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The Efficiency of Automated Control Microprocessor Systems for LED Irradiation Installations

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Abstract. Crop productivity is significantly affected by the dose of optical radiation. In particular, southern crops do not have enough time to ripen in a temperate climate because of decreased daylight duration. In conditions of protected soil due to low irradiance and a short daylight duration in autumn-winter months, the cultivation of fully developed plants is possible only with the use of artificial radiation sources. The use of LED phytoinstallations with the help of microprocessor-based automatic control systems allows obtaining the required dose of optical radiation. (*Purpose research*) To substantiate, as exemplified by meristematic grape plants, the effectiveness of LED phytoinstallations and their impact on the increase in the leaf surface area; to develop multicolored LED phytoinstallations; to offer new technical solutions to improve the efficiency of the microprocessor system of automatic control of LED phytoinstallations. (*Materials and methods*) the authors have carried out experiments with meristematic grape plants of RF-48 variety (in vitro) at the stages of their rooting and adaptation. The following equipment has been used: LED phytoirradiator with a changing spectrum using a microprocessor control system, “blinking” led phytoirradiator, multicolored phytoiradiator with the addition of UV LEDs. The authors have developed on the basis of microcontroller Arduino uno a microprocessor dispensing system of the spectral components of the areas of the photosynthetically active radiation to automatically control the operation of LEDbased phytoinstallations. (*Results and discussion*) it has been shown that a LED irradiator with a changing spectral composition, as compared to a luminescent irradiator, at the stage of rooting of grape microsprouts contributes to a significant increase in the leaf surface area of microplants at 100 percent rooting of sprouts. The blinking phytoirradiator and the UVLED phytoirradiator, as compared to the fluorescent ones, contributed to an insignificant increase in leaf area of plants at the adaptation stage of grape microplants. (*Conclusions*) The authors have confirmed the need to further improve the efficiency of the microprocessorbased automatic control system of LED irradiation installations.
Keywords: LED phytoinstallations, plants in vitro, microprocessor control system, LED strips.

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Crop productivity is significantly affected by the dose of optical radiation. For example, southern crops fail to mature in a temperate climate because of decreased daylight duration and the sun's height angle.

The use of multi-colored LEDs, or RGB-LEDs, allows modelling the spectrum of any geographical area, and the use of microprocessor-based automatic control systems for the operation of these units allows the required dose of optical radiation to be applied. A part of the optical range actively used by plants is called photosynthetically active radiation (PAR). The PAR has a special significance in conditions of protected soil, where, due to low irradiance and a short daylight duration in autumn-winter months, the cultivation of full-fledged plants is possible only with the use of artificial radiation sources. Properly controlling of LED phytoinstallations with the help of microprocessor-based automatic control systems allows obtaining the required dose of the spectral component of the phased zone.

Of particular importance is LED lighting for plants, in vitro, the nutrition of which is not completely autotrophic. Meristem plants are grown this way. Meristem is a plant tissue that is able to intensively divide cells [1-5]. Clonal micropropagation of plants has become one of the modern forms of improving nursery farming. This method allows not only to ensure a high multiplication factor, but also to deliver the planting material from pests and a number of pathogens. Traditionally, work aimed at increasing the efficiency of microclonal propagation of plants is reduced to optimizing the composition of the nutrient medium and the cultivation conditions. However, stimulation of morphophysiological processes in plants is possible by using phytoregulatory methods [1, 2].

Numerous studies indicate a positive effect of LED lighting on farm crops.

A feature of LED-based irradiators is that the spectral composition of their light fluxes corresponds most closely to PAR [6-9]. The urgency of the work is due to the need to improve the methods of clonal micropropagation of plants and the development of energy-saving technologies for their cultivation.

Research purpose is to increase the efficiency of the microprocessor control system for the operation of various LED irradiation facilities and to study their effect on the growth of the leaf surface of meristem grape plants.

To achieve this goal, the following tasks were formulated:

- to develop various multi-colored LED phytoinstallations;
- to conduct experiments on meristem grape plants;
- to offer new technical solutions for increasing the efficiency of a microprocessor-based automatic control system for the operation of LED-phytoinstallations.

Materials and methods. The experiments were carried out in a meristem laboratory of Udmurt Research Institute for Agriculture. Cultivated in vitro grape plants of grade RF-48 during the stages of rooting and adaptation were used for the research (Fig. 1).

Fig. 1. General view of meristem plants of grape culture

Rooting of microplants in vitro was carried out in a light-room of the laboratory on a nutrient medium according to Murasige-Skog's formulation with the addition of indolyl-butyric acid (IMC) at a dose of 0.5 mg/l with a daytime duration of 16 hours and an air temperature of 23-25 °C. Adaptation of meristem plants was carried out under the same conditions in 0.5 liter containers with peat-based ground.

For irradiation, use was made of:

- LED phytoirradiator with a changing spectrum operated with a microprocessor control system (Fig. 2);

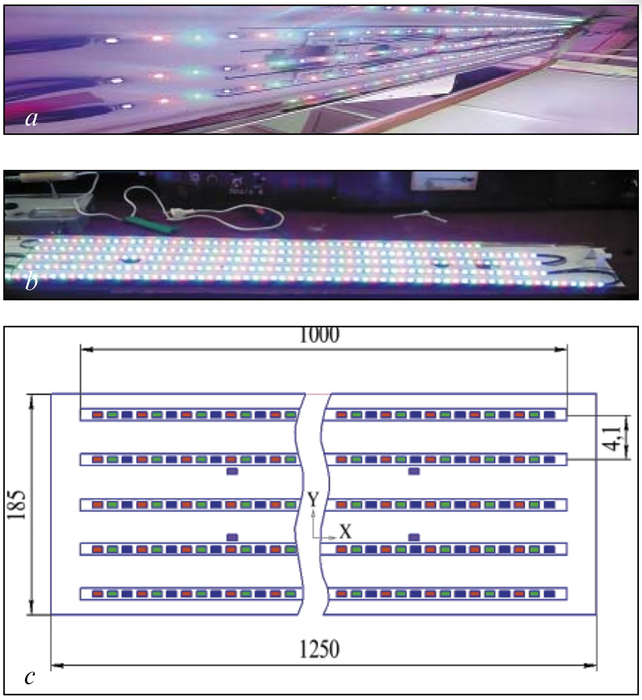


Fig. 2. LED-phyto-installation: a, b – general view; c – scheme with UV LEDs and its dimensions, mm

- "blinking" LED phytoirradiator, which shone for 0.5 s, then there was a dark pause of 1.0 s; this blinking lasted for 30 seconds and was followed by continuous irradiation for 15 seconds;
- a multi-colored phytoirradiator with the addition of UV-LEDs (Fig. 2);
- control-luminescent irradiator with an LB lamp.

Parameters of LED-phytoirradiators are given in the table.

Table

Technical characteristics of LED-phyto-radiator

Parameters	LED-phyto-radiator	LPO 2×18 (control)
Operating voltage, V	12,4	220
Power consumption, W	29,76	36
Illumination, lx	2200	1400

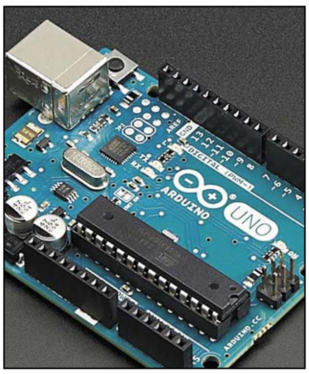


Fig. 3. Arduino Uno Board

For the automatic control of the operation of the LED phytoirradiator on the basis of the Arduino Uno microcontroller, a microprocessor system for dispensing the spectral components of the FAP zone has been developed (Fig. 3).

The principle of the automatic control system for the operation of LED phytoirradiators is described in the following reference sources [11-16].

The control program provides keys for adding cultivated crops, as well as takes into account the conditions for their cultivation.

In each variant of the experiment, 10 meristem plants were used. The area of the leaf surface was evaluated every 5 days after the beginning of irradiation. The root system of microplants was evaluated at the end of the stage by the prescribed methods (OST 10069 95).

The stage of rooting grape microsprouts was 25 days, the adaptation stage lasted for 20 days. The works on microclonal propagation were carried out according to "Technology of production of virus-free planting stock of fruit, berry crops and grapes".

The rooting stage completes the process of plant cultivation in vitro. By the end of the stage, the quality of the leaf device and the root system of the microplants can be evaluated. To successfully transfer from sterile conditions to non-sterile ones (adaptation), the imbalance between a sprout and its root system is unacceptable.

Results and discussion. The LED irradiator with a changing spectrum had a positive effect both on the area of the leaf surface of the grape microplants and root system (Fig. 4). The greatest effect was obtained on the sheet device of grape microplants. As compared to the traditional luminescent irradiator, a noticeable but insignificant increase in the leaf surface area (14.0 mm^2) was noted already on the fifth day of the rooting stage. Starting from the 10-day period and until the end of the rooting stage, this gain is statistically reliable and amounts to 39.7 mm^2, 48.9 mm^2, 61.3 mm^2, 82.9 mm^2, respectively.

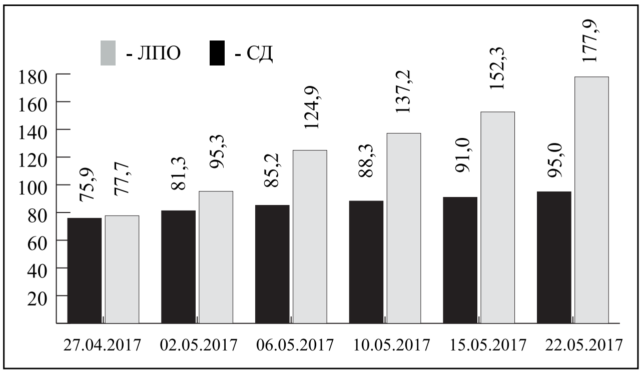


Fig. 4. The impact of lighting on the growth dynamics of leaf area of grape culture micro plants, mm^2

Rooting of grape microsprouts by the end of the stage accounted for 100% regardless of the lighting. But microplants exposed to the action of the LED irradiator featured a more developed root system. All grape microplants corresponded to OST 10 068-95 at the end of the rooting stage.

The transfer of plants from sterile to non-sterile cultivation conditions is the most critical stage of clonal micropropagation. Factors influencing the viability of microplants during the adaptation period include: the substrate type, air humidity, lighting, infectious load and others. It is at this stage that you can lose a huge amount of already propagated material.

Adapted meristem plants are planted to grow into the open ground of a nursery. A well-developed leaf system not only allows plants to take roots well, but also assists in obtaining a standard planting material by the end of the season.

According to the results of the first two five-day stages of adaptation, the irradiation of grape meristem plants with LED installations, as compared to the luminescent irradiator, did not have a significant positive effect: the leaf surface area did not increase, remaining at the level of the control values (Fig. 5).

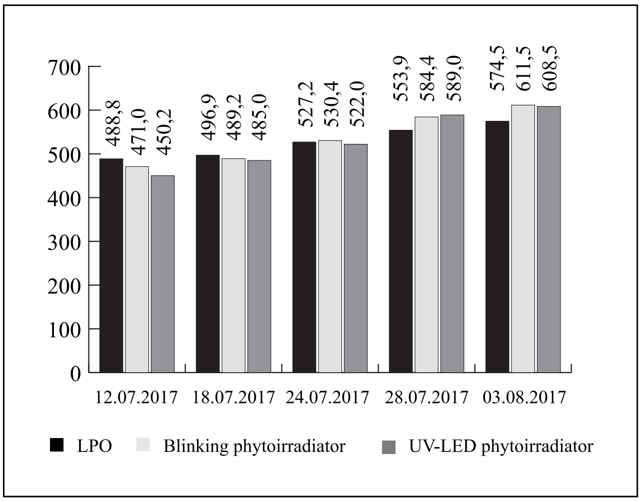


Fig. 5. The impact of lighting on the growth dynamics of leaf area of adapted grape culture micro plants, mm^2

According to measurements on the 15th and 20th days of adaptation, both LED installations, as compared to the control ones, insignificantly contributed to an increase in the grape leave area. By the end of the stage, 100% of the grape plants corresponded to OST 10 069-95.

To obtain an accurate PAR dose, it is necessary to add spectrum analyzers to the microprocessor-based automatic control system, by means of which it is possible to analyze and change the spectrum of LED-

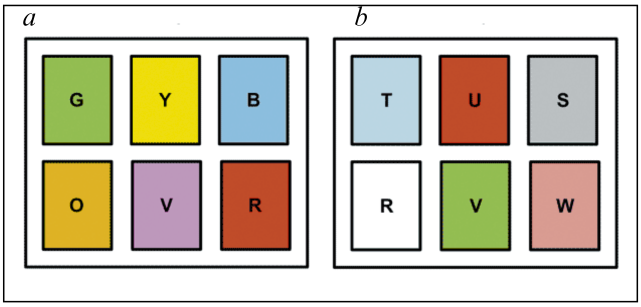
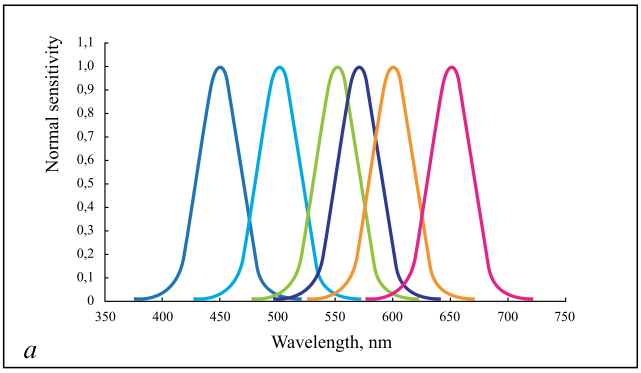


Fig. 6. Photodiode spectrum analyzers assembly: a – AS7262; b – AS7263



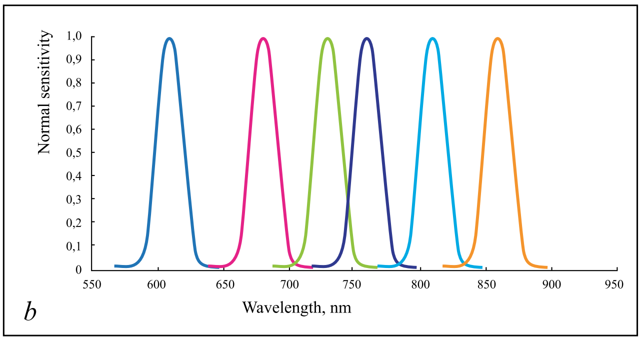


Fig. 7. The spectral sensitivity of the analyzers:
a – AS7262; b – AS7263

phytoinstallations in real time.

To solve this problem, information was found on 6-channel integrated spectrum analyzers AS7262 and AS7263. The AS7262 chip is designed to work with the visible part of the spectrum (450-650 *nm*), and AS7263 – with the infrared range (610-860 *nm*).

The key element of the AS7262 and AS7263 is photodiode assemblies (Fig. 6). In both cases they are matrices of six photodiodes with a narrow sensitivity spectrum.

The AS7262 spectrum analyzer chip is designed to work with the visible part of light (Fig. 7). Its photodiodes have a selective sensitivity of 450/500/550/570/600/650 *nm* with a spectral width of 40 *nm*. Apparently, their peak frequencies are spaced at 50 nm (with the exception of 570 *nm* orange color). The AS7263 is designed for analyzing the near-infrared range. Its photodiodes operate at frequencies of 610/680/730/760/810/860 *nm* with a sensitivity spectrum width of 20 *nm*. To develop a microprocessor system for automatic control of an LED phytoinstallation, a block diagram was developed (Fig. 8).

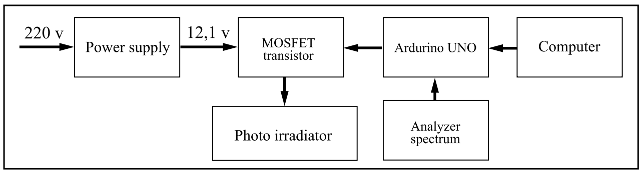


Fig. 8. The block diagram of the LED-phyto-installation control

Conclusions

1. The LED irradiator with a changing spectral composition, as compared to the luminescent irradiator, at the rooting stage of grape microsprouts contributes to a significant increase in the leaf surface area of the microplants, with their rooting being equal 100%.

2. Flashing phytoemitter and phytoembrant with UV-LEDs, as compared to luminescent ones, at the stage of adaptation of grape microplants contributed to an increase in the leaf surface area of plants, but insignificantly and only from the second half of the stage.

3. Positive results of the experiments confirmed the need to further enhance the efficiency of the microprocessor-based automatic control system for the operation of LED irradiators.

REFERENCE

1. Pronina I.N., Matushkina O.V. Economic aspects of the use of clonal micropropagation in the production system of planting material of fruit and berry crops // *Fruit growing and gourd cultivation of Russia*. 2011; 26: 82-88.

2. Markova M.G., Somova E.N. Techniques to increase the rooting microgrooves of wild strawberry in the ground NVITRO // Bulletin of the Mari State University. Series: *Agricultural sciences. Economic sciences*. 2017; 2 (10): 34-39.

3. Tertyshnaya Yu.V. Levina N.S. Vliyaniye spektral'nogo sostava sveta na razvitiye sel'skokhozyaystvennykh kul'tur [Influence of spectral composition of light on development of agricultural crops] // *Sel'skokhozyaystvennyye mashiny i tekhnologii*. 2016. N5: 24-29.

4. Tertyshnaya Yu.V. Levina N.S., Yelizarova O.V. Vozdeystviye ul'trafioletovogo izlucheniya na vskhozhest' i rostovyye protsessy semyan pshenitsy [Influence of ultraviolet radiation on the germination and growth processes of wheat seeds] // *Sel'skokhozyaystvennyye mashiny i tekhnologii*. 2017. N2: 31-36.

5. Martirosyan Yu.Ts., Polyakova M.N., Dilovarova T.A., Kosobryukhov A.A. Fotosintez i produktivnost' rasteniy kartofelya v usloviyakh razlichnogo spektral'nogo oblucheniya [Photosynthesis and the potato productivity under different spectral irradiation] // *Sel'skokhozyaystvennaya biologiya*. 2013. N1: 107-112.

6. Bolshin R.G., Ilyasov I.R., Kondratieva N.P., Korepanov R.I, Krasnolutskaya M.G., Litvinova V.M., Filatova O.M. Development of a microprocessor dosing system for photosynthetically active radiation // Bulletin of the NNIII. 2017; 9: 46-56.

7. Kondratieva N.P., Bolshin R.G., Krasnolutskaya M.G. Energy-efficient energy-saving LED irradiators // *Vestnik VIESH*. 2016; 3 (24): 48-53.

8. Il'yasov IR Increase in the effectiveness of dosing of PHAs (photosynthetically active radiation) / Ilyasov IR. // Scientific works of the students of the Izhevsk State Agricultural Academy of the Federal State Educational Establishment of the Russian Federation «Izhevsk State Agricultural

Academy». Izhevsk, 2017: 212-213.

9. Kondrat'yeva N.T., Vladykin I.R., Baranova I.A., Bol'shin R.G. Krasnolutskaya M.G., Energosberegayushchiye elektrotekhnologii i elektrooborudovaniye v sel'skom khozyaystve [Energy-saving electrotechnologies and electrical equipment in agriculture] // *Innovatsii v sel'skom khozyaystve*. 2016. N4(19): 11-16.

10. Somova E.N., Kondratieva N.P., Bolshin R.G., Krasnolutskaya M.G., Korepanov R.I., Ilyasov I.R., Litvinova V.M. Results of experiments on dosing photosynthetically active radiation by a microprocessor system controlling the operation of LED phyto-plants // *Vestnik VIESH*. 2017; 3 (28): 56-64.

11. Ilyasov I.R. Development of software for the implementation of the irradiation regime // In the collection: Scientific works of students of the Izhevsk State Agricultural Academy. The electronic resource. Izhevsk State Agricultural Academy. Izhevsk, 2017: 490-494.

12. Me Cree H.J., Joomis R.S. Photosynthsis in fluctuaning light // Ecology. 1969; 3: 50.

13. Murashige T. Plant tissue an cell culture application to crop improvement. Prauge: Czechosl. Acad. Sci., 1984: 23-32.

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