Influence of LED lighting power on basil (Ocimum basilicum L.)

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Abstract. The article examines the response of four varieties of basil to the power of lighting with LED lamps. Basil cultivars reacted poorly to the increase in lighting power at different stages of development, with the exception of Emily, which showed a positive reaction. The Ararat cultivar formed compact plants with a wide habitus and the largest average weight of 4.11 g at an illumination power of 110 μmol / m² / s. The Yerevan sapphire variety formed compact plants with a wide habit and the largest average weight of 4.89 g at an illumination power of 170 μmol / m² / s. Variety Emily formed compact plants with a wide habit and the largest average weight of 5.44 g at an illumination power of 140 μmol / m² / s. The Marian cultivar formed compact plants with a wide habit and the highest average weight of 11.50 g at an illumination power of 140 μmol / m² / s.

1. Introduction

Now, the cultivation of vegetable crops in closed systems is actively developing. A closed cultivation system is a facility designed for the year-round production of vegetables, vegetable seedlings and ornamental crops on vertical farms in controlled artificial conditions. Closed growing systems include plant factories with artificial lighting, for which, at present, generally accepted technologies for growing individual crops are being formed, in view of their biological characteristics and specific attitude to abiotic environmental factors [1-8].

Basil (Ocimum basilicum L.) is an annual plant from the Lamiaceae family with a branched stem 20 to 60 cm high, leaves are ovoid, small and large. Basil is a heat-loving plant, the seeds germinate at a temperature of 28-300 ⁰C, and shoots appear on the 6-7th day. The optimum air humidity is 60-70% [4].

The study [1] points to the fact that 5 to 20% of blue light in the total photosynthetic photon flux is necessary for normal growth and development, as well as minimizing the response to shading (elongation of internodes, decreased chlorophyll production and early flowering) under controlled conditions. With an increase in the irradiation power, the biomass of basil plants increases, but in different varieties the maximum yield was achieved at different values of the irradiation power, possibly due to different degrees of light saturation of growth processes and photosynthesis in each variety [5]. At low illumination power, the Sweet Genovese basil variety formed compact plants with low weight, smaller leaf area, fewer shoots, higher specific leaf area, and low photosynthesis rate [9-10]. Basil has many varieties, each with its own flavor: aniseed, clove, caramel, lemon and pepper. There are large-leaved and small-leaved varieties, as well as with green and purple pigmentation. In our study, the following varieties were grown [9]:

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Marian is early maturing. The period from full shoots to the beginning of the economic shelf life is 40-45 days. Plant of medium height, erect, dense, green leaf. Originator(s): ENZA ZADEN BEHEER B.V.

Emily is early maturing. The period from full shoots to the beginning of the economic shelf life is 40-45 days. Plant of medium height, erect, medium density, green leaf. Originator(s): ENZA ZADEN BEHEER B.V.

Ararat is mid-season. The period from full germination to the beginning of flowering is 71 days. The plant is erect, semi-spreading, 60 cm high, the leaf is purple. Originator(s): LLC Agrofirma poisk.

Yerevan sapphire is mid-season. The period from full germination to the beginning of the economic shelf life is 40-46 days. The plant is tall, erect, of medium density, the leaf is purple. Originator(s): LLC Gavrish selection firm.

At the moment, there are no basil varieties bred specifically for full photo culture conditions, therefore, the purpose of our study is to study the response of four basil varieties to the power of lighting with LED lamps during the growing season.

2. Materials and methods
The studies were carried out in the phytotron of the Laboratory of Photoculture and City-Farming of the SPbGAU in 2020. All varieties are included in the State Register for growing in open and protected ground [9].

Sowing of seeds was carried out manually on the surface of the substrate. Dornit nonwoven fabric was used as a substrate. Germination was carried out at 23-24 0C and air humidity 94%. Growing conditions: photoperiod was 16 hours a day, 8 hours a night; the average power of irradiation, μmol / m² / s - 80 ± 8, 110 ± 10, 140 ± 12, 170 ± 15; light spectrum - ratio of blue spectrum to red spectrum 1: 5; air temperature - 24-25 ⁰C, air humidity - 55-65%.

The plants were fed by the aeroponic method. The composition of the nutrient solution, mg / l: N - 134, P - 40, K - 183, Mg - 41, Ca - 173, S - 86 and trace elements; The pH was maintained at 5.5-5.7, the conductivity of the solution was 1.5 mSm / cm. Planting density was 180 plants per m². The growing season from mass germination to harvesting was 43 days.

When carrying out biometric measurements (plant height, leaf width), the following guidelines were followed: "Guidelines for studying the collection of cabbage and leafy green crops (lettuce, spinach, dill)" [2] and "Methodology of field experiment in vegetable growing" [3].

The illumination power was measured with a TKA-Spektr (PAR) spectrophotometer (LLC Scientific and Technical Enterprise TKA, St. Petersburg) at a suspension height of the lamps of 40 cm. The average illumination power was calculated according to PNST 211-2017 "Irradiation of plants with LED light sources. Measurement methods".

The placement of variants is systematic; the studies were carried out in 3 analytical replicates and 10 biological replicates. Statistical processing of the experimental data on the average weight of one plant was carried out by the method of analysis of variance according to the Student's t-test (the significance of the difference between the means was estimated at a 5% significance level) using Microsoft Excel software. To determine the degree of influence of illumination power on the morphometric parameters and the average weight of one plant, the coefficient of determination was calculated. Average values of indicators are indicated with standard error of the mean.

3. Results
Table 1 shows the results of biometric measurements of four varieties of basil with different illumination power on the 31st, 38th and 43rd days from mass shoots. Table 2 presents data on the average weight of one plant of four varieties of basil at different illumination power on days 31, 38 and 43 from mass shoots.
Table 1. Morphometric parameters of the basil with different illumination power according to counts, 2020.

| Variety name, factor A | Illumination power, μmol / m² / s, factor B | Plant height, mm | | | | Plant diameter, mm | | | |
|------------------------|-------------------------------------------|------------------|---|---|---|---|---|---|---|
|                        | 31 days ±Sx | 38 days ±Sx | 43 days ±Sx | 31 days ±Sx | 38 days ±Sx | 43 days ±Sx | 31 days ±Sx | 38 days ±Sx | 43 days ±Sx |
| Ararat                 | 80          | 54         | 12.5       | 90         | 14.1       | 78         | 9.7         | 128        | 9.7        | 141        | 9.3        | 136        | 7.5        |
|                        | 110         | 90         | 9.1        | 118        | 13.8       | 94         | 31.3        | 138        | 8.6        | 130        | 14.1       | 118        | 6.5        |
|                        | 140         | 93         | 12.0       | 86         | 22.5       | 44         | 9.0         | 168        | 4.3        | 141        | 7.2        | 80         | 16.8       |
|                        | 170         | 43         | 12.5       | 50         | 12.4       | 84         | 13.0        | 103        | 16.4       | 116        | 22.7       | 126        | 17.5       |
| r²                     | 0.02        | 0.49       | 0.04       | 0.05       | 0.49       | 0.13       |             |             |             |             |             |             |
| Yerevan sapphire       | 80          | 28         | 6.6        | 49         | 15.6       | 52         | 16.4        | 87         | 13.7       | 118        | 19.1       | 113        | 19.2       |
|                        | 110         | 16         | 5.5        | 41         | 12.3       | 45         | 17.6        | 71         | 20.8       | 100        | 18.6       | 90         | 22.9       |
|                        | 140         | 38         | 15.5       | 48         | 7.8        | 83         | 13.3        | 108        | 19.2       | 103        | 8.3        | 140        | 19.7       |
|                        | 170         | 35         | 5.4        | 43         | 7.5        | 54         | 10.3        | 106        | 9.0        | 129        | 0.8        | 103        | 6.3        |
| r²                     | 0.32        | 0.14       | 0.11       | 0.48       | 0.12       | 0.01       |             |             |             |             |             |             |
| Emily                  | 80          | 23         | 7.3        | 48         | 11.6       | 52         | 3.5         | 66         | 12.5       | 117        | 9.0        | 120        | 6.5        |
|                        | 110         | 26         | 5.6        | 74         | 8.7        | 61         | 16.8        | 103        | 17.2       | 104        | 9.0        | 125        | 19.5       |
|                        | 140         | 48         | 9.2        | 73         | 14.5       | 89         | 23.8        | 150        | 15.5       | 95         | 6.9        | 130        | 22.5       |
|                        | 170         | 50         | 2.0        | 68         | 3.1        | 90         | 4.9         | 150        | 5.4        | 91         | 6.1        | 127        | 6.5        |
| r²                     | 0.87        | 0.39       | 0.89       | 0.90       | 0.95       | 0.64       |             |             |             |             |             |             |
| Marian                 | 80          | 51         | 21.5       | 83         | 7.5        | 64         | 5.5         | 94         | 18.2       | 118        | 9.5        | 113        | 10.3       |
|                        | 110         | 53         | 8.4        | 114        | 28.7       | 154        | 51.5        | 145        | 3.6        | 112        | 21.0       | 189        | 31.4       |
|                        | 140         | 128        | 17.9       | 121        | 17.4       | 115        | 19.5        | 168        | 14.4       | 191        | 22.7       | 119        | 18.6       |
|                        | 170         | 68         | 10.1       | 95         | 4.1        | 88         | 29.5        | 143        | 14.1       | 195        | 16.7       | 150        | 26.3       |
| r²                     | 0.02        | 0.10       | 0.01       | 0.50       | 0.79       | 0.02       |             |             |             |             |             |             |

Table 2. Average weight of one basil plant at different illumination power according to counts, g, 2020.

| Variety name, factor A | Illumination power, μmol / m² / s, factor B | 31 days ±Sx | 38 days ±Sx | 43 days ±Sx |
|------------------------|-------------------------------------------|---|---|---|
| Ararat                 | 80                                      | 1.57 | 0.47 | 2.54 |
|                        | 110                                     | 1.60 | 1.12 | 2.61 |
|                        | 140                                     | 2.53 | 0.45 | 2.85 |
|                        | 170                                     | 0.94 | 0.41 | 2.48 |
| r²                     | 0.03                                    |     |     | 0.00 |
| Yerevan sapphire       | 80                                      | 0.77 | 0.23 | 1.85 |
|                        | 110                                     | 0.44 | 0.27 | 1.18 |
|                        | 140                                     | 0.86 | 0.26 | 1.32 |
|                        | 170                                     | 0.93 | 0.14 | 2.32 |
| r²                     | 0.28                                    |     |     | 0.17 |
| Emily                  | 80                                      | 0.96 | 0.38 | 2.30 |
|                        | 110                                     | 1.74 | 0.72 | 3.12 |
|                        | 140                                     | 2.19 | 0.54 | 3.32 |
|                        | 170                                     | 1.91 | 0.09 | 4.41 |
| r²                     | 0.65                                    |     |     | 0.95 |
| Marian                 | 80                                      | 0.96 | 0.38 | 2.30 |
|                        | 110                                     | 1.74 | 0.72 | 3.12 |
|                        | 140                                     | 2.19 | 0.54 | 3.32 |
|                        | 170                                     | 1.91 | 0.09 | 4.41 |
| r²                     | 0.65                                    |     |     | 0.95 |

HCP<sub>0.05</sub> factor A 0.16 factor B 0.15
4. Discussion
An increase in the illumination power had a predominantly weak effect on the morphometric parameters (table 1) and the average weight of basil varieties at different stages of development. According to the average weight of one plant (table 2), there are significant differences between the experimental variants for each variety at different stages of development.

An increase in the illumination power had an average degree of influence on the 38th day on the height ($r^2 = 0.49$) and width ($r^2 = 0.49$) of the plants of the Ararat variety. The average weight of one plant of the Ararat variety weakly depended on the increase in illumination power ($r^2 = 0.00-0.30$) during the growing season. By the end of the growing season, on the 43rd day, plant height was 44-94 mm, leaf width - 80-136 mm, average weight - 3.17-4.11 g. Variety Ararat formed compact plants with a wide habitus and the largest average weight 4.11 g at an illumination power of 110 μmol / m$^2$ / s.

The height and diameter of plants of the Yerevan Sapphire variety reacted poorly to an increase in the illumination power ($r^2 = 0.11-0.32$ and 0.01-0.48, respectively) during the growing season. At the time of harvesting, an average increase in the average weight of one plant was provided by an increase in power ($r^2 = 0.56$). By the end of the growing season, on the 39th day, the plant height was 45-83 mm, leaf width - 90-140 mm, average weight - 2.28-4.89 g. The variety Yerevan sapphire formed compact plants with a wide habit and the largest average weight 4.89 g at an illumination power of 170 μmol / m$^2$ / s.

The height and diameter of the plants of the Emily variety reacted strongly to the increase in the illumination power ($r^2 = 0.39-0.89$ and 0.64-0.95, respectively) during the growing season. During the growing season, an increase in the average weight of one plant was largely ensured by an increase in power ($r^2 = 0.64-0.95$). By the end of the growing season, on the 39th day, the plant height was 52-90 mm, leaf width - 120-130 mm, average weight - 1.72-5.44 g. Variety Emily formed compact plants with a wide habitus and the largest average weight 5.44 g at an illumination power of 140 μmol / m$^2$ / s.

The change in the height of Marian plants did not depend on an increase in the illumination power ($r^2 = 0.01-0.20$), the diameter of the plants depended largely on an increase in the illumination power ($r^2 = 0.50-0.79$) up to 38 days, then the degree influence decreased to 0.02. By the end of the growing season, on the 39th day, the plant height was 64-154 mm, leaf width - 113-189 mm, average weight - 5.50-11.50 g. The Marian variety formed compact plants with a wide habitus and the highest average weight 11.50 g at an illumination power of 140 μmol / m$^2$ / s.

5. Conclusion
Based on the results of our research, the following conclusions can be drawn:

- Basil cultivars reacted poorly to an increase in illumination power at different stages of development, with the exception of Emily, which showed a positive reaction.
- The Ararat variety formed compact plants with a wide habitus and the largest average weight of 4.11 g at an illumination power of 110 μmol / m$^2$ / s.
- The variety Yerevan sapphire formed compact plants with a wide habit and the largest average weight of 4.89 g at an illumination power of 170 μmol / m$^2$ / s.
- Variety Emily formed compact plants with a wide habitus and the largest average weight of 5.44 g at an illumination power of 140 μmol / m$^2$ / s.
- Variety Marian formed compact plants with a wide habitus and the largest average weight of 11.50 g at an illumination power of 140 μmol / m$^2$ / s.

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