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# The influence of supplementary lighting sources on agro-biological performance in greenhouse-grown cucumbers

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**Abstract**. The paper presents the research of the influence of supplementary lighting sources on growth and yielding capacity of cucumber hybrids. The experiment was carried out in 2020-2021 in commercial greenhouses. Two sources of supplementary lighting were studied (option 1 – high-pressure sodium arc reflector lamps (SRL) "super" (Reflux), option 2 – LED-lamps (Phillips) on two cucumber hybrids: F1 Meva and F1 Svyatogor. The present research revealed statistically significant influence of factor B (source of supplementary lighting) on the overall crop productivity. To obtain the maximal yield (Meva F1 – 20,86 kg/m$^2$, Svyatogor F1 – 18,21 kg/m$^2$), we recommend using LED-lamps as supplementary lighting sources.

## 1 Introduction

Greenhouse facilities have been developed successfully worldwide, providing cutting-edge solutions for technical, economical and biological problems in vegetable crops cultivation [1]. To provide year-round supply of fresh vegetables to the population according to medical requirements [2] and to ensure sustainable off-season supply of greenhouse-grown vegetables, better pricing in retail, supplementary lighting is used in addition to the natural one in order to optimize the light environment [3]. Light is one of the key factors for plant growth and development [4]. For green plants as primary producers, light is the source of energy, eventually to be consumed by humans at the end of the food chain. It also serves for regulatory purposes, influencing cell elongation and plant growth, absorption of plant food compounds, stomatal opening and transpiration [5]. Several literary sources have been dedicated to the study of light quality and its influence on the growth and development of plants [6, 7]. High-Pressure Sodium (HPS) lamps are the predominant lighting source in industrial greenhouses due to their high efficiency in converting energy into active photosynthetic emissions [8]. However, HPS lamps are spectrally and energetically non-optimal, since most of the emissions are in the yellow and orange ranges with a small amount of red in the 550-650 nm range, and about 5% fall in the blue range of 400-500 nm. The insufficient range of blue light and other wavelengths that affect photosynthesis causes this light source's low efficiency [9; 10]. A published study assessed the effects of blue light on leaves and whole plants [11]. The blue spectrum of light affects many plant processes such as photomorphogenesis, phototropism, photosynthetic functioning of leaves [12].

In commercial greenhouses, to obtain high crop productivity and high quality when natural illumination is low, supplementary lighting is used up to 18-120 hours a day with the intensity from 200 to 500 $\mu$mol · m$^{-2}$ · c $^{-1}$ [13; 14]. High pressure sodium arc (reflector) lamps (hereinafter referred to as SRL) appear to be main light sources in greenhouses, as well as LED bulbs, which have some additional advantages, such as reduction of energy consumption [15; 16]. Moreover, rapidly developing LED technologies form an alternative light source [17]. LEDs can provide a light spectrum from ultraviolet to infrared. The LED lamp service life is longer than that of HPS and can last up to 100,000 hours [18]. Previously, authors noted [19] that LED light sources can provide energy savings during greenhouse operations. A noteworthy LED lamp characteristic is the emission of less heat during operation compared to that of sodium lamps. As a result, it is necessary to regulate one of the microclimate parameters, air temperature, in order to maintain leaf temperature at the same level and eliminate fluctuations in thermal emissions when switching on and off the lamps [20]. –

The current research is aimed at estimating the influence of a supplementary lighting source on the growth, development and productivity of parthenocarpic (seedless) cucumber hybrids.

## 2 Materials and methods

The experiment was carried out in commercial greenhouses in 2020-2021 in light zone III during the winter-spring period. Parthenocarpic cucumber hybrids Svyatogor F1 and Meva F1 were used (originator is

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Rijk Zwaan, the Netherlands) in tall Venlo greenhouses.

The present two-factor experiment involved Factor A: cucumber “hybrid genotype” (Meva F1, Svyatogor F1), and Factor B: “supplementary lighting source” (option I: high-pressure sodium arc reflector lamps (SRL) “super” (Reflux); option II: light emitting diode (LED) bulbs (Phillips)). SRLs 600 W were hung over each row spaced 2.5 m between them. The microclimatic parameters were controlled by the Hoogendoorn climate computer; the $CO_2$ content was maintained at 0,05%-0,09%.

20-day seedlings were planted in Grodan slabs with the density for hybrids; under LED bulbs the crop crowdedness was maintained at 2,5 plants/m$^2$, under sodium reflector lamps – 2,8 plants / m$^2$.

Photoculture technology involves switching lamps on and off. The dark period lasted from 5 pm till 9 pm. The illumination of leaves at different levels was measured using LI-190 SA meter (Licor Inc., UK). For measurements, fully developed leaves from 10 model plants were used. To measure the leaf weight and area, 10 plants were divided into organs and weighted. Leaf samples were then dried at 70°C. The specific leaf surface area was calculated as their weight / area ratio. The leaf area index (LAI, m$^2$/m$^2$) was calculated by multiplying the leaf area of a plant by the number of plants per 1 m$^2$.

The yield was accounted dynamically by weighing cucumbers harvested from a plot upon each harvesting [21].

When statistically processing the obtained results, the significance of differences was estimated by means of Student’s test and considered statistically significant at $p \leq 0,05$. For statistical purposes, Microsoft Excel 7.0 and STATISTICA software were used.

## 3 Results and discussion

Table 1 contains the experimental data (averaged values per month for the entire growing period) on the formation of the leaf surface in the studied cucumber hybrids under different supplementary lighting sources as a factor of their adaptation capacities to evaluate their flexibility.

**Table 1.** Leaf surface formation factors in cucumber hybrids with different supplementary lighting.

| Hybrid genotype (A) | Supplementary lighting source (B) | Number of leaves | Leaf length, cm | Leaf width, cm | Leaf area, $dm^2$ | Leaf area index (LAI), $m^2/m^2$ |
|---|---|---|---|---|---|---|
| Meva $F_1$ | LED | 19.6 | 26.8 | 35.2 | 953 | 4.9 |
| | Sodium reflector lamp | 20.2 | 25.7 | 31.7 | 81.8 | 2.0 |
| Svyatogor $F_1$ | LED | 20.4 | 25.8 | 35.1 | 91.1 | 4.7 |
| | Sodium reflector lamp | 20.8 | 25.1 | 32.0 | 80.6 | 1.8 |
| $HCP_{05}B$= | | – | – | – | 6.3 | 0.2 |

Significant differences in the leaf surface area using different supplementary lighting sources (LED vs sodium reflector lamps) in hybrids were revealed ($HCP_{05}B$=6,3 $dm^2$). The contribution of the influence of Factor B (supplementary lighting source) on the leaf surface area is significant, comprising 14%. Averages for the leaf surface area in hybrids did not differ significantly in the experiment. Factor A (hybrid genotype) was not found to have a significant effect on the leaf surface. The highest contribution in terms of influence on the leaf surface area (71%) appeared to be due to random factors.

Only Factor B was found to significantly influence the LAI ($HCP_{05}B$=0,2 $m^2/m^2$), the contribution of the factor's influence accounted for 32%; the highest effect on LAI (73%) was due to random factors.

Growth dynamics in partenocarpic cucumber hybrids with different supplementary lighting sources is presented in Table 2.

The height of the main stem reflects photosynthetic potency of plants and appears to change in ontogeny. In the propagation department, all hybrids had the same source of light, SRL-600 lamps; in this relation, the difference in the plant heights on the 23$^{rd}$ day was influenced by the hybrid genotype. According to the two-factor experiment results, having evaluated the effect of Factor A (hybrid genotype) and Factor B (supplementary lighting source), we must indicate that both factors had statistically significant effects on the growth dynamics in cucumber plants. According to the biometric observations, the greatest daily increase in the plant length was found on the 102$^{nd}$ day and further, which can be explained by the increase of natural lighting.

Yield is the key criterion for each variety or hybrid, reflecting the effectiveness of these or those factors, techniques or methods. The effect of the supplementary lighting source on yields in the winter-spring period was studied. According to the obtained experimental data it was revealed that the overall crop productivity of the Meva F1 hybrid under SRL lamps was 19,26 $kg/m^2$, whereas of the Svyatogor F1 hybrid it was 17,65 $kg/m^2$. The highest crop productivity appeared to be in Option II – when using LED bulbs (Meva F1 was 20,86 $kg/m^2$, Svyatogor F1 was 18, 21 $kg/m^2$).

Factor B (supplementary lighting source) had a significant effect on the overall crop productivity ($HCP_{05}B$=2,5 $kg/m^2$), contribution of influence was 28%. Factor A (hybrid genotype) had an insignificant effect (contribution was 6%, $HCP_{05}A$ = 1,2 $kg/m^2$).

**Table 2.** The influence of hybrid genotype and supplementary lighting sources on growth dynamics in cucumbers.

| Hybrid genotype (A) | Supplementary lighting source (B) | Plant age (days after mass sprouting) | | | | | | Average daily growth during cultivation period, cm |
|---|---|---|---|---|---|---|---|---|
| | | 23 | | 68 | | 102 | | |
| | | 11.01 | | 26.02 | | 02.04 | | |
| | | 1 | 2 | 1 | 2 | 1 | 2 | |
| Meva $F_1$ | LED | 39.4 | – | 370.0 | 52.4 | 670.2 | 60.0 | 59.1$\pm$7.2 |
| | SRL | 46.5 | – | 355.4 | 52.1 | 629.2 | 54.8 | 55.2$\pm$4.1 |
| Svyatogor $F_1$ | LED | 33.1 | – | 406.2 | 60.6 | 752.5 | 62.3 | 64.5$\pm$6.2 |

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | SRL | 40.1 | – | 394.5 | 57.7 | 723.3 | 63.8 | 60.0±5.2 |
| $HCP_{05}A$ | | | | | | | | 5.4 |
| $HCP_{05}B$ | | | | | | | | 6.1 |

Note: 1 is the plant height, cm; 2 is the weekly growth, cm.

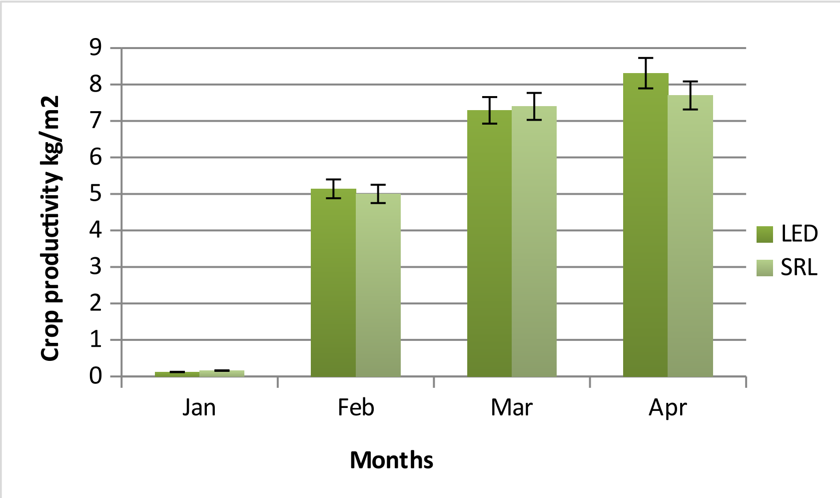


**Fig. 1.** Crop productivity dynamics in Meva F1 using different supplementary lighting sources.

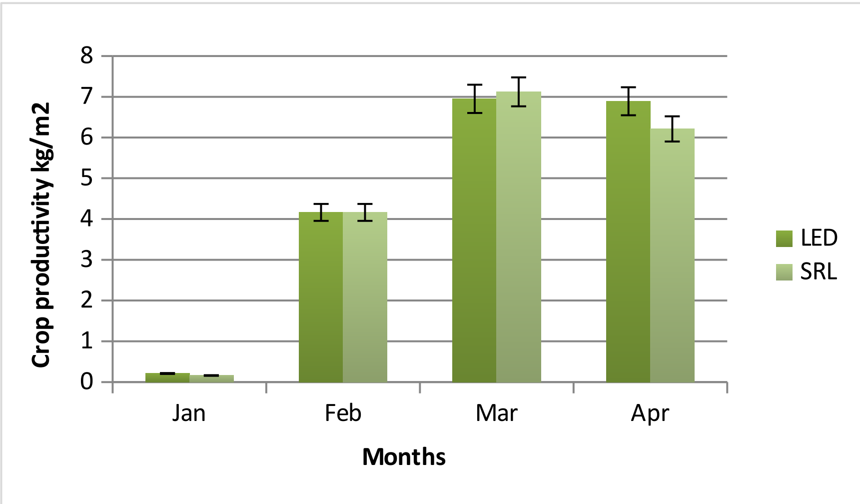


**Fig. 2.** Crop productivity dynamics in Svyatogor F1 using different supplementary lighting sources.

## 4 Conclusion

In our studies, the sources of supplementary illumination influenced the agrobiological indicators of the cucumber greenhouse culture. Investigation of measuring the distribution of light in the cenosis and the efficiency of using the thermal culture of cucumber in the winter-spring circulation of scattering coming from LED lamps. Cases of revealing differences in leaf surface areas during the collection of various sources of supplementary illumination (LED lamps and DNaZ lamps) of the studied cucumber plants were established.

The “test genotype” factor is no exception. In our studies, the largest share of the analysis of leaf area and leaf area index (FLI) falls on random factors - microclimate parameters. The conducted studies have revealed the prospects of the LED lamp as artificial lighting, which is based on objective measurements of completeness. The lighting mode used in the experiment makes it possible to obtain a positive dynamics of the oral processes of the studied cucumber hybrids Meva F1 and Svyatogor F1 and to consistently obtain yields in the winter-spring turnover.

To obtain maximal productivity, we recommend using LED bulbs as sources of supplementary lighting, so crop productivity of Meva F1 is 20,86 kg/m$^2$; that of Svyatogor F1 is 18,kg/m$^2$.

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