradiator, obtained on the basis of 12 LEDs of FM-CP3030WDS-460W-R80 type, which have a continuous spectrum and $T_ц$ = 4000 K, and 12 LEDs of L1SP-PRP1003500000 Purple type (12.5% Blue) with the quasimonochromatic emission spectrum, turned out to be the most “preferable” for salad growth from three spectral compositions.

The results of photobiological studies create the scientific basis for phytoradiator production organization on the basis of LEDs at the OJSC “Ardatovsky Lighting Engineering Plant”, the spectral density of the radiation flux of which takes into account the “preferences” of salad-green crops. The use of LEDs with the continuous emission spectrum in combination with LEDs that have a quasimonochromatic emission spectrum will affect effectively the photomorphogenetic processes in the plant and achieve the efficiency of more than 3 µmol/joule.

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