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The influence of different lighting sources on growth and development of tomato plants

Mikhail S Yamburov[1], Svetlana B Romanova[1], Valentina M Smolina[1], Anastasia A Burenina[1], Tatyana P Astafurova[1], Sergey B Turanov[2] and Sofia A Romanenko[2]

[1]National Research Tomsk State University, Lenin avenue 36, Tomsk, 634050, Russia
[2]National Research Tomsk Polytechnic University, 30 Lenin Avenue, Tomsk 634050, Russia

E-mail: tyrsb@yandex.ru

Abstract. Comparative study was conducted on morphofunctional parameters of tomato plants (*Solanum lycopersicum* L.) under diverse supplementary lighting conditions – electrodeless lamps (EL), high-pressure mercury arc lamps (HPM) and high-pressure sodium arc lamps (HPS). The work showed, that plants, cultivated under 5,000 lux EL lighting, had higher morphometric parameters, their leaves contained more chlorophyll, and they were outgrown, in comparison to plants, growth in HPS and HPM lighting conditions. These results demonstrate the profitableness of EL light flux, which contains constant PAR spectrum, for tomato plants growth and development.

1. Introduction

Spectrum structure of emission has massive influence on plants development: it affects photosynthesis process, controls morphogenesis, hormonal state, ontogeny and secondary metabolism. However, results vary among different species and even breeds [1-5]. Considering that, general guidance for light spectrum appliance, appropriate for plants cultivation under photoculture conditions, is impractical [6].

According to different authors, optimum spectral structure contains blue (400–500 nm), green (500–600 nm) and red (600–700 nm) PAR radiation at the intensity ratio of 3:2:5 [7].

Nowadays, HPS and HPM lamps are widely used in major greenhouse facilities, though lighting technique market offers the latest power saving sources, which have greater luminous power and spectrum, specially selected for plants cultivation. These include electrodeless lamps (EL), where the combination of 3 physical processes – electromagnetic induction, gas discharge and phosphor glow in reaction with gas – is used to produce light emission. EL has improved technical characteristics (extended working period, greater photooptical efficiency, low heating temperature, etc.) over the other lighting sources.

The research is aimed at the examination of electrodeless lamp impact on growth and development processes of tomato plants, in comparison to HPS and HPM lamps illumination.

2. Equipment and methods

Tomato plant (*Solanum lycopersicum* L.) of Karamelka variety was chosen as model site. Plants were grown in Siberian Botanic Garden in moderate tropical stove at day temperature 25°C and night temperature 22°C. Seeding was performed into plastic cultivating containers of 500 cm^3 volume. Soil mix consisted of acid-free turf, vermicompost and sand at the ratio of 3:1:1. In each container 1 sample of tomato was grown. Containers with plants were placed on rack, equipped with different lamp types: electrodeless "Ekosvet" (EL), high-pressure sodium arc lamps (HPS) and high-pressure mercury arc lamps (HPM). Light units were arranged at height which ensured equal irradiance level. EL had constant spectrum and light flux, which contained constant PAR spectrum; HPS lamp – banded spectrum and significantly broadened D-lines of sodium with high self-reversal and maxima of 470, 483, 589 and 810 nm; HPM lamp – line spectrum and maxima of 365, 404, 435, 546 and 578 nm. As plants were growing, lamps height was raised every 2 weeks to ensure, that luminance of the upper parts of shoots maintained constant throughout the vegetation period. Diurnal supplementary lighting was 12 h. 3 versions of the experiment were conducted, and 25 plants per each variant were cultivated.

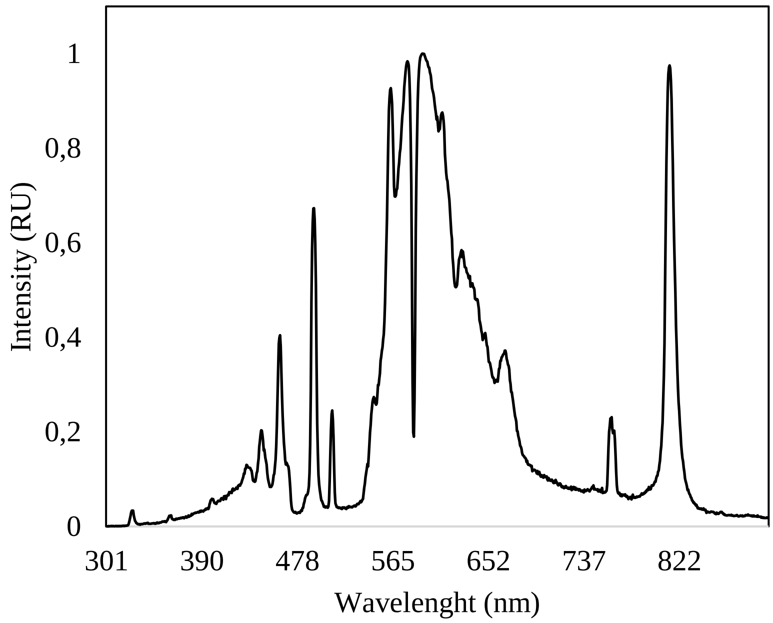

Figure 1. HPS lamp spectral structure.

After 70 days from sprouts rise, measurements of physiological and morphofunctional parameters of the plants were carried out. Physiological parameters determination included investigation of chlorophyll and polyphenols amounts and valuation of nitrogen balance index. The examinations were conducted on leaves of living plants by field non-destructive testing device – flavonoid- and chlorophyllmeter Dualex (Forse-A, France). Morphological and physiological parameters of 25 differentiated leaves (1 leaf per 1 plant) were determined in every alternative experiment.

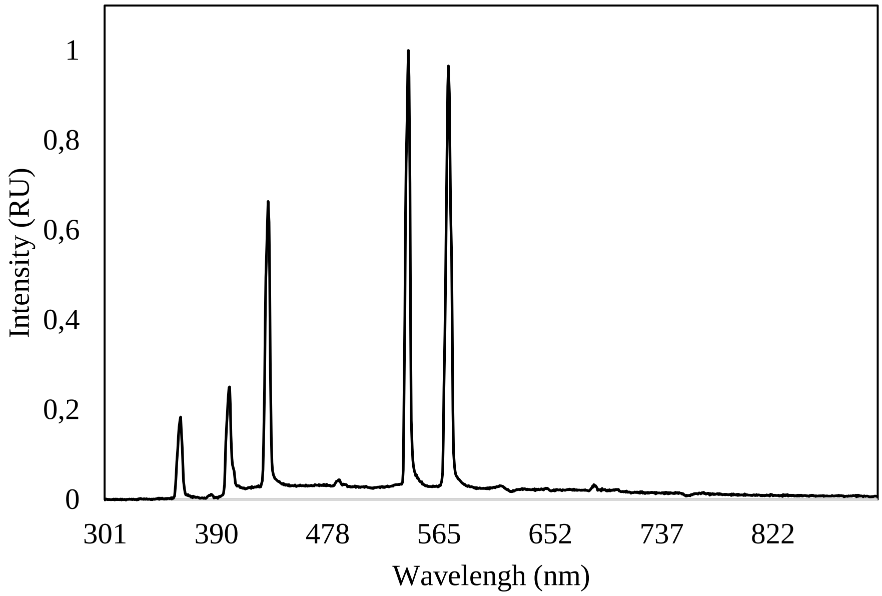

Figure 2. HPM lamp spectral structure.

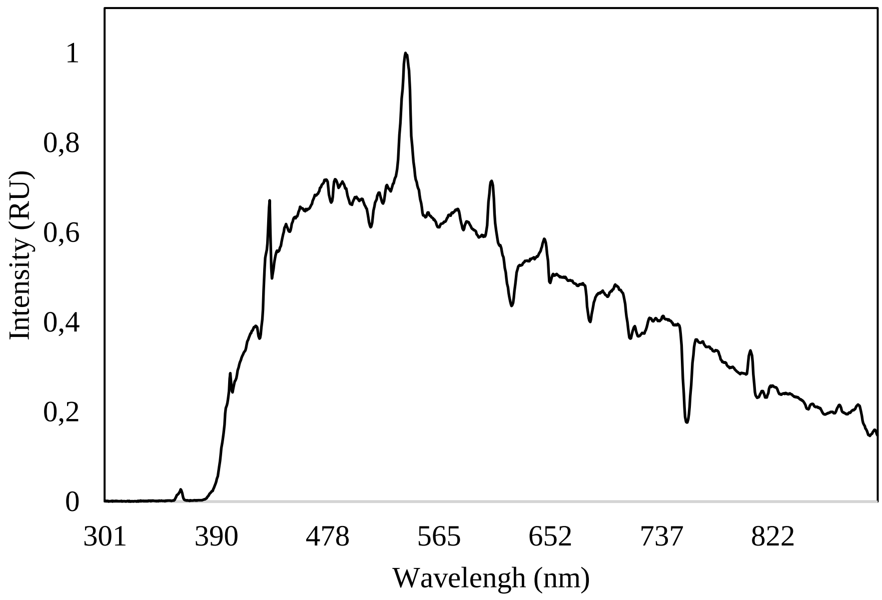

Figure 3. Electrodeless lamp spectral structure.

Following factors of tomato plants were defined: plant height, diameter of central section of the stem, internode length, dry weight of aerial part, leaves number on the main stem, leaf length, lamina area and leaf dry weight. To evaluate the lamina area, we scanned 2 leaves from the central section of each plant stem, measured leaf area in pixels, using the program AxioVision (Carl Zeiss), and converted obtained data into cm^2.

Statistical processing of the data was conducted on program Statistica (StatSoft). The average values of parameter and standard deviation were calculated. Statistical significance of differences was determined by Student's t-test ($p \leq 0.05$). For leaves of plants grown under EL lighting significance of differences was evaluated with use of t-test and then contrasted with other experimental samples.

3. Results and discussion

Plants, cultivated under EL supplementary lighting conditions, were more developed and outgrown on all morphometric indicators, contrasted with samples from alternative experiments (HPS and HPM). Stem diameter, height of the plant and internode length were 30% and 35% greater relatively. Moreover, dry weight of aerial part was also higher by 15 and 21 percent (see figure 4, table 1).

Figure 4. Plants which were cultivated in 12 h supplementary lighting conditions, provided by different lamps: 1 – electrodeless lamp (EL); 2 – high-pressure sodium arc lamps (HPS); 3 – high-pressure mercury arc lamps (HPM).

Table 1. Morphological and physiological parameters of tomato plants, grown in different variants of the experiment.

Factor	Light source Electrodeless lamp (EL)	High-pressure sodium arc lamps (HPS)	High-pressure mercury arc lamps (HPM)
Plant height, cm	80.4±13.1	52.0±9.1[a]	52.3±8.4[a]
Stem diameter, mm	4.3±1.0	3.1±0.5[a]	3.1±0.2[a]
Internode length, cm	69.1±13.9	45.0±9.7[a]	44.9±8.4[a]
Dry weight of aerial part, g	171.2±19.8	145.7±22.5[a]	134.9±23.8[a]
Leaves number, pcs	11.8±1.6	10.3±1.5[a]	9.9±1.3[a]
Leaf length, mm	115.0±31.8	80.9±16.1[a]	81.3±16.1[a]

Length of lobe of a leaf, mm	56.0±15.3	38.5±12.7[a]	37.2±13.2[a]
Lamina area, cm^2	60.0±20.3	25.8±8.3[a]	22.0±8.1[a]
Leaf dry weight, mg	108.8±52.6	54.9±18.4[a]	59.8±28.6[a]
Chlorophylls sum, mg/cm^2	20.66±3.52	16.35±2.11[a]	16,87±2.50[a]
Flavonoids sum, mg/cm^2	0.60±0.21	0.74±0.12[a]	0.61±0.17
Nitrogen balance index	34	22[a]	28[a]

[a] Statistically significant difference to EL lighting under $p \leq 0.05$ (Student's t-test).

EL illuminated plants were more foliate, the number of leaves on the main stem was 13% and 16% higher than in plants illuminated by HPS and HPM relatively. Leaf length and leaf length lobe under EL lighting raised by 30 and 31–34 percent, in contrast with other variants. The increase of length, number of lobes and leaf size in EL illumination conditions refers to considerably greater value of total assimilating area of leaves. For the plants grown under HPS lamp, area and dry mass were 57% and 50% lower, under HPM lamp – 63% and 45% lower, as relevant.

The content of photosynthetic pigment chlorophyll in leaves, illuminated by EL, was considerably higher, than in alternative experiments – 21% (HPS) and 18% (HPM). The content of flavonoids between EL and HPM lamp illumination were insignificantly different for statistics, but for HPS lamp flavonoids were accumulated for 23% more intensively than in other alternatives. Nitrogen balance index of EL illuminated leaves was far greater, than for variants – 36% (HPS) and 20% (HPM). Large nitrogen balance index can be ascribed to reproductive state reaching and fruit setting under EL light conditions; it is well known, tomato plants actively consume nitrogen from soil especially during 1-7 raceme development [8].

Cultivated under EL light plants outgrew samples from alternative experiments, and by the end of examination 62% of plants achieved reproductive state (1 raceme initial blossom). Only 11% plants reached reproductive state in HPM experiment. Moreover, 38% of EL samples had off-shoots, intended to grow; off-shoots were not detected in other experiments.

We should point out, that plants cultivated with the use of HPS and HPM lamps had early aged and sallowed leaves at the stem bottom.

4. Conclusion

When irradiating tomato plants, electrodeless lamps, as a source of supplementary lighting, assure higher morphometric parameters of plants, content of chlorophyll in leaves and outgrowing, in comparison to HPS and HPM lamps. These results demonstrate the profitableness of EL light flux, which contains constant PAR spectrum, for tomato plants growth and development.

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