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ESTABLISHMENT OF SOME CULTIVATION STAGES AT VEGETATION HOUSE LEVEL IN ECOLOGICAL SYSTEM ON THREE ROMANIAN TOMATO VARIETIES

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Abstract

The aim of our research was to establish the effect of some cultivation stages in ecological system in which are use the LED light on biological material of three Romanian tomato varieties. For this purpose, young tomatoes (Lycopersicon esculentum Mill.) plants have been grown in protected crop space (vegetation house), by daily supplementing natural light for short periods of time with light provided by high power LED panels with red, blue and white monochromatic light. In order to carry out the integrated studies of the cultivation method in the ecological system, products accepted as natural and biodegradable and approved in Romania, for fertilization and control of the attacks of diseases and pests, were used . The tested varieties were selected with indefinite habitus and special forms of fruits, namely: Sonia de Buzău, Hera and Coralina. The recorded differences in the increase of the stems' length (average values) recorded, after 50 days from the beginning of the experiments, have revealed to us that the results are differentiated according to genotype, spectrum and exposure time to the used additional light. Plants of the variety "Sonia de Buzău" exposed daily under LED light recorded high values in most variants, followed by those of the variety Hera and Coralina. The results obtained after the application of additional treatments with LED light, were dynamically analysed, evaluated by statistical calculation and compared with the values obtained by the Control plants maintained only under the effect of natural light and which were treated with the fertilization and phytosanitary protection products.

Key words*: agroecosystem, artificial light, morphological assessments, tomatoes.*

INTRODUCTION

Light Emitting Diode (LEDs) were developed after 1962 and for many years they have been used only in signs or light displays due to the low light emitted and the restricted colour palette. LEDs are semiconductor diodes that have the property of converting electricity into light. The conversion operation is done cold, which gives a much better light efficiency than incandescent lamps (Davis & Burns, 2016; Morrow, 2008).

Among the many advantages of LED light sources the following are worth to be mentioned: high light efficiency (over 60 lm/W); low absorption powers, on the order of watts; long lifespan (because they have no filament or hot electrodes) of tens of thousands of hours; small in terms of size; resistant to weather elements and chemical agents; they have their own dispersion lens, so they can be used in projectors without the addition of optical systems; offer a wide range of colours, but also white light with different colour temperatures (mainly cold white); they have extremely short reaction times (fractions of milliseconds) and many more (Brazaityte et al., 2009).

The light emitted by a LED is usually monochromatic, and the color of the emitted light depends on the composition and the state of the LED properties.

The luminescent diodes can be manufactured to emit on all wavelengths of the visible spectrum, from red lighting (620 nm to 750 nm) to blue-violet lighting (380 nm to 490 nm). Because the luminous flux of a single LED is small, it is

necessary to use more LEDs concentrated on a single support. Their number varies from 3 to hundreds - depending on the destination of this light source (Gómez & Mitchell, 2015; Morrow, 2008; Kim et al., 2005).

The effect of light emitted by LEDs with different spectra has been studied in a significant number of crop species both from the point of view of stimulation on seed germination (Montagnoli, 2018; Enache & Livadariu, 2016; Gómez & Mitchell, 2015; Hernández & Kubota 2014; Yorio et al., 2001), but also on the growth of plants at different stages of development (Davis & Burns, 2016; Gómez & Mitchell, 2015). The research carried out by Cope & Bugbee (2013) aimed to study the photobiological effects of three types of white LEDs (warm, neutral and cold), in combination with blue light in different percentages (11%, 19% and 28%) on the growth and development of radish, soybean and wheat plants.

Another aspect studied was the action of light emitted by blue LEDs in the treatment of microbiological cultures in order to increase the percentage of inactivation and to inhibit the viability of pathogenic microorganism colonies (Wang et al., 2017; Popa et al., 2008).

Taking into account the results of the aforementioned research studies, the purpose of the researches carried out in this paper was to analyse the morphological response of 3 varieties of tomato lines (Coralina, Hera and Sonia de Buzau) selected from Romanian tomato species, under the conditions of supplementing the natural illumination with light from LEDs of red, blue and white colours, in the protected culture space represented by the vegetation house of USAMV Bucharest.

MATERIALS AND METHODS

Biological material

In the experiments, seedlings from three approved tomato lines from Vegetable Research and Development Station Buzău, Romania (VRDS Buzău): Sonia de Buzău, Hera and Coralina were used. The productive characteristics of the analyzed tomato varieties differ in color and shape of the fruits but also by the habit of growing of the plants.

According to the description presented in the "General Catalog of Varieties and Hybrids of Vegetables" by VRDS Buzău, Romania, the **Sonia de Buzău** variety, approved in 2014, is of early type, it forms vigorous plants, with indeterminate growth of the stems. The fruits are of the cherry cocktail type, with a cordiform shape and concentrated ripening of the fruit in bunches, with an average weight of 38.7 g/fruit. Sonia de Buzău variety is suitable for cultivation both in protected systems (greenhouse, solar) and also in open fields (https://www.madr.ro/docs/cercetare/Rezultate_activitate_de_cercetare/SCDL_Buzau.pdf).

Regarding the main characteristics of the **Hera** variety, it is noteworthy in particular the elongated form of the fruits, similar to the Capia pepper, with a weight of 160-220 g/fruit. This variety is quite adaptable and can be grown in protected areas and also in fields (https://www.buzau.net/stiri-buzau/hera).

The variety **Coralina**, obtained at VRDS Buzău, Romania, and approved in 2009, is of early type, with indeterminate growth of the stems. The fruits are of the cherry type, with a round shape and an average weight of 19.7 g/fruit. The crop can be set up in protected areas and open field, with a production potential of about 2.5 kg / plant, being able to easily obtain over 60 t/ha (https://www.madr.ro/docs/cercetare/Rezultate_activitate_de_cercetare/SCDL_Buzau.pdf).

Three experiments were carried out: Experience I/Sonia de Buzău variety, Experience II/Hera variety and Experience III/Coralina variety. Three LED panels with different colours (red, blue and white) were used in the experiments. Each type of LED panel was suspended at a height of 1 meter above the three types of tomato seedlings.

The experiments took place in the UASVM Bucharest Vegetation House. Each of the 3 VEGETA model LED panels were made by S.C. ELECTROMAGNETICA S.A., Bucharest, Romania, with the dimensions of: 385 mm x 264 mm x 169 mm and provided an additional lighting of 10,000 lx.

The electrical and optical manufacturing parameters for the VEGETA model devices with red, blue and white LEDs placed at the panel level were as follows:

- nominal frequency = 50 Hz;
- nominal voltage = 230 V;
- rated power = 77 W ± 10%;
- power factor> 0.95;

- degree of protection IP66;
- luminous flux: red = min. 700 lm; blue = min. 1000 lm; white-neutral = min. 7900 lm;
- LED spectral domain: red = 660 nm; blue = 456 nm;

The white and neutral LED spectral range: warm, neutral, cold; colour rendering index > 80.

Devices built with LED (red, blue and white) placed in groups (sub-panels) mounted in parallel, have been adapted to the suspension support system for additional light coverage of a larger exposure surface (Figure 1).

Figure 1. Installation aspect of devices used in the lighting of tomato seedlings, with monochrome LED light in the vegetation house of USAMV Bucharest

Applied working methods

The seedlings provided by VRDS Buzău, Romania, were obtained after germination and cultivation for 45 days in alveolar pallets in the protected greenhouse. Immediately after receiving them, the tomato plants of the 3 varieties were transplanted into 15 x 15 x 15 cm square pots (1 plant/pot) which were then placed in support trays, at a density of 15 plants/m². Each pot was filled with 750 ml substrate consisting of Kekkila DSM 2 W peat, which is a light peat (well ground), pre-fertilized with a basic fertilizer (NPK 14-16-18), with the pH adjusted to 5.5/5.9 values.

The fertilization of the tomato seedlings was carried out 2-3 days after transplantation, using with Florovit plant regenerator (foliar sprays) with NPK (7-5-6); this treatment being repeated 3 times at intervals of 1 week.

Starting with the second week, foliar fertilization with Lumbreco organic fertilizer based on organic biohumus extract, has been applied for the rich source of nutrients and the growth stimulating effect.

In order to prevent the onset of pest attacks specific to tomato plants, 2 products recommended as non-toxic and environmentally friendly were selected and applied: Rock Effect (product range Natura, by producer AGRO CS) and PIPERCIP microemulsion insecticide (by AMIA International producer).

Statistical analysis

The bifactorial type experiments with tomatoes were located according to the method of subdivided plots in 3 repetitions, within each experience being tested the influence of artificial lighting using LEDs on the growth dynamics of tomato plants belonging to the three varieties tested (Sonia de Buzău, Hera and Coralina).

The experimental factors considered in the study were the following:

Factor A - the colour of the light emitted by the applied LEDs with 3 graduations: a1 - blue light; a2 - red light; and a3 - white light.

Factor B - duration of lighting treatment with 4 graduations: b1 - 0 minutes (Control variant); b2 - 15 minutes; b3 - 30 minutes; and b4 - 45 minutes.

After exposure to the selected period (at 15, 30 and 45 minutes) under the LED device, we continued to grow the tomato plants in natural light for about 14 hours/day (between sunrise and sunset), this being the period corresponding to day light for July-August, when the experiments took place, in the southern part of Romania (Bucharest). The natural day light, was supplemented for the experimental variants, after 2 weeks from the moment when tomato plants were transplanted into 15 x 15 x 15 cm square pots (1 plant/pot), with light from LEDs of red, blue and white colours, in vegetation house of USAMV Bucharest, each of them in combinations with 3 variants of exposion (15, 30 and 45 minutes).

As a result of the combination of the two experimental factors, for each of the 3 experiences: Experience I/Sonia de Buzău variety, Experience II/Hera variety and Experience III/Coralina variety), 12 experimental variants, interpreting the experimental results obtained by method of analysis of variance.

In the experimental scheme, we simbolize the Control sample with "b1" and was represented

by natural day light, for all combinations, between the variants of factor A, as follows:
✓ a1b1 - 0 minutes at blue LED lighting;
✓ a2b1 - 0 minutes at red LED lighting;
✓ and a3b1 - 0 minutes at white LED lighting.
Significance of differences between different experimental variants was performed based on the analysis of the variant (ANOVA).
The results were expressed as mean values and their specific standard errors, using MS Excel software. To determine the significance of the differences at P≤5%, compared to the Control sample, the t test was used.

RESULTS AND DISCUSSIONS

Experience I - Sonia de Buzău

The first evaluation of the stem length in tomato plants was made on 16.07.2019, after the application of 5 treatments, with monochrome LED light within 1 week for plants in the experimental variants. Compared to the average values obtained in experience I, taken as a Control in which the height of the tomato plants (Figure 2) determined on the 16.07.2019 was, on average, 49.18 cm, between the 12 sample variants (in which 9 is experimental and 3 is control) tested in the experiment of the tomato variety Sonia de Buzău, recorded differences of the values of this biometric parameter that ranged from -20.98 cm to 28.19 cm (Table 1) so:
- statistically very significant negative differences (ooo) in the case of experimental variants a1b2 and a1b3;
- distinctly significant negative (oo) in the variant a1b4;
- significantly negative (o) to a2b4 and a3b2;
- insignificant in the experimental variants a2b2, a2b3, a3b3 and a3b4;
- differences that became very significant positive (***) in the variants a1b1, a2b1, a3b1, in which case the plant stem elongate as the result of the effect of the natural light that the tomato plants cultivated under greenhouse conditions had at their disposal.
After approximately one week of vegetation, the determinations made on the plants showed the same variability compared to the Control sample (a1b1, a2b1 and a3b1) of the experience so that, on 25.07.2019, the differences related to the size of the plants were between -2.72 cm and 22.95 cm, with statistical assurance very significant negative (ooo) for experimental variants a1b2, a1b3 and a1b4, insignificant (NS) for variants a2b3, a2b4, a3b2, a3b3 and a3b4, significant positive (*) for variant a1b1, distinctly significant positive at variant significantly positive (***) in experimental variants a2b1 and a3b1.

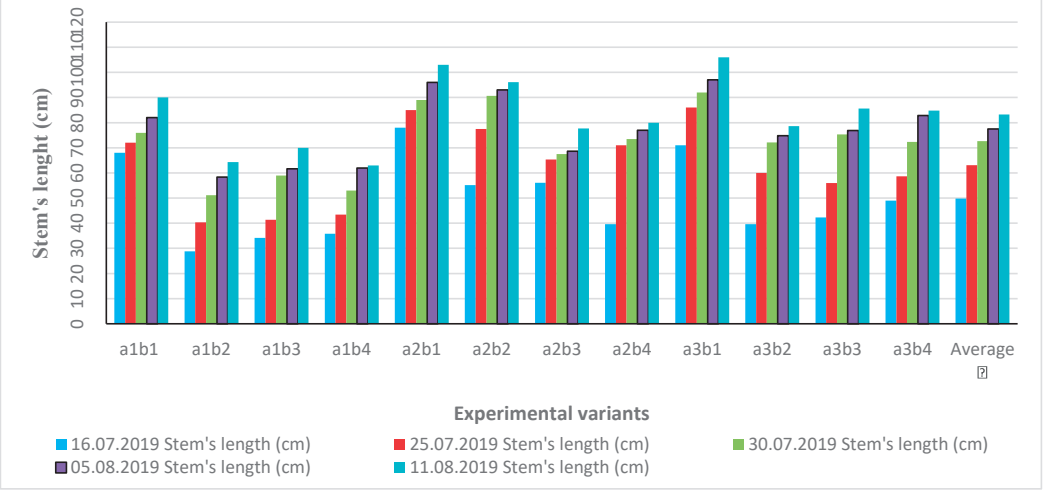

Figure 2. The values of the measured stem's length (cm), tomatoes plant- **Sonia de Buzău** variety

Table 1. The values of the statistically assured differences calculated for **Sonia de Buzău** variety

Experimental variants	Date of experimental determination									
	16.07.2019		25.07.2019		30.07.2019		05.08.2019		11.08.2019	
	Dif. (cm)	Significance level	Dif. (cm)	Significance level	Dif. (cm)	Significance level	Dif. (cm)	Significance level	Dif. (cm)	Significance level
a1b1	18.19	***	8.95	*	3.37	NS	4.49	NS	6.73	NS
a1b2	-20.98	ooo	-22.72	ooo	-21.53	ooo	-19.18	ooo	-18.94	Ooo
a1b3	-15.64	ooo	-21.72	ooo	-13.63	oo	-15.84	ooo	-13.27	Oo
a1b4	-13.98	oo	-19.62	ooo	-19.63	ooo	-15.51	ooo	-20.27	Ooo
a2b1	28.19	***	21.95	***	16.37	***	18.49	***	19.73	***
a2b2	5.36	NS	14.45	**	18.04	***	15.49	***	12.73	**
a2b3	6.49	NS	2.28	NS	-5.13	NS	-8.84	o	-5.60	NS
a2b4	-10.14	o	7,95	NS	0.87	NS	-0.51	NS	-3.27	NS
a3b1	21.19	***	22.95	***	19.37	***	19.49	***	22.73	***
a3b2	-10.21	o	-3.05	NS	0.07	NS	-2.68	NS	-4.60	NS
a3b3	-7.48	NS	-7.05	NS	2.7	NS	-0.68	NS	2.4	NS
a3b4	-0.81	NS	-4.38	NS	-0.30	NS	5.32	NS	1.56	NS
Average, %	**49.81**		**63.05**		**72.63**		**77.51**		**83.27**	
$DL_{5\%} = 8.02$; $DL_{1\%} = 11.61$; $DL_{0.1\%} = 14.87$										

***, **, *, NS indicate statistical significance at the DL5%; DL1% and DL0.1% level and nonsignificant, respectively

As the tomato plants advanced in the vegetation stage, the evolution of this biometric parameter was approximately similar being registered with the average of the experience differences between -21.53 cm and 19.37 cm in the case of the determinations made on 30.07.2019, between -19.18 cm and 19.49 cm on 5.08.2019, respectively between -20.27 cm and 22.73 cm following the determinations made on 11.08.2019.

These directions were provided, from a statistical point of view, from the very significant negative (ooo) to the variants a2b2 and a1b4, to the very significant positive (***) to the experimental variants a2b1 and a3b1, the tomato plants belonging to these variants showing an accentuated phenomenon elongation throughout the entire vegetation period.

Experience II - Hera variety

The tomato plants belonging to the Hera variety (Figure 3) have registered compared to the average of the experience differences in the height of the stems between -13.29 cm and 19.71 cm at the date of the first biometric determinations (16.07.2019), the differences being (Table 2) very significant negative (ooo) in the variant experimental a3b3, distinctly significantly negative (oo) in the case of a1b3 variant, significantly negative (o) in the variants a1b2, a2b2 and a2b3, insignificant (NS) in a1b4, a2b3, a3b1, a3b2 and a3b4 and very significantly positive (***) in the a1b1 and variants a2b1, in the case of these experimental variants, the tomato plants showing a marked elongation of the stalk.

As of 25.07.2019, (Table 2) it is observed that in most experimental varieties the phenomenon of plant elongation, irrespective of the color of the light or the duration of plant illumination, was observed, the differences recorded compared to the average of the experience taken as a Control sample, sweeping between 1.04 cm and 28.71 cm, with statistical assurance from insignificant positive (NS) in the case of experimental variant a3b3, to very significant positive (***) in experimental variants a1b1, a1b4, a2b1 and a3b1.

After another week of vegetation (30.07.2019), the biometric determinations revealed a lower variability between the 9 experimental variants, are taken in the study regarding the size of the plants, the comparative differences with the 3 Control samples (a1b1, a2b1 and a3b1), of the experience being between -10.65 cm and 12.85 cm, statistically insured from very significantly negative (ooo) to variant a2b4, to very significant positive (***) for experimental variants a1b1 and ab4.

Following the determinations made in the first decade of August (5.08.2019-11.08.2019) the same variability is observed, in the case of the same experimental variants being recorded very significant positive differences (***), differences with respect to the Control sample that ranged from -10.77 cm and 12.23 cm.

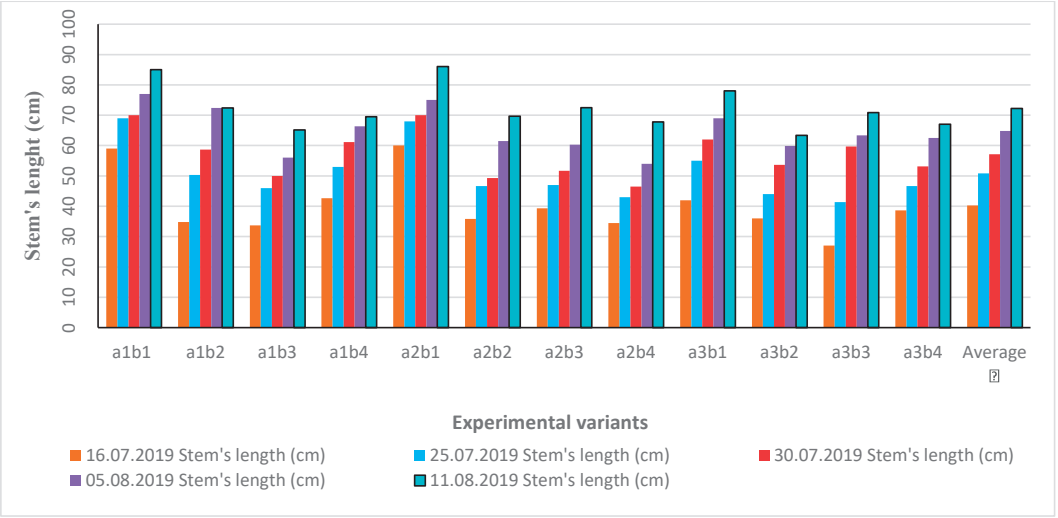

Figure 3. The values of the measured stem's length (cm), tomatoes plant- **Hera** variety

Table 2. The values of the statistically assured differences calculated for tomatoes plant- **Hera** variety

Experimental variants	Date of experimental determination									
	16.07.2019		25.07.2019		30.07.2019		05.08.2019		11.08.2019	
	Dif. (cm)	Significance level	Dif. (cm)	Significance level	Dif. (cm)	Significance level	Dif. (cm)	Significance level	Dif. (cm)	Significance level
a1b1	18.71	***	28.71	***	12.85	***	12.23	***	12.73	***
a1b2	-5.46	o	10.04	**	6.52	NS	7.66	**	0.16	NS
a1b3	-6.62	oo	5.71	*	9.71	**	-8.77	oo	-7.1	Oo
a1b4	2.38	NS	12.71	***	4.02	*	1.56	NS	-2.77	O
a2b1	19.71	***	27.71	***	12.85	***	10.23	***	13.73	***
a2b2	-4.49	o	6.38	**	-7.82	oo	-3.27	o	-2.60	O
a2b3	-0.96	NS	6.71	**	-5.48	o	-4.44	o	0.23	NS
a2b4	-5.79	o	2.71	*	-10.65	ooo	-10.77	ooo	-4.44	O
a3b1	1,71	NS	14.71	***	4.85	*	4.23	*	5.73	*
a3b2	-4.29	NS	3,71	*	-3.48	o	-4.94	o	-8.94	Oo
a3b3	-13.29	ooo	1.04	NS	2.52	*	-1.4	NS	-1.44	NS
a3b4	-1.62	NS	6.38	**	-4.05	*	-2.27	NS	-5.27	O
Average, %	**40.29**		**50.83**		**57.15**		**64.77**		**72.27**	
DL5% = 2.46; DL1% = 6.08; DL0.1% = 10.22										

***, **, *, NS indicate statistical significance at the DL5%; DL1% and DL0.1% level and nonsignificant, respectively

The experience III - Coralina variety

The differences registered with the average of the Experience III (Figure 4) in terms of their height, ranged between -13.58 cm and 21.79 cm on July 16, 2019, between -10.33 cm and 17.67 cm following the biometric determinations performed on July 25, 2019, between -14.19 cm and 16.48 cm on July 30, 2019, while the determinations made in the first decade of August highlighted differences in this biometric indicator between -20.79 cm and 13.88 cm (5.08.2019), respectively between -25.10 cm and 15.57 cm, values that were recorded on 11.08.2019.

If we do a detailed analysis on these differences it is found that they were insured during July (16.07.2019-30.07.2019), from a statistical point of view, from very significant negatives (ooo) in the case of experimental variants a2b2, a3b2, a3b3 and a3b4, up to very significant positive (***) in Control sample variants a1b1, a2b1 and a3b1. The differences in plant height at the beginning of August (5.08.2019) had very negative statistical assurance (ooo) for the experimental variants a1b3 and a3b2, distinctly significant negative (oo) to a2b2, significantly negative (o) to a3b3, insignificantly negative (NS) for variants a2b3 and a2b4, significantly

positive (*) for variants a1b2 and a1b4, distinctly significant positive (**) for a3b1 and a3b4, respectively very significantly positive (***) for Control variants a1b1 and a2b1 (Table 3).

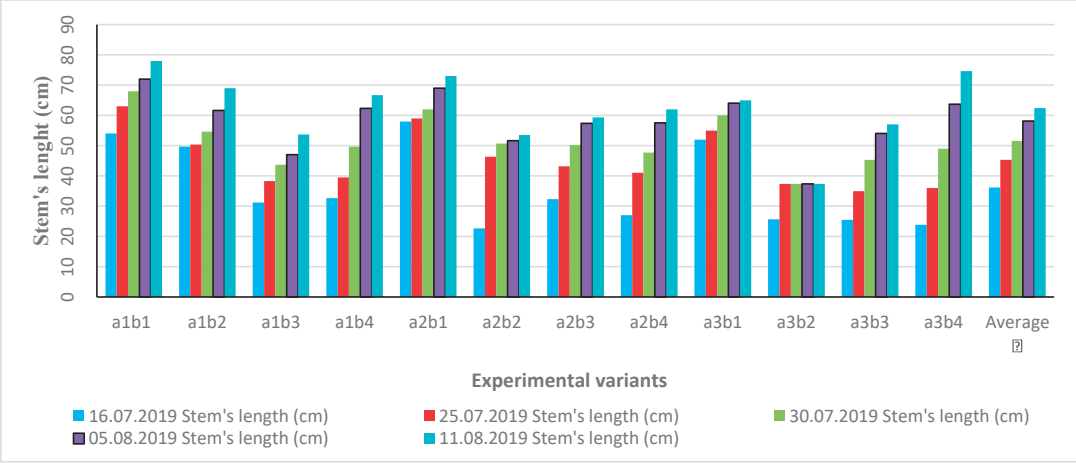

Figure 4. The values of the measured stem's length (cm), tomatoes plant- **Coralina** variety

Table 3.The values of the statistically assured differences calculated for the **Coralina** variety

Experimental variants	Date of experimental determination									
	16.07.2019		25.07.2019		30.07.2019		05.08.2019		11.08.2019	
	Dif. (cm)	Significance level	Dif. (cm)	Significance level	Dif. (cm)	Significance level	Dif. (cm)	Significance level	Dif. (cm)	Significance level
a1b1	17.79	***	17.67	***	16.48	***	13.88	***	15.57	***
a1b2	13.46	***	5.00	**	3.15	*	3.54	*	6.57	**
a1b3	-5.04	oo	-7.00	oo	-7.85	oo	-11.12	ooo	-8.76	Oo
a1b4	-3.54	o	-5.83	oo	-1.85	NS	4.21	*	4,24	*
a2b1	21.79	***	13.67	***	10.48	***	10.88	***	10.57	***
a2b2	-13.58	ooo	1.00	NS	-0.85	NS	-6.45	oo	-8.93	Oo
a2b3	-3.88	o	-2.16	o	-0.82	NS	-0.79	NS	-3.10	O
a2b4	-9.21	oo	-4.33	o	-3.85	o	-0.62	NS	-0.43	NS
a3b1	15.79	***	9,67	***	8.48	**	5.88	**	2.57	*
a3b2	-10.54	ooo	-8.00	oo	-14.19	ooo	-20.79	ooo	-25.10	Ooo
a3b3	-10.71	ooo	-10.33	ooo	-6.19	oo	-4.12	o	-5.43	Oo
a3b4	-12.38	ooo	-9.33	oo	-2.52	o	5.55	**	12.24	***
Averag, %	**36.21**		**45.33**		**51.52**		**58.12**		**62.43**	
DL5% = 2.46; DL1% = 6.08; DL0.1% = 10.22										

***, **, *, NS indicate statistical significance at the DL5%; DL1% and DL0.1% level and nonsignificant, respectively

Approximately, the same evolution is observed following the determinations made on 11.08.2019, the differences related to the size of plants being statistically ensured, from very significant negative (ooo) to experimental variant a3b2, to very significant positive (***) in the case of tomato plants tested in variants a1b1, a2b1 and a3b4., the lowest values of this biometric parameter being obtained in the case of plants belonging to the experimental variant a3b2, the plants developing under optimum lighting conditions, which led to obtaining some vigorous plants.

CONCLUSIONS

The results obtained at the biometric measurements (the size of the stems) showed that the answers were different in terms of all the factors involved: the assortment of tomatoes (3 varieties), the color spectrum of the light emitted by the LED devices (red, blue and white) but

also depending on the duration of exposure to daily treatments of additional short-term lighting (15, 30 and 45 minutes).

Thus, for tomato plants belonging to the Sonia de Buzău variety, the statistically significant was negative (ooo) response was registered for the combination of factors a2b2- (LEDs with red light x 15 minutes) as well as the combination of factors a1b4- (LEDs with blue light x 45 minutes exposure).

For the tomato plants of Hera variety, the statistically significant negative force (ooo) response was recorded at the combination of factors a2b4 (red light LEDs x - 45 minutes).

And in the case of the tomato seedlings of the Coralina variety, the statistically insured response, very negative (ooo) was registered to the experimental variant a3b2 consisting of the combination of factors a3 - LEDs white light x b2 - 15 minutes.

The analysis of the results recorded by the investigation of the biometric parameters, shows that by these additional lighting treatments, the tomato plants have developed much better compared to the plants of the control variant (without additional LED lighting treatment), which the plant stems they have gone a long way.

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