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Cultivation Technologies Applied in the Production of Tomato Plants for Obtaining Safe Food Products under the Conditions of Climate Change

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RESEARCH ARTICLE

Abstract

This paper presents the results obtained from the research realized in controlled environmental conditions in a horizontal greenhouse where seedlings from varieties of tomato lines in the process of testing for approval in Romania were used. The research was carried out in a three-factorial experimental scheme, in which were taken into consideration as variation factors: three cultivars of tomatoes, 3 colors of light emitted by the LED bulbs and 3 intervals of time (15, 30 and 45 minutes/day) for plant exposure to the monochromatic additional light treatment. Biometric measurements were made on the height and diameter of the stems and assessments of seedling weight, as well as analyzes on nutrient composition, accumulated after three months of cultivation in the greenhouse. The results obtained are within the limits mentioned by the specialized literature for the best seedlings for the tested varieties of tomatoes.

Keywords: monochrome LEDs lighting; sustainable technology; tomato.

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INTRODUCTION

Food production, food security and food safety are greatly influenced by climate change that occurs in present days. The impact of climate change is known very well for food production and security, while for food safety the impact is still being studied (Muehe et al., 2019). Climate change affects every year the accessibility, availability and stability of a major percent of food products, thus bringing major modifications in human health (micronutrients availability, malnutrition) and diet choices (Nelson et al., 2018). The0 quantity of precipitations also presents a great influence on food safety and security. Zheng et al*.*, 2013 studied the intake of foodborne pathogens through plant roots, this phenomenon being dangerous for human who will consume those plants. Foodborne diseases caused by different pathogens (*Salmonella* spp., *Escherichia coli*) are a threat to people health if the food products are consumed uncooked, as these pathogens can't be removed just by washing (Hirneisen et al., 2012).

Synthetic pesticides are used more often in the last years, and are designed to combat pest infestation that could lead to great food safety issues. The global pesticide market consists of approximately 45 billion dollars per year, and 4.2 million tonnes of pesticide active ingredients are used in the world's croplands (Pretty and Bharucha, 2015). As the pesticide market grows, food production systems are more vulnerable to the effects of contamination from pesticide pollution, thus being very important to reduce the dependence on synthetic pesticides in agriculture.

Concerns over the impact of pesticides used on crops all over the world are now more pressing, and registration procedures are becoming more stringent. These new regulations have reduced the number of available pesticides in some agricultural sectors, but there are still a lot of pesticides that are being used (Litskas et al., 2019; Badawy and Rabea, 2011). In order to solve the problems in agricultural production (biological diversity damage, natural and agricultural system harms, and public health concerns), it is important to develop environment friendly techniques that can be use while ensuring the healthy development of plants and sustainable agriculture. Therefore, alternative methods for disease and pest control include both biocontrol agents and biologically derived pesticides are developed also in Romania (Boiu-Sicuia et al., 2020; Toader et al., 2019). At the same time, in the current climate change, in order to prevent the intensification of soil, water resources and atmosphere degradation, it is especially recommended to use conventional agrochemicals with caution, and to replace them with ecological ones. (FAO, 2020; Lee-Ann et al., 2008).

Light emitting diodes (LEDs) represent a promising technology for the greenhouse horticultural industry through a series of technical advantages compared to traditional lighting sources. LEDs can be designed to emit broad band (white) light or narrow spectrum (color) bands for the desired plant responses (Mickens et al., 2019; Davis and Burns, 2016; Gómez and Mitchell, 2015; Singh et al., 2015; Lin et al., 2013; Olle and Virsile, 2013; Massa et al., 2008; Bula et al., 1991). In view of the above, current technology for the production of tomato plants aims to obtain healthy food, with as little input as possible

Through evaluations from previous studies conducted by various authors (Zheng et al., 2019; Burescu et al., 2015; Olle and Virsile, 2013; Morrow, 2008) and also by manufacturer companies (Philips data sheet # DS68), it is estimated that the efficiency of light emitting diodes (LEDs) in the conversion of electricity into photonic energy is constantly increasing. According to Mitchell et al., (2012), another major advantage of LEDs over all other types of lamps used for plant lighting is that LED technology is evolving at a rapid pace in term of the efficiency of electrical use.

The objectives proposed by the present research aimed at reducing energy consumption in greenhouses, by applying an environmentally efficient lighting technology with high-power LEDs, which are designed to support sustainable development, increase the competitiveness and development of the knowledge-based economy, in line with the requirements of the current society, saving energy and counteracting the effects of climate change.

MATERIALS AND METHODS

For the present studies, the seeds from three lines of tomato plants were used as biological material: L-75, L-76, L-1.03, provided by the Vegetable Research and Development Station Buzău (VRDS Buzău). The lines from the mentioned hybrids are currently in the process of homologation in Romania. Regarding the fruit characteristics of the three hybrids represented by the studied tomato lines, we mention that the L-75 line has red fruits, line L-76 presents orange fruits and line L-1.03 forms ox-heart type fruits, with a maximum weight up to 140 g/fruit. As for the morphology of the plants, all the analyzed varieties form stems of undetermined growth.

The seeds from the three lines of tomato were sown in alveolar trays, and grown in the Vegetation House of UASVM Bucharest starting with the first decade of September 2019. At approximately 7-8 days from the date of sowing, the germination of the first seeds was observed as well as the development of the seedlings resulting from them. About 30 days after sowing the seeds, the seedlings of the three varieties of tomato developed 2-3 layers of leaves on the stems.

Conditions for cultivation in the automated greenhouse

After 45 days from the sowing date, the tomato seedlings were transplanted in 7 cm plastic cups, and later in the experiment they were transferred to the automated horizontal greenhouse compartment (belonging to the Research Center for Studies of Food Quality and Agricultural Products from the UASVM Bucharest), to ensure the optimal temperature and light conditions necessary for development. The second transplanting of the seedlings was done in 15 cm square pots to 55 days in order to apply additional treatments by daily exposure to monochromatic light emitted by the LED diode devices.

For the seed sowing and after for tomato seedlings cultivaton a KEKKILÄ Professionl Substrate DSM 2W peat substrate, pre-fertilized with N:P:K base fertilizer (15-5-24 kg/m^3) and N-P_2O_5-K_2O (15-12-29 g/l) was used. This mixture had the pH adjusted to 5.9. The fertilization of seedlings was performed after transplanting with a complex fertilizer type Azofoska, having in composition macroelements like N:P:K (13.6-6.4-19.1 g/l) and small amounts of microelements (Mg, S, B, Fe, Mn, Mo, Zn). A first fertilization was applied three days after transplantation, in a concentration of 0.05% (5 g/10 l), using 150 ml of fertilizer solution for each vessel. For the experimental setting, the test period was selected in the light-deficient season or with accentuated clouds (September-November 2019).

For light supplementation, devices based on monochromatic light (blue and red) and areas of white light emitted by LEDs high power and continuous operation for short periods of time during the day, added to natural light, have been used, to analyze and compare the influence in the production of tomato plants (Figure 1). The LED devices were provided by ELECTROMAGNETICA S.A. Bucharest. In the experiments, the supplementary LED light was added in three time periods: 15, 30 and 45 minutes/day.

Figure 1. Aspect of artificial lighting with LED light application to tomato seedlings in the greenhouse compartment (UASVM Bucharest)

In order to evaluate the influence of artificial lighting on the main biometric parameters of tomato plants belonging to Lines L-75, L-76 and L-1.03, three bifactorial experiments were organized, experiments that were placed in protected space according to the method of subdivided plots, in three repetitions, resulting in 10 experimental variants, respectively: **V1**: non-artificial lighting (Control-Mt.); **V2**: white light for 15 minutes/day; **V3**: white light for 30 minutes/day; **V4**: white light for 45 minutes/day; **V5**: red light for 15 minutes/day; **V6**: red light for 30 minutes/day; **V7**: red light for 45 minutes/day; **V8**: blue light for 15 minutes/day; **V9**: blue light for 30 minutes/day; **V10**: blue light for 45 minutes/day.

The experiment was conducted with the three tomato plant varieties (lines), divided into three samples for Control variants (nontreated) and 27 samples for Experimental variants (with additional LEDs light treatments). In the case of each analyzed variety of tomato seedlings, the experience was conducted in three repetitions.

All tomato seedlings (control and experimental samples) were periodically watered and fertilized with organic products. Preventive treatments were applied in order to combat diseases and pests. Also, due to the climatic conditions with low intensity of natural lighting manifested in November and December 2019, in the compartment where the seedlings were grown, lamps with halogen, placed at the level of the canopy in the horizontal greenhouse remained functional for 7-8 hours/day.

Methods used to perform agrochemical parameter determinations

At the beginning and during the experiments, the plants were harvested and analyzed in terms of supply of nutrients absolutely necessary for the growth and development of crops. In the tomato plants analyzed in the stages of juvenile (seedlings) and mature (flowering) development, the following agrochemical analyzes were performed on the whole plant: $N\text{-}NO_3$ (ppm), $P\text{-}PO_4$ (ppm), K^+ (ppm).

The plant analyzes were performed according to the INCDAP Bucharest methodology (ICPA Bucharest, 1980) and included the following: determination of $N\text{-}NO_3^-$ by extraction in 2% CH_3COOH, 1:20 and colorimetric dosing with AFDS (Griess assay–STAS 3048-77), determination of $P\text{-}PO_4^{3-}$ extraction in 2% CH_3COOH, 1:20 and colorimetric dosing with Duval reagent; and determination of K^+ extraction 2% CH_3COOH, 1:20 and flamphotometric dosing (SR ISO 3696-2002).

Simultaneously, the nutrients and agrochemical indices from the culture substrates of the experimental variants were analyzed. The following analyzes were performed: pH in aqueous extract 1:2.5 and potentiometric dosing (SR ISO 10523-2012), soluble salt content extraction in water 1:5 and conductometric dosing (SR EN 27888-1997), N:P:K extraction in distilled water 1:5 and colorimetric dosing with AFDS for nitrates, colorimetric dosing with Nessler reagent for $N\text{-}NH_4^+$, $P\text{-}PO_4^{3-}$- colorimetric dosing with Duval reagent and K^+ flamephotometric dosing (STAS

7184/19-82). The methodology of analysis and interpretation of the results was performed according to the existing standards and norms in our country (ICPA Bucharest, 1987). The statistical method selected in interpreting the results was that of polynomial functions. Mathematical regression (R) was calculated using Microsoft Excell software.

RESULTS AND DISCUSSIONS

Results obtained in biometric measurements

During the analysis of the experimental results (Series I at 30 days/Series II at 42 days from the application of additional lighting treatments with monochrome LEDs) to the three lines of tomato and their exposure in the process of growth in white, red and blue LED light. The values obtained at the biometric parameters regarding: the average length of the stem (cm), the average weight of the plant (g) and the average diameter of the stem (cm), at the level of the plants from the Experimental variant samples and the Control for each were taken into account three varieties of tomatoes analyzed.

In each experiment was tested the influence of artificial lighting with LEDs on the growth dynamics of tomato plants belonging to Lines L-75 (Experience 1), L-76 (Experience 2), and L-1.03 (Experience 3), the interpretation of experimental results being made by the method of analysis of variance.

The performances registered at the parameters at plants level from the L-75 line, after 42 days from the application of additional lighting treatments with monochrome LEDs, are presented in Table 1, by analyzing the calculation of the statistically assured differences.

Analyzing the behavior of L-75 tomato line samples (Table 1), regarding the influence of artificial lighting with LEDs on the main biometric parameters of plants, it is observed that the height of the plants recorded values between 80 cm and 101.5 cm. The tallest plants were represented by variant V10, closely followed by the variant V8, the variant in which the tomato plants reached a height of 100 cm, both experimental variants differing very significantly positive (xxx) from the control variant V1, the variant in which the tomato plants had the smallest height of the stem, respectively 80 cm.

Table 1. The influence of artificial lighting with LED light on biometric parameters (average values)
Tomato line L-75 (Experience 1)

Experimental variants	Values of the statistically assured differences						Significance level		
	Stem length (cm)	Dif. (cm)	Weight (g)	Dif. (g)	Stem diameter (cm)	Dif. (cm)			
V1 (Control-Mt.)	80.00	-	51.44	-	0.50	-	-	-	-
V2	83.50	3.50	35.98	-15.46	0.30	-0.20	-	o	-
V3	85.00	5.00	72.92	21.48	0.30	-0.20	x	oo	-
V4	83.00	3.00	42.44	-9.00	0.30	-0.20	-	-	-
V5	69.50	-10.50	42.00	-9.44	0.20	-0.30	oo	-	-
V6	89.50	9.50	75.30	23.86	0.30	-0.20	xx	xxx	-
V7	82.00	2.00	45.65	-5.79	0.20	-0.30	-	-	-
V8	100.00	20.00	76.63	25.19	0.30	-0.20	xxx	xxx	-
V9	86.00	6.00	57.80	6.36	0.30	-0.20	x	-	-
V10	101.50	21.50	83.04	31.60	0.30	-020	xxx	xxx	-
	LSD $_{5\%}$ = 4.36 LSD $_{1\%}$ = 9.27 LSD $_{0,1\%}$ = 13.18		LSD $_{5\%}$ = 11.19 LSD $_{1\%}$ = 18.83 LSD $_{0,1\%}$ = 22.92		LSD $_{5\%}$ = 0.093 LSD $_{1\%}$ = 0.122 LSD $_{0,1\%}$ = 0.167				

Legend for Statistical significance: (-) – insignificant, (o) - significantly negative, (oo) - distinctly significant negative, (ooo) - very significant negative, (x) - significantly positive, (xx) - distinctly significant positive, (xxx) - very significant positive.

The weight of the tomato plants presented values between 35.98 g, the minimum value of this biometric indicator recorded for tomatoes belonging to variant V2, and 83.4 g, the maximum weight of tomato plants recorded for the experimental variant V10. Compared to tomato plants that benefited from natural lighting (V1), in which the total weight of the plants was 51.44 g, the rest of the experimental variants in which the influence of artificial lighting on plant growth and development were tested, differences between 15.46 g and 25.19 g were observed, differences with distinctly significant negative (oo) statistical assurance for variant V3, significantly negative (o) for experimental variant V2, insignificant (-) for variants V4, V5, V7 and V9 , the rest of the experimental variants registering very significant positive differences (xxx), in terms of plant weight.

Regarding the stem diameter (cm), it was found that the tomato line L-75 did not register significant differences in the experimental variants, the stem diameter measured varying between 0.2 and 0.5 cm, with statistically insignificant assurance (-), thus being able to say that the stem thickness in tomato plants was largely influenced by the genotypic characters and to a lesser extent by the color of the light or the duration of exposure of the plants to the artificial LED lighting.

For the performances registered at the parameters of the plants from the L-76 line (Experience 2) the results are presented in Table 2, by analyzing the calculation of the statistically assured differences.

Tomato plant samples belonging to the L-76 line (Table 2) were characterized by a vigorous growth, the height of the stem at the time of determination varying between 62 cm, the smallest height recorded in the case of plants grown in the experimental version V4, and 113 cm the highest value of this biometric indicator being determined for tomato plants grown in the experimental variant V5. Variants V10 (108 cm) and V7 (100 cm) were characterized by a large size, and presented a harmonious vegetative growth and development in the conditions in which they were artificially illuminated for 45 minutes/day.

Table 2. The influence of artificial lighting with LED light on biometric parameters (average values)-
Tomato line L-76 (Experience 2)

Experimental variants	**Values of the statistically assured differences**						**Significance level**		
	Stem length (cm)	Dif. (cm)	Weight (g)	Dif. (g)	Stem diameter (cm)	Dif. (cm)			
V1 (Control-Mt.)	98.00	-	78.73	-	0.40	-	-	-	-
V2	71.00	-27.00	51.80	-26.93	0.30	-0.10	ooo	ooo	oo
V3	96.00	-2.00	67.58	-11.15	0.30	-0.10	-	o	oo
V4	62.00	-36.00	27.23	-51.50	0.20	-0.20	ooo	ooo	ooo
V5	113.00	15.00	70.32	-8.41	0.20	-0.20	xxx	-	ooo
V6	89.00	-9.00	62.10	-16.63	0.20	-0.20	oo	oo	ooo
V7	100.00	2.00	58.73	-20.00	0.30	-0.10	-	oo	oo
V8	98.50	0.50	59.39	-19.34	0.40	0.00	-	oo	-
V9	93.50	-4.50	62.20	-16.53	0.30	-0.10	o	oo	oo
V10	108.00	10.00	58.55	-20.18	0.40	0.00	xxx	oo	-
	LSD 5% = 2.52 LSD 1% = 6.31 LSD 0,1% = 9.13		LSD 5% = 9.33 LSD 1% = 13.94 LSD 0,1% = 24.86		LSD 5% = 0.042 LSD 1% = 0.091 LSD 0,1% = 0.137				

Legend for Statistical significance: (-) – insignificant, (o) - significantly negative, (oo) - distinctly significant negative, (ooo) - very significant negative, (x) - significantly positive, (xx) - distinctly significant positive, (xxx) - very significant positive.

Compared to the control variant (V1), in which the tomato plants were naturally illuminated, the plant height being in this case 98 cm. In the other experimental variants, there were differences that ranged between 15 cm and 36 cm, differences that had very significant negative (ooo) statistical assurance for experimental variants V2 and V4, distinctly significant negative (oo) for variant V6, significantly negative (o) for V9 and very significantly positive (xxx) of 10-15 cm in the case of experimental variants V5 and V10. In the rest of the experimental variants, the differences related to the plant size were statistically insignificant (-).

In regard of the tomato plants weight, a fairly wide variation was observed between the experimental variants, the values recorded following the determination of this biometric parameter being between 27.23 g and 78.73 g, the highest values being obtained for cultivated tomato seedlings under natural lighting conditions (V1). Comparing the experimental variants that benefited from artificial LED lighting and the non-artificially illuminated Control variant, it is observed that the weight differences of tomato plants were statistically very significant negative (ooo) in the case of experimental variants V2 and V4, significantly negative (o) in V3, insignificant (-) in V5 and distinctly significant negative (oo) in the rest of the experimental variants tested in the experiment.

Following the biometric determinations related to the stem diameter (cm) of the tomato plants tested in the different experimental variants, it was found that the most vigorous plants were identified in the experimental variants V8 and V10, the plants having a stem diameter of 0.4 cm, similar to the values obtained in the variant taken as control of the experiment (V1), variant in which the tomato plants did not benefit from the contribution of artificial LED lighting. Thus, the differences from the control variant were statistically from very significant negative (ooo) in variants V4, V5 and V6, distinctly significant negative (oo), in variants V2, V3, V7 and V9, becoming insignificant (-) in the experimental variants V8 and V10.

At the level of the plants from line L-1.03 (Experience 3), the results for the performances registered at biometric parameters are presented in Table 3, by analyzing the calculation of the statistically assured differences.

Table 3. The influence of artificial lighting with LED light on biometric parameters (average values) **-** Tomato line L-1.03 (Experience 3)

Experimental variants	Values of the statistically assured differences						Significance level		
	Stem length (cm)	Dif. (cm)	Weight (g)	Dif. (g)	Stem diameter (cm)	Dif. (cm)			
V1 (Control-Mt.)	74.50	-	52.80	-	0.30	-	-	-	-
V2	73.00	-1.50	42.40	-10.40	0.20	-0.10	o	ooo	ooo
V3	73.00	-1.50	39.12	-13.68	0.20	-0.10	o	ooo	ooo
V4	110.00	35.50	68.70	15.90	0.20	-0.10	xxx	xxx	ooo
V5	69.50	-5.00	49.10	-3.70	0.20	-0.10	o	o	ooo
V6	79.00	4.50	39.74	-13.06	0.20	-0.10	x	ooo	ooo
V7	95.00	20.50	61.25	8.45	0.20	-0.10	xxx	x	ooo
V8	73.00	-1.50	41.34	-11.46	0.30	0.00	o	ooo	-
V9	83.00	8.50	39.59	-13.21	0.30	0.00	xx	ooo	-
V10	83.00	8.50	41.86	-10.94	0.20	-0.10	xx	ooo	ooo
	LSD 5%= 0.13; LSD 1%= 5.78; LSD 0,1%= 9.08		LSD5%= 3.06; LSD 1%= 8.54; LSD 0,1%= 9.63		LSD 5%= 0.046; LSD 1%= 0.062; LSD 0,1%= 0.087				

Legend for Statistical significance: (-) – insignificant, (o) – significantly negative, (oo) – distinctly significant negative, (ooo) – very significant negative, (x) – significantly positive, (xx) – distinctly significant positive, (xxx) - very significant positive.

The research results on the influence of artificial lighting on biometric indicators in tomato plants belonging to the L-1.03 line (Table 3) highlighted a great variability between the 10 experimental variants studied in terms of plant height and weight, while in terms of stem diameter, there were no large variations between tomato plants grown under artificial lighting, the differences becoming very significant only when comparative analysis is made with tomato plants grown under natural lighting.

Thus, following the measurements related to the height of the plants, it was found that this indicator had a value between 69.5 cm and 110 cm, the best results V4 tomato plants that presented an accelerated growth rhythm under the experimental conditions.

Compared to the height of the Control variant V1 (74.5 cm) in which the plants were exposed to natural lighting conditions, the other experimental variants studied the height of the plants registered differences between 1.5 cm and 35.5 cm, statistically significant differences (o) in variants V2, V3, V5 and V8, significantly positive (x) in variant V6, distinctly significant positive (xx) in V9 and V10, differences that were very significantly positive (xxx) in in the case of experimental variants V4 and V7.

Regarding the weight of the plants, it was observed that they behaved differently under the influence of artificial light, this biometric parameter being influenced by both the color of light and the duration of artificial lighting. The plants with the highest growth and development rate being experimental variant V4, the variant in which the weight of the plants was 68.7 g. At the opposite end were the tomato plants grown in conditions of artificial lighting with white LED, for 45 minutes/day, the weight of the plants in this case being only 39.12 g, well below the values recorded in the case of the other experimental variants.

The differences from the Control variant V1 were between 13.68 and 15.9 g, with a very significant negative statistical assurance (ooo) in V1, V3, V6, V8, V9 and V10, significantly negative (o) in variant V5, significantly positive (x) in V7 and very significantly positive (xxx) in the case of variant V4.

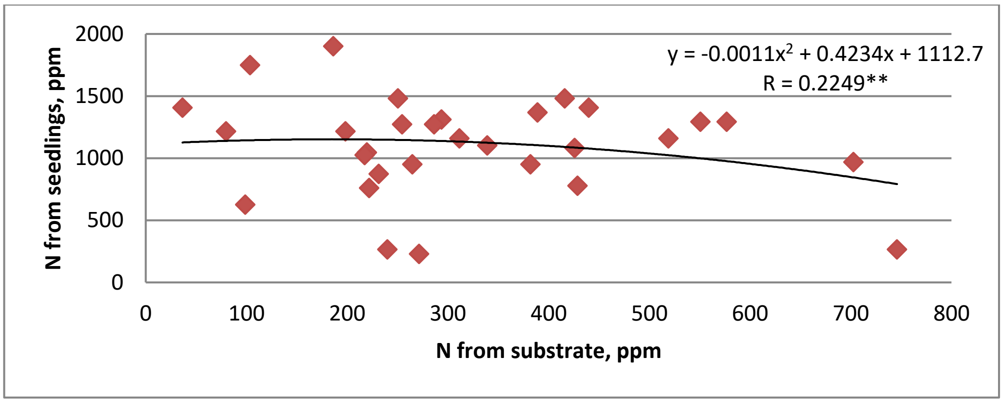
The stem diameter (cm) of the tomato plants ranged between 0.2 cm and 0.3 cm, with insignificant differences (-) compared to the Control in the case of experimental variants V8 and V9, the rest of the variants tested in the research registering very significant negative differences (ooo) in terms of the diameter of the stem of tomato plants.

Results obtained in agrochemical analyses

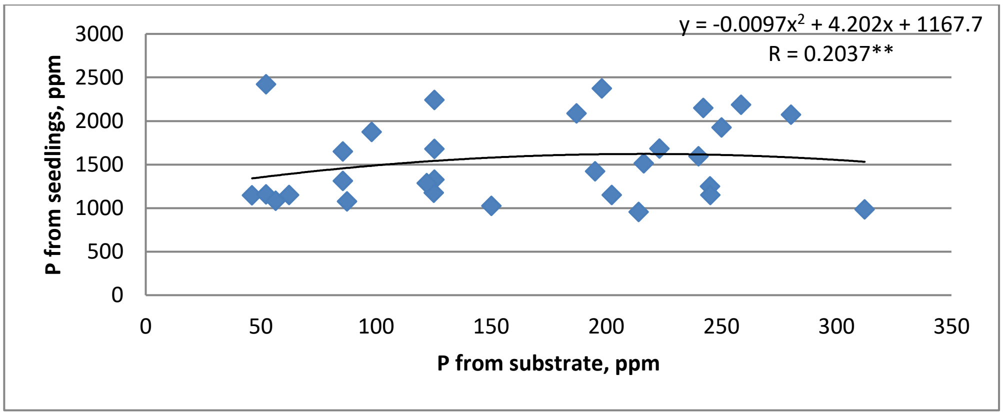
The first agrochemical analysis of the substrate was performed before applying additional treatments with LED light, at the time the seedlings were 55 days old, at sunrise. Thus, the results recorded in the seedling culture substrate of the 3 analyzed tomato lines were as follows: for the L-75 line concentrations of: 8.50ppm/N-NH^4, 504 ppm/N-NO_3, 217.17ppm/P-PO_4^{3-} and 67ppm/K^+; for the L-76 line concentrations of: 8.50ppm/N-NH^4, 414ppm/N-NO_3, 205.70ppm/P-PO_4^{3-} and 70ppm/ K^+; and in the soil of the L-1.03 line concentrations of: 4.25ppm/N-NH^4, 112.50 ppm/N-NO_3; 95.25ppm/P-PO_4^{3-} and 65ppm/K^+.

During the experiment, agrochemical analyzes were performed on the absorption of nutrients in seedlings. When planting, the chances of success of seedlings are higher if plants is supplied with nutrients such as N, P, and K. In order to see how the absorption was performed, statistical interpretation using polynomial regression curves were made.

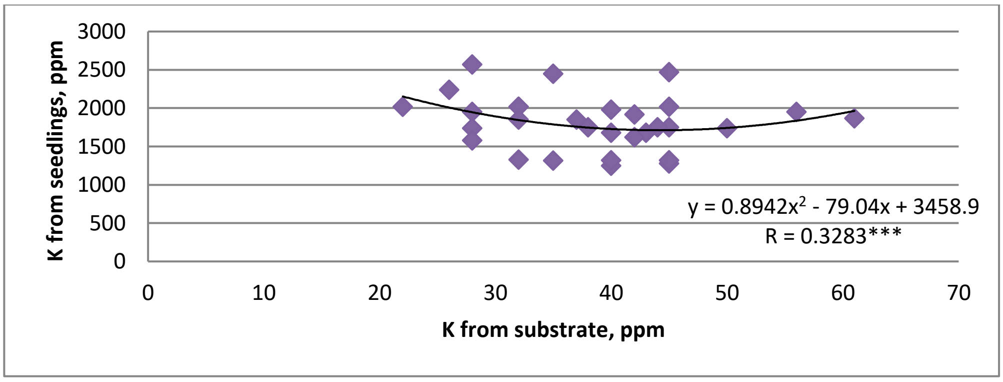
Statistical analysis in Series I (n=30), performed 30 days after the application of additional lighting treatments with monochrome LEDs, showed that nitrogen and phosphorus were absorbed in plants significantly different of the regression curve with correlation coefficient R=0.2249 to nitrogen (Figure 2a) and 0.2037 to phosphorus (Figure 2b) and potassium was very significantly absorbed at a rate of 0.3283 (Figure 2c).



(a)



(b)



(c)

Figure 2. Absorption of elements: a = N, b = P and c = K in seedlings of Series I analysis (after 30 days)

In the case of the Series II of analyzes (n=30), performed 42 days after the application of the additional lighting treatments with monochrome LEDs, the absorption rate of the nutrients increased (Figure 3a, b, c) so that at all nutrient elements we have registered a very significant absorption.

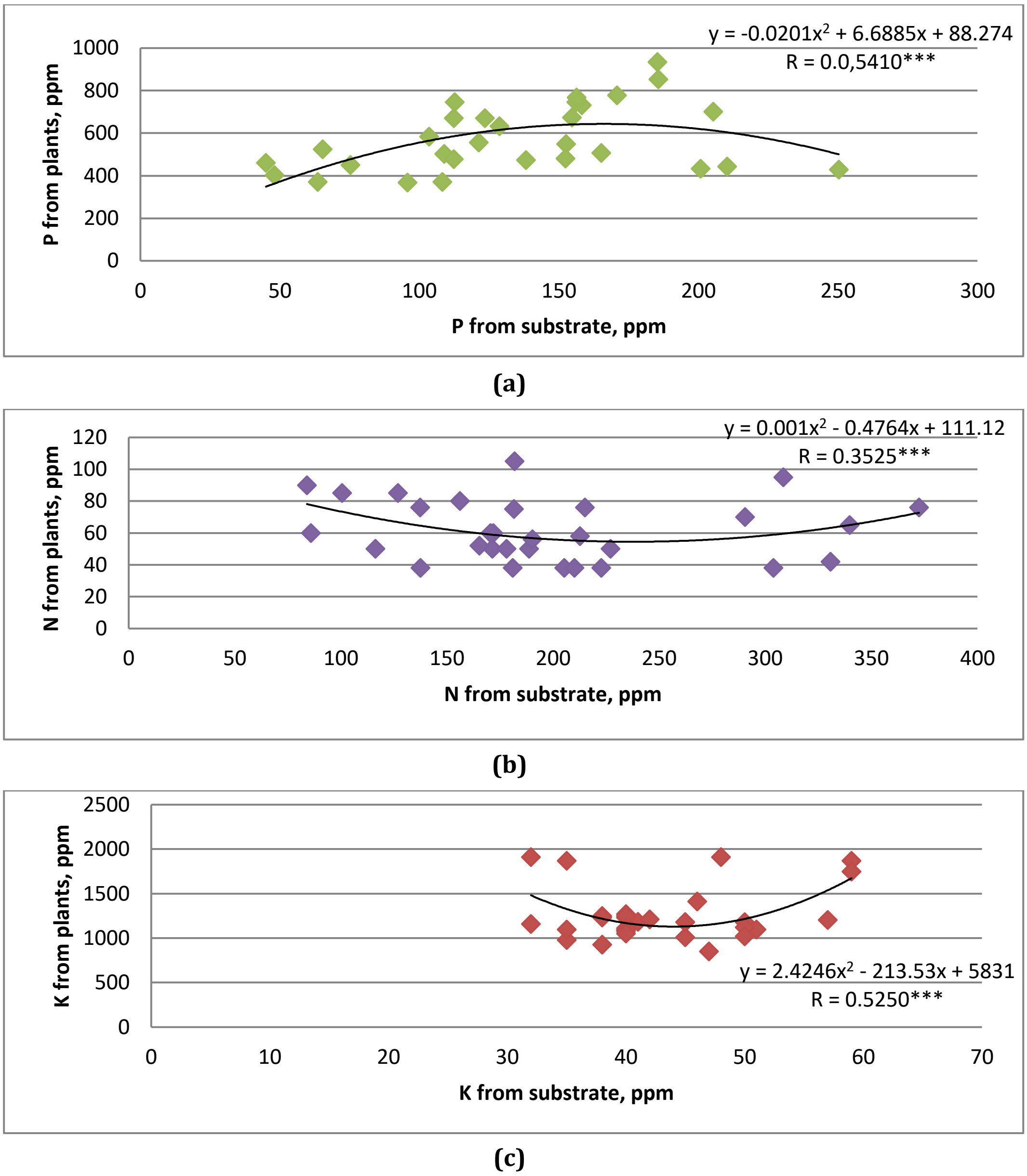


Figure 3. Absorption of elements: a = N, b = P and c = K, determined in seedlings of Series II of analyzes (after 42 days)

CONCLUSIONS

The high-power LED lighting technology, applied in the present experiment, on tomato seedlings is considered to be useful for sustainable development, in compliance with the requirements of nowadays society, energy saving and counteracting the effects of climate change.

For the average height (cm) parameter, the results obtained at the level of tomato seedlings, showed that: line L-75, responded favorably to the blue LED light 45 minutes/day as well as to the red LED light time of 30 minutes/day; for those in line L-76, the results exceeded those of the control after exposure to red light for 15 minutes/day and to the blue LED light 45 minutes/day; and in the case of tomato seedlings in line L-1.03 favorable for those exposed to white and red light 45 minutes/day.

The results obtained in biometric measurements demonstrated in the case of the average weight (g) determined at the level of tomato seedlings in line L-75, that they were favorable for those exposed to blue light for 15 and 45 minutes/day and to red light for 30 minutes/day. At the same parameter analyzed, for tomato seedlings in line L-1.03, the results exceeded those of the control after exposure to white light for 45 minutes/day.

The absorption and accumulation of nutrients N, P and K at the level of Romanian tomato seedlings in the studied lines (L-75, L-76, L-1.03), showed that for those in the experimental variants, it was rapid ensuring significant growth and development.

Author Contributions:

S.M.D-G, G.N., F.B., P.A.P., R-V.D., M.D., V-L.V., G.M., E.E.P., A.C.M., M.G-C., G.O., M.E.P. Conceived and designed the analysis; S.M.D-G , G.N., P.A.P. Collected the data; G.N., S.M.D-G, R-V.D., P.A.P., G.M., E.E.P. Contributed data or analysis tools; G.N., R-V.D., P.A.P., S.M.D-G, G.M., E.E.P. Performed the analysis; S.M.D-G, G.N., R-V.D., P.A.P. Wrote the paper.

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