The influence of LED lighting on the development of *Monarda* L. in the conditions of hydroponics

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Abstract. The article presents the results of a study of the significance of the influence of the white and combined (red-blue-white) light spectrum on the growth and productivity of plants of the genus *Monarda* L. in the conditions of hydroponics. The optimal lighting mode has been found for the highest productivity of the monarda. A quantitative analysis of the content of photosynthetic pigments was carried out. The yield, leaf size and content of photosynthetic pigments in monarda leaves when grown under white LED lamps turned out to be higher than under colored ones.

1 Introduction

Monarda (*Monarda* L.) is a unique plant of the *Lamiaceae* family. *Monarda dydima* L. and *Monarda citriodora* L. belong to spicy-aromatic and medicinal crops and they are widely used in ornamental gardening, vegetable growing and medicine. In the food industry, monarda essential oil is used as an antiseptic and natural flavor in the production of beverages and cheeses [1]. This plant is a valuable source of biologically active substances: essential oil, bioflavonoids [2], water-soluble antioxidants [3], chlorophylls, carotenoids. Extracts and essential oil of monarda have bactericidal, antioxidant, anti-inflammatory, sedative effects, they are used to prevent acute respiratory infections, strengthen immunity, atherosclerosis and anemia [3-4]. The development of new medicinal drugs based on them is a promising area of scientific research [5].

In the wild, representatives of the genus *Monarda* (12–20 species) grow in North America, the range is from Mexico to Canada [6], they do not occur on the territory of Russia. It is cultivated in the Crimea and the Caucasus, in the Moscow region, Bashkortostan [3-4].

Due to the prospects of culture and the need for comprehensive research of introduction and biochemistry of the plant raw materials, it is important to develop modern agrobiotechnological methods of the plants growing that allow obtaining high-quality planting material and medicinal raw materials.

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The aim of the research is to study the effect of LED lighting spectra on the development of various monarda species and varieties when grown by the hydroponic method.

2 Materials and methods

The objects of the study were samples of *Monarda didyma* and *Monarda citriodora*.

Monarda citriodora of Diana variety is an annual ornamental and medicinal plant with a lemon aroma, up to 80 cm high. It is distinguished by lanceolate leaves. Due to strong branching, it forms bushes up to 45 cm in diameter. Flower-bearing shoots end with 5–7 whorls of bilabiate purple flowers. Flowering is abundant and long-lasting.

Monarda didyma of Zhar-ptitsa (Firebird) variety is a perennial plant, up to 100 cm tall. The leaves are oval, and pointed at the tip. The flowers are red, small, in head-shaped inflorescences, up to 4 cm in diameter. The duration of flowering in the open ground is about two months [6].

The plants were grown on a hydroponic installation, in pots with a diameter of 6 cm with holes, expanded clay was used as a substrate. The plants were fed with a nutrient solution supplied to the root growth zone with ebb and flow method. "Yara Ferticare Hydro" complex fertilizer and "Yara Liva Calcinit" were used for the hydroponic system. The nutrient solution was supplied 5 times a day for 15 minutes [7-8]. Optimal cultivation conditions were maintained: pH of the nutrient solution 5.5–6.5, electrical conductivity 1.6–2.0 mS/cm, solution temperature +22°C, indoor air temperature +20–24°C, humidity – 50–60 %. Lighting with phytolamps was carried out in two modes: combined (color) – LED light with red, blue and white diodes (32:16:32), luminous flux 6573 lm, PPF 143 μmol/s/m2, dominant for blue lamps 470 nm, dominant for red lamps 625 nm; white – LED light with white diodes, luminous flux 8000 lm, color temperature 4000 K, PPF 165 μmol/s/m2. The plants were grown under a 16-hour light regime [9-11].

Biometric measurements of plants were carried out every 7 days. The height of the shoot, the number of leaves, the length and width of the leaf were measured, the mass of plants was determined and the crop yield was calculated according to the B. A. Dospekhov method [12]. The plants were grown for 126 days before the flowering phase, 3 biomass cuts were carried out with an interval of 28–30 days [13]. The amount of photosynthetic pigments in plant leaves was determined using a PE-5400V spectrophotometer. The concentration of chlorophylls *a* and *b* was calculated using the Wintermans and de Mots equations [14]. Statistical processing was carried out using MS Excel.

3 Results and Discussion

Lighting is an important parameter for growing plants by hydroponics. It is well known that the productivity and yield of plants largely depend on the spectral composition of light [13]. At the Department of Biology and Biotechnology of Surgut State University, *Monarda didyma* and *Monarda citriodora* were grown on multi-level hydroponic farming system in order to assess the effect of LED lighting on biometric indicators, yield and quality of perspective medicinal crops. The dynamics of plant growth had been surveyed throughout the entire growing cycle under white and colored lamps. In the course of the survey, it was found that, depending on the type of LED lighting, the height of *Monarda didyma* Firebird variety varies from 23.3 to 35.43 cm, *Monarda citriodora* Diana variety varies from 23.6 to 37.5 cm (Figure 1). The maximum height of the hydroponically grown plants is observed under colored lamps in the first cut (35.4 cm) for Firebird variety and under white lamps in

the third cut (37.5 cm) for Diana variety. It is found that the height of plants is due to the varietal characteristics of the culture.

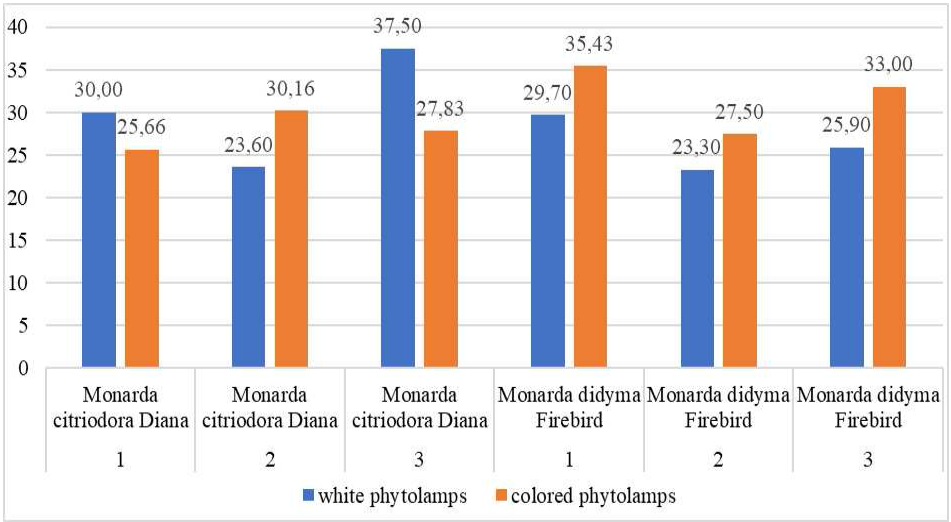

Fig. 1. Height of plants depending on the type of lighting (in dynamics of 1, 2, 3 cut), cm.

Regardless of the type of light, *Monarda citriodora* showed intensive leaf formation under white (419.33±27.44) and colored (467.33±28.51) LEDs (Figure 2). *Monarda didyma* had significantly fewer leaves – 78.57±11.95 and 52.87±9.39 pcs. per plant respectively. It was revealed that under optimal cultivation conditions in the ebb and flow system Diana variety of *Monarda citriodora* increases the productive phytomass with each subsequent cutting (due to the formation of lateral shoots during early cutting of plants), which makes this variety attractive for commercial cultivation. Such a biological feature of *Monarda citriodora* grown in various hydroponic systems has also been registered for other varieties [13].

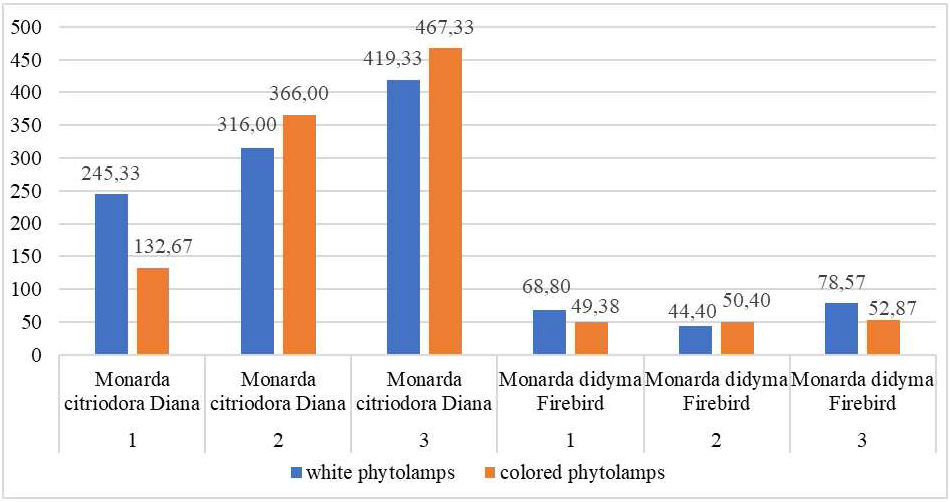

Fig. 2. Leaves quantity depending on the plant species and the type of lighting (in dynamics of 1, 2, 3 cut), pcs. per plant.

The average leaf length for 3 cycles of *Monarda citriodora* and *Monarda didyma* under white LEDs is 6.39 and 6.10 cm and under colored LEDs is 5.22 and 5.99 cm respectively. In general, the length of the leaves varies depending on the specific features of the plants, the type of lighting and the quantity of cuts (Figure 3).

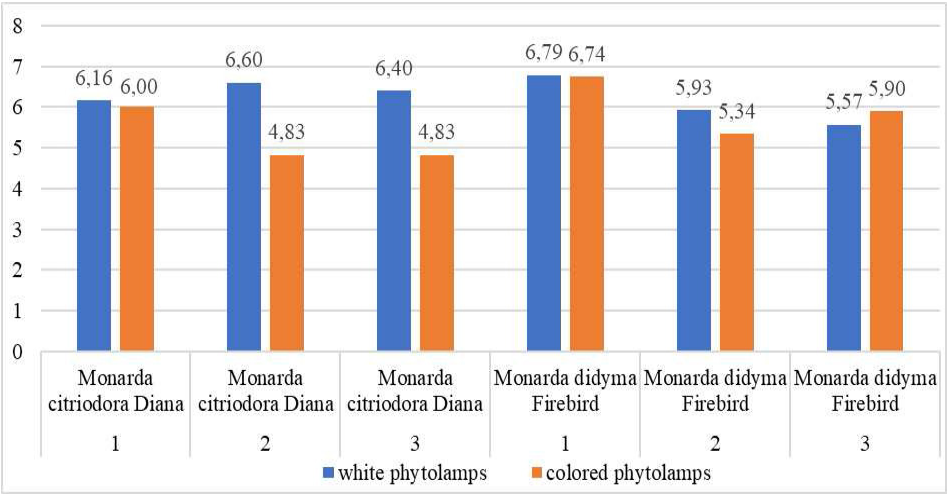

Fig. 3. The average length of leaves in different lighting conditions (in dynamics of 1, 2, 3 cut), cm.

The width of the leaves, as opposed to the length, depends on the type of lighting (Figure 4). The width of the leaves of *Monarda didyma* under different types of light is the maximum in the first cut: under white LEDs – 6.2 cm, under colored LEDs – 4.78 cm. The width of the leaves of *Monarda citriodora* is 2.53 cm under white LEDs in the third cut and 2.03 cm under colored LEDs in the first cut. The difference of these indices is due to the specific features of each culture. For both species white LED lighting is more favorable for the leaves width. The obtained data do not contradict the literature on the influence of white, blue and red spectra on the increase in the leaf surface area [8, 15, 16].

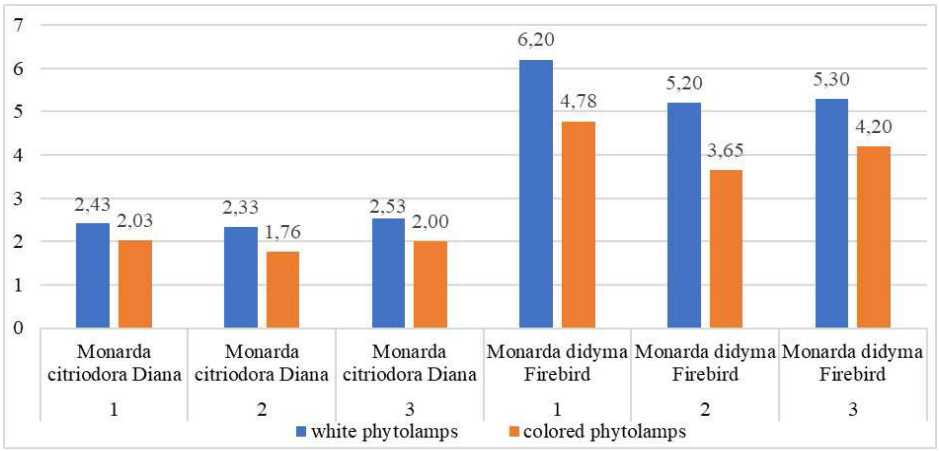

Fig. 4. Width of monarda leaves depending on the type of lighting (in dynamics of 1, 2, 3 cut), cm.

In the regions of culture field cultivation (Moscow, Leningrad region) monarda enters the generative stage of development at the mid-July – August (when sowed in the first

decade of March) [13]. In our experiment in hydroponic conditions, 3 cuttings of biomass were carried out with an interval of 28–30 days, starting from day 56, which could affect the timing of flowering. Diana variety of *Monarda citriodora* cultivated under white LEDs enters the flowering phase 126 days after sowing and after 147 days under colored LEDs; Firebird variety of *Monarda didyma* under white LEDs enters the flowering phase on day 148 and on day 151 under colored LEDs (Figure 5). The flowering phase of *Monarda citriodora* under white LEDs occurs 21 days earlier than under colored LEDs, which must be taken into account when growing plants in artificial light conditions. Despite the cuttings of green mass, the flowering phase onset is comparable to open ground, which means that the hydroponic method of cultivation can be used to obtain planting material and medicinal plant materials in the adverse climatic conditions of the North.

a) b)

Fig. 5. Monarda blooming under white (a) and colored (b) LEDs.

Yield and productivity are important indicators of the effectiveness of the used culture cultivation technology. It was found that in hydroponic systems the productivity of monarda depends on the specific features of the crop and number of cuts, as well as on the type of light (Table 1). At the first development stages of *Monarda citriodora* the differences in plant mass under different types of light are insignificant, but during their further growth the advantage of plants under white LEDs increases up to 2.7 times compared to colored one. The average weight of *Monarda didyma* plants under white LEDs was significantly higher than the values obtained under colored LEDs at 1 and 3 cuts.

Table 1. Monarda productivity indicators depending on the type of light.

Culture, variety	Cut number	Average weight of 1 plant, g		Average weight in a pot, g	
		white	colored	white	colored
Monarda citriodora, Diana	1	18.60±0.9	18.70±0.7	37.20±0.9	37.40±1.9
	2	21.80±2.9	18.03±3.7	32.70±1.6	27.05±0.6
	3	39.03±2.9	14.43±2.4	58.55±3.9	21.65±3.6
	average	26.48	17.05	42.82	28.70
Monarda didyma, Firebird	1	17.58±2.5	10.69±1.8	35.15±3.3	21.38±3.7
	2	10.38±1.7	10.98±0.9	19.27±3.5	19.21±2.1
	3	11.96±2.1	8.41±1.6	20.94±3.6	15.78±2.9
	average	13.31	10.03	25.12	18.79

The average yield of Firebird variety of *Monarda didyma* under the white phytolamps is 2.4 kg/m^2 and the average yield of Diana variety of *Monarda citriodora* is 4.08 kg/m^2

(Figure 6); the yield under colored phytolamps is 1.79 and 2.74 kg/m^2, respectively. The highest yield of Firebird variety of *Monarda didyma* under different lights was registered in the first cut (3.35 kg/m^2); there is a decrease of 1.5–2 times with subsequent cuts. Early cutting of *Monarda citriodora* promotes branching and the formation of new shoots on plants; the process is especially active under white LEDs. Thus, the yield of *Monarda citriodora* increases to 5.59 kg/m^2 by the 3rd cut, which is 1.5 times more than that at the 1st cut. Due to the biological features Monarda can be cut off on average every 28–30 days during the year as its vegetative mass increases.

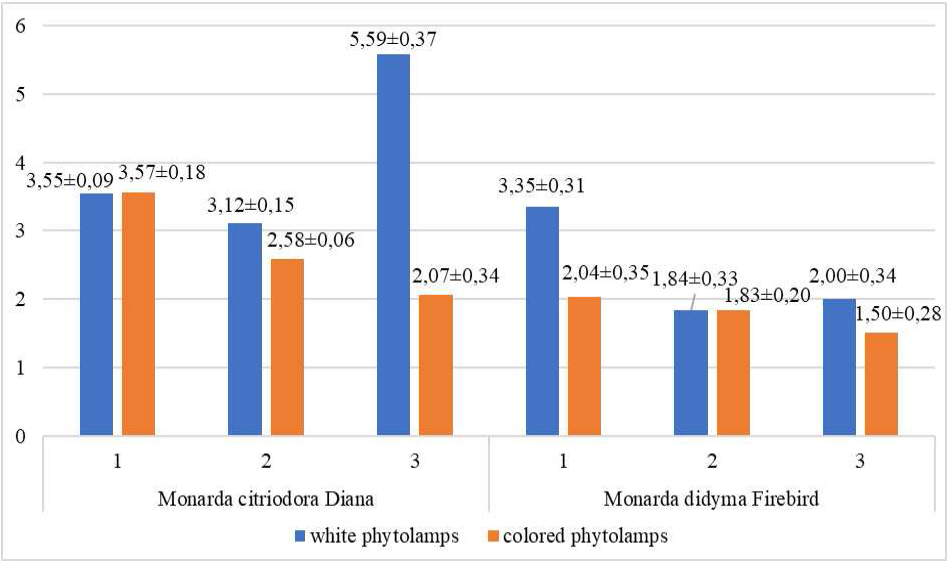

Fig. 6. Monarda yield depending on the type of lighting (in dynamics of 1, 2, 3 cutting), kg/m^2.

According to L. V. Bespalko [13] a yield of 1.2–2.5 kg/m^2 per month was achieved during hydroponic cultivation of *Monarda citriodora* in a mineral wool substrate. According to the literature, in field conditions the yield of the aboveground mass of monarda, depending on the species, in the territory of the Crimea and the Republic of Adygea, ranges from 0.4–2 kg/m^2, and is up to 2.2 kg/m^2 in the North-West of Russia. On the territory of Moldova, the yield of the aboveground mass is slightly lower and is in the range of 1.36–1.86 kg/m^2 [5].

The content of photosynthetic pigments in monarda leaves was different depending on the type of lights (Table 2). The average values of chlorophylls *a* (1.84±0.12, 1.95±0.12) and *b* (2.07±0.11, 2.05±0.07) under white LEDs in all surveyed varieties are higher than those of chlorophylls *a* (1.83±0.08, 1.82±0.07) and *b* (1.86±0.08, 1.81±0.07) under colored LEDs.

The effect of colored light with red, blue and white diodes in a ratio of 32:16:32 caused a decrease in the amount of chlorophyll in particular due to chlorophyll *b* decrease, in comparison with illumination with white LEDs (Table 2). This could be conditioned by the greater need for pigments in photosystems in conditions of an excess of absorbed light energy under white LEDs.

Table 2. The content of photosynthetic pigments in monarda leaves depending on the light spectrum, mg/g of dry biomass.

Culture, variety	White phytolamps			Colored phytolamps		
	Chlorophyll *a*	Chlorophyll *b*	*a*+*b*	Chlorophyll *a*	Chlorophyll *b*	*a*+*b*
Monarda didyma, Firebird	1.84±0.12	2.07±0.11	3.91±0.23	1.83±0.08	1.86±0.08	3.69±0.16
Monarda citriodora, Diana	1.95±0.12	2.05±0.07	4.00±0.19	1.82±0.07	1.81±0.07	3.63±0.14

According to V. I. Malarovskaya [16], in unfavorable light conditions plants compensate for the lack of one parameter with another one. At poor light intensities poor photosynthesis is partially compensated by increased leaf growth, while at rich light intensities a smaller leaf surface can be compensated by increased synthesis of photosynthetic pigments.

4 Conclusion

Monarda varieties (Firebird and Diana) cultivated in ebb and flow hydroponic systems are promising for commercial cultivation. High biometric indicators of plants (leaf size, yield) in multi-level hydroponic farms are observed under white phytolamps. In optimal cultivation conditions (temperature +24°C, air humidity 60 %, the nutrient solution pH 5.8–6.3), monarda forms a productive ready-for-sale phytomass every 28–30 days. The studied varieties easily tolerate early cuts, and therefore (according to preliminary data), at least three cuts can be carried out during a year. Long-term cultivation of plants (126–150 days) in hydroponics leads to monarda flowering, strong roots overgrowth, stem lignification, large number of adventitious roots over the entire surface of the stem, which leads to compaction of planting, stretching of shoots, leaf fall and contamination of the hydroponic system. However, it is obvious that the technology of growing monarda in multi-level hydroponic farms under controlled conditions has significant advantages over field growing in such indicators as productivity, yield and quality of finished products. The method of hydroponic monarda cultivation is recommended for wide use for practical vegetable growing and cityfarming (to expand the range of valuable food crops), pharmacological production (continuous production of medicinal raw materials).

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