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ASSESSMENT OF YIELD AND PHYSIOLOGICAL INDICES OF SMALL-SIZED TOMATO CV. 'BIANKA F_1' UNDER THE INFLUENCE OF BIOSTIMULATORS OF MARINE ALGAE ORIGIN

Małgorzata Mikiciuk, Renata Dobromilska
West Pomeranian University of Technology in Szczecin

Abstract. In the years 2009–2011 small-sized tomato plants cv. 'Bianka F_1' were sprayed with biostimulators on the basis of marine algae extracts: Acadian (at concentration 0.5%), Bio-algeen S-90 (at 0.5%) and Labimar 10S (at 0.3%). They were used three times: in the stage of 2–3 leaves, before planting and at the beginning of flowering. The aim of study was to evaluate of relationship between tomato yield, cluster features and physiological indices under various seaweed biostimulators. The experiment was carried out in a high plastic tunnel in the Vegetable Experimental Station near Szczecin. Total and marketable yield of tomato sprayed with Acadian and Labimar 10S was increased in comparison the plants treated with preparation Bio-algeen S-90 and the control plants (sprayed with water). All applied preparations had a beneficial influence on the early harvest of tomato fruits, length of clusters and number of fruits in the cluster. Spraying of leaves with Bio-algeen S-90 resulted in a significant increase chlorophyll a, b, a + b and carotenoids content. The applied of Labimar 10S increased of chlorophyll b and a + b level. The higher rate of CO_2 assimilation, larger index of effectiveness of water use in the photosynthesis and no effect stomatal conductance for water and CO_2 concentration in the intercellular pores of leaves were obtained after spraying of tomato with biostimulators. The applied of Labimar 10S and Bio-algeen S-90 decreased the rate of transpiration and significantly increased value of the relative water content index in the tissues of leaves.

Key words: *Lycopersicon esculentum* var. *cerasiforme* Alef., Acadian, Bio-algeen S-90, Labimar 10S, chlorophyll, photosynthesis, transpiration

INTRODUCTION

The growing interests in ecological and sustainable production of vegetables and a decreasing number of crop-protection preparations allowed for the application result in the tendency towards searching for preparations based on biological substances that

Corresponding author: Renata Dobromilska, Chair of Gardening, West Pomeranian University of Technology in Szczecin, Papieża Pawła VI 1, 71-459 Szczecin, e-mail: renata.dobromilska@zut.edu.pl

can be used in the production instead of synthetic means [Basak 2008, Jayaraj et al. 2008, Khan et al. 2009]. Some of these substances act like typical elicities – factors inducing acquired system plant resistance to pathogens [Jayaraj et al. 2010] or damages, others provide required microelements and components or organic substances ready for a direct use by plants, e.g. amino acids, proteins [Stępowska 2008]. Biostimulators can also contain hormones and enzymes [Hong et al. 1995, Boehme et al. 2005, Craigie 2010]. According to the Plant Protection Act of December 18th 2003 [Dz. U. nr 11], these are active substances or preparations containing one or more active substances in the form provided to the user, the purpose of which is (…) to affect vital processes of plants in a different way from that performed by a nutritive component. The expected aim of the application of biostimulators to cultivation is, among other things, to increase the tolerance of plants to stress conditions: heat and freezing temperatures [Sharma et al. 2005, Rayirath et al. 2009], drought [Zhang and Ervin 2008] or salinity [Matysiak and Adamczewski 2006].

The applied biostimulators: Bio-algeen S-90, Labimar 10S and Acadian are produced on the basis of marine algae extracts. Their large biological activity results from a high content of natural growth regulators: auxins, cytokines and gibberellins and other organic substances such as betain, laminarin, arginine, vitamins and nucleic acids [Lung 1999, Lapin 2008]. The aim of the carried out studies was to evaluate the effect of three biostimulators on the physiological indices determining the productivity of small-sized tomato, cv. 'Bianka F_1'.

MATERIAL AND METHODS

In 2009–2011 an experiment, in which preparations of marine algae origin were applied to cultivation of small-fruited tomato, cv. 'Bianka F_1' (ToMVFol:0.1 ForVaVd-MaMiMjSi), was carried out in the Vegetable Experimental Station of West Pomeranian University of Technology in Szczecin (53°27'N and 14º25'E). The experiment was set up in a high plastic tunnel in a system of random blocks in four replications. The experimental factor was the kind of the applied biostimulator, i.e.: Acadian (Agritech Nova Scottia, Canada), Bio-algeen S-90 (Schulze & Herman GmbH) and Labimar 10S (Polger Kido Sp. z o.o.). The control objects were the plants that were sprayed only distilled water. The surface of one plot amounted to 3.5 m^2 (10 plants in the plot). Bio-algeen S-90 is a preparation produced on the basis of the extracts of *Ascophyllum nodosum* (L) Le Jol. marine algae. It contains among other things: N (0.02%), K (0.096%), P (0.006%), Mg (0.21%), Ca (0.31%), Fe (6.3 mg·kg^{-1}), B (16 mg·kg^{-1}), Mo, Co and Se [Patier et al. 1993]. Labimar 10S produced with the contribution of the extract of brown algae includes: dry matter (45%), organic matter (36% – amino acids, vitamins, mono-, poly- and oligosaccharides, enzymes, phytohormones), organic boron (2.5%) [http://www.polger-kido.pl/lab10s/lab10s.html]. Acadian Seaplants is a microfertiliser obtained from *Ascophyllum nodosum* (L) Le Jol. algae. According to the manufacturer, this preparation contains substances determining many biochemical changes in plants, leading, among other things, to an increase in the synthesis of proteins and enzymes, improvement of parameters of water balance and integrity of membranes. Acadian contains: organic matter (13–16%), N (0.3–0.6%), K_2O (5–7%), P_2O_5 (<0.1%), S (0.3–0.6), Mg (0.05–0.1%), Ca (0.1–0.2%), Na (1–1.5%), Fe (30–80 ppm), B (20–50 ppm), Zn (5–15 ppm), Cu (1–5 ppm), Mn (1–5 ppm), carbohydrates (alginic acid, mannitol, laminarin), amino acids (total 1.01%) and vitamins [http://www.acadianagritech.com].

Tomato seeds were sown in the propagating greenhouse on 25 March. Seedlings were planted in the unheated plastic tunnel in the second decade (second ten day period) of May in row spacing of 1.4 × 0.25 m. The plants were led to one shoot, diagonally in a V shape per 6 clusters. Plants were cultivated in soil with optimum content of mineral elements for tomato. Foliar application of biological preparations: Acadian (0.5%), Bio-algeen S-90 (0.5%), Labimar 10S (0.3%) was performed three times. The first spraying was carried out in the stage of 2–3 leaves, the second one – before planting the plants in the tunnel and estimation the third spraying – at the beginning of flowering. The fruits were picked from the third decade of July to the first decade of September. The total, marketable and early yield was estimated (early yield = over first 3 harvests).

The measurements of gas exchange in leaves consisted in the determination of the intensity of the process of net photosynthesis (A), transpiration (E) stomatal conductance for water (g_s) and the CO_2 concentrations in the intercellular pores of assimilation parenchyma (c_i). They were made on the leaves at the lower, middle and upper part of the tomato stems in 8 replications. The results were averaged. Parameters of gas exchange were determined using the TPS-2 gas analyser with a PLC-4 chamber (PAR – 1000 $\mu mol \cdot m^{-2} \cdot s^{-1}$), manufactured by PP Systems (UK). The results of the measurements carried out on healthy, fully grown leaves of tomato after stabilisation of the gas analyser reading. On the basis of the obtained results of the intensity of assimilation and transpiration, the index of effectiveness of water use in the process of photosynthesis (ω_F) evaluated by the A: E ratio, was calculated.

The measurement of the content of assimilation pigments was made on the same leaves of tomato on which the activity of gas exchange had been studied earlier. The content of chlorophyll was determined by Arnon and co-workers' method [1956] modified by Lichtenthaler and Wellburn [1983] whereas the determination of carotenoids was made using the method of Hager and Mayer-Berthenrath [1966].

The content of water was defined in the same leaves and the same time in which the intensity of gas exchange was measured on the basis of the relative water content (RWC) [Bandurska 1991].

The obtained results were worked out using the one-factor analysis of variance in the system of random blocks, using Statistica 7.1 (Statsoft, Poland). In order to compare averages, Duncan's test (significance level $\alpha = 0.05$) was used and homogenous groups were created. Due to homogeneity of error variance, a synthesis of the results of two year studies was carried out. Coefficients of linear correlation between the measured variables describing gas exchange in tomato were calculated. When the coefficient of linear correlation between the variables was significant at the level of significance $\alpha = 0.05$, the relationship was illustrated in diagrams (fig. 2, 3).

RESULTS AND DISCUSSION

The results of tomato yielding proved, that the total yield and the marketable yield depended significantly on the kind of biostimulators (tab. 1). Three-time-spraying with preparation Acadian and Labimar had increased the total yield average by 0.8, and the marketable yield by 0.54 kg·m^{-2} in comparison the plants sprayed with preparation Bio-algeen and to the control plants. All applied in the experiment biostimulators have significantly increased the early harvest of tomato, average by 0.19 kg·m^{-2} in relation to the control. Many years ago, Abetz [1980] and Abetz and Young [1983] have written about positive effect of seaweed extract from *Ascophyllum nodosum* (L) Le Jol. on yield and quality of vegetables. According to Dobromilska and Gubarewicz [2008] spraying tomato plants cv. 'Conchita F$_1$' with Bio-algeen S-90 in the concentration of 0.3% significantly increased the total, marketable yield and biological value of fruit. The plants treated with biostimulators made longer clusters and also greater number of fruits in the cluster. Verkleij [1992] have added about benefit results seaweed extract in agricultural crops.

Table 1. Effect of seaweed extracts on the yielding and some features of small-sized tomato cv. 'Bianka F$_1$'

Kind of biostimulators	Yield of fruit (kg·m^{-2})			Length of cluster (cm)	Fruit number in cluster (pcs)
	total	marketable	early		
Acadian	9.56 b*	8.81 b	2.67 b	11.3 b	6.1 b
Bio-algeen S90	8.57 a	8.15 a	2.59 b	10.7 b	5.9 b
Labimar 10S	9.28 b	8.67 b	2.61 b	10.6 b	6.0 b
Control	8.65 a	8.24 a	2.43 a	9.8 a	5.5 a
Mean	9.02	8.47	2.58	10.6	5.9

* – Averages followed by the same letter do not differ significantly at $\alpha = 0.05$ (Duncan's range test)

Assimilation pigments (chlorophylls and carotenoids) play a key role in the processes of the absorption of light energy and its conversion to chemical energy stored in the products of photosynthesis [Dżugan 2006]. According to Eris et al. [1995], Blunden et al. [1997], Pramod et al. [2000] and Radžepowič et al. [2006] the application of extracts of marine algae origin to plant cultivation influences the content of chlorophyll in leaves and the observed content of these pigments is determined mainly by the amount of betain contained in the extracts. On the basis of the data included in tab. 2, it can be stated that treating the plants with the studied biostimulators increased the content of chlorophyll a, b and total in leaves of small-fruited tomato, cv. 'Bianka F$_1$'. The smallest increase in the synthesis of these pigments was observed after the application of Acadian, whereas the largest – in plants treated with Bio-algeen S-90. The leaves of plants sprayed with Bio-algeen S-90 contained more chlorophyll a, b and total by 42.8, 80.4 and 51.9%, respectively, as compared to the control objects (tab. 2). It is assumed that chlorophyll a and chlorophyll b occur in plants most frequently in the ratio 3 : 1 [Kung-Fang 2000]. In the carried out studies the highest ratio of these forms of chlorophyll was observed in control plants (3.14). Whereas, a lower ratio was recorded in tomatoes sprayed with biostimulators. It ranged from 2.22 in the case of plants treated with Labimar 10S to 2.49 in plants sprayed with Bio-algeen S-90. It resulted from the significant influence of Bio-algeen S-90 and Labimar 10S on increase in the content of chlorophyll b in leaves.

Table 2. Content of assimilation pigments in leaves of small-sized tomato cv. 'Bianka F_1'

Kind of biostimulators	Content of assimilation pigments ($mg \cdot g^{-1}$ f. w.)				
	chlorophyll a	chlorophyll b	chlorophyll a + b	ratio a:b	carotenoids
Acadian	1.369 a*	0.570 ab	1.939 ab	2.40	0.721 a
Bio-algeen S90	1.927 b	0.774 c	2.701 c	2.49	0.968 b
Labimar 10S	1.515 a	0.683 bc	2.198 b	2.22	0.792 a
Control	1.349 a	0.429 a	1.778 a	3.14	0.716 a
Mean	1.540	0.616	2.156	2.56	0.978

* – Averages followed by the same letter do not differ significantly at $\alpha = 0.05$ (Duncan's range test)

In the case of carotenoids the statistical analysis did not show any significant differences between the content of these pigments in the leaves of plants treated with Acadian and Labimar 10S and the control plants. Whereas, Bio-algeen S-90 caused a significant increase in the content of carotenoids in leaves of the studied variety of tomato (35.2% as compared to the control objects). Similar results of the studies of the influence of Bio-algeen S-90 on the content of chlorophyll and carotenoids in the leaves of small-fruited tomato, cv. 'Conchita F_1' were shown by Dobromilska et al. [2008].

Photosynthesis and transpiration and also photosynthetic effectiveness of water use, otherwise called effectiveness of gas exchange are the basic physiological processes determining the crop yields. Plants treated with biostimulators were characterised by a significantly higher intensity of CO_2 assimilation than that of the control objects (tab. 3). A particularly distinct was the effect of Acadian, for the intensity of photosynthesis in tomato sprayed with this preparation was two times higher than in the control plants. Biostimulators Labimar 10S and Bio-algeen S-90 significantly decreased the intensity of transpiration in the studied variety of tomato. Plants treated with Acadian were characterised by transpiration at a similar level as the control plants.

In plants sprayed with biostimulators a significant increase in the index of effectiveness of water use in the photosynthesis (ω_F) was observed. The largest increase in the value of ω_F was recorded in plants treated with Labimar 10S (133.7% in relation to the control variant) and with Bio-algeen S-90 (124.3% as compared to the control). The studies by Dobromilska et al. [2008] on the influence of Bio-algeen S-90 on physiological parameters of small-fruited tomato cv. 'Conchita F_1', showed that the intensity of assimilation and transpiration and the index of effectiveness of water use depended on the number of spraying with this preparation. In plants sprayed twice or three times, a higher rate of transpiration and assimilation was observed, but lower effectiveness of use of water.

Table 3. Parameters of gas exchange of small-sized tomato cv. 'Bianka F_1'

Kind of biostimulators	Parameter				
	A^*, μmol·m^{-2}·s^{-1}	E, mmol·m^{-2}·s^{-1}	ω_F, mmol·mol^{-1}	g_s, mol·m^{-2}·s^{-1}	c_i, μmol·mol^{-1}
Acadian	13.90 b**	3.58 b	3.88 b	0.268 a	361.50 a
Bio-algeen S90	11.70 b	2.58 a	4.53 b	0.285 a	298.67 a
Labimar 10S	10.60 b	2.43 a	4.36 b	0.243 a	311.83 a
Control	6.68 a	3.46 b	1,94 a	0.267 a	304.33 a
Mean	10.70	3.01	3.55	0.266	319.08

*A – intensity of CO_2 assimilation, E – intensity of transpiration, ω_F – water use photosynthetic efficiency, g_s – stomatal conductance for water, c_i – concentration of CO_2 in the intercellular spaces; ** – averages followed by the same letter do not differ significantly at $\alpha = 0.05$ (Duncan's range test)

The intensity of the processes of photosynthesis and transpiration depends on the stomatal conductance (g_s), the characteristic feature of which is simultaneously the rate of diffusion of water vapour from the leaf and the linear rate of the forced flow of air through the leaf [Ludlow 1982]. Stomatal conductance is regulated by interaction of many environmental factors, e.g. soil drought, salinity, and also internal factors such as, for example, CO_2 concentration in intercellular pores, water potential in the leaves, hydraulic resistance of xylem and a physiological state and a kind of plant [Sultana et al. 1999, Maleszewski et al. 2003, Tuzet et al. 2003, Wróbel 2006]. Stomatal conductance for the water vapour in leaves of the studied variety of tomato treated with three different biopreparations and in control plants was approximate and it varied from 0.243 for Labimar 10S to 0.285 mol·m^{-2}·s^{-1} for Bio-algeen S-90 (tab. 3). The statistical analysis did not show any significant differences between compared experimental variants in respect of the CO_2 concentration in the intercellular pores of parenchyma (c_i), either. Only in the leaves of tomato treated with Acadian, c_i was higher by 18.8% as compared to the control objects.

The index of relative water content (RWC) is a measure of hydration of leaf tissues, which determines to a large extent their biochemical and physiological activity. The largest values of this index were characteristic of the leaves of tomato treated with Labimar 10S and Bio-algeen S-90 (they amounted to 94.1 and 95.2%, respectively). While the relative content of water in the leaves of plants sprayed with Acadian varied at a lower level, approximate to the content of water in the control objects (fig. 1).

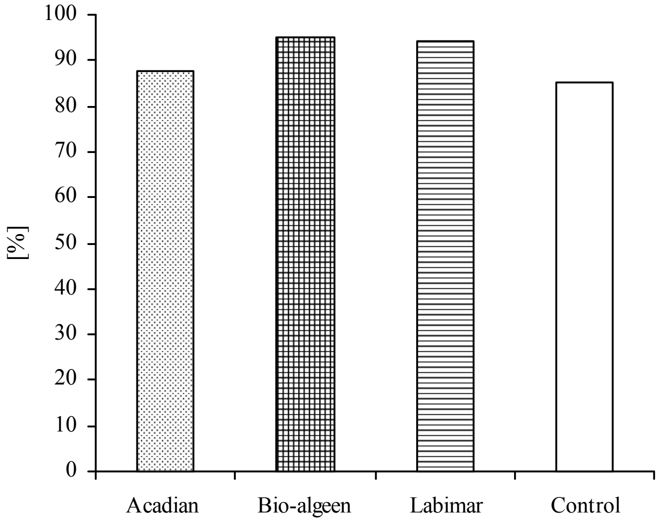

Fig. 1. Changes in relative water content (RWC) in leaves of small-sized tomato cv. 'Bianka F_1' depending of kind of biostimulators

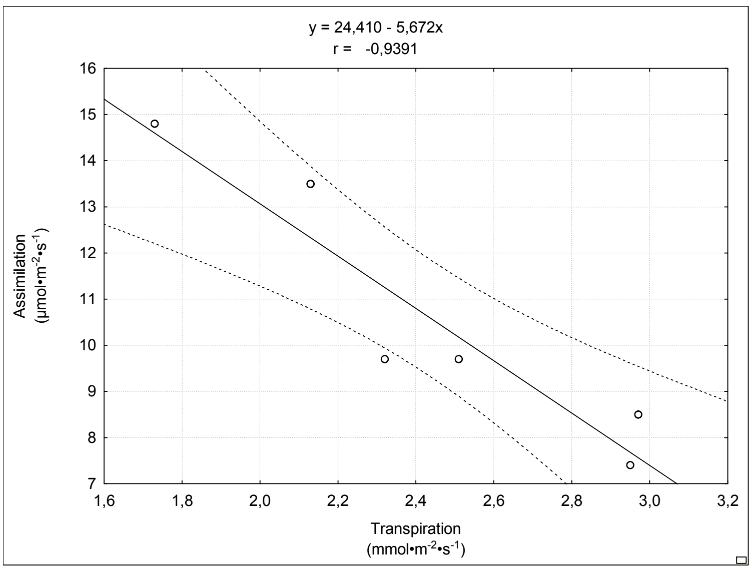

Fig. 2. Dependence of CO_2 assimilation on transpiration of small-sized tomato cv. 'Bianka F_1 sprayed with Labimar 10S

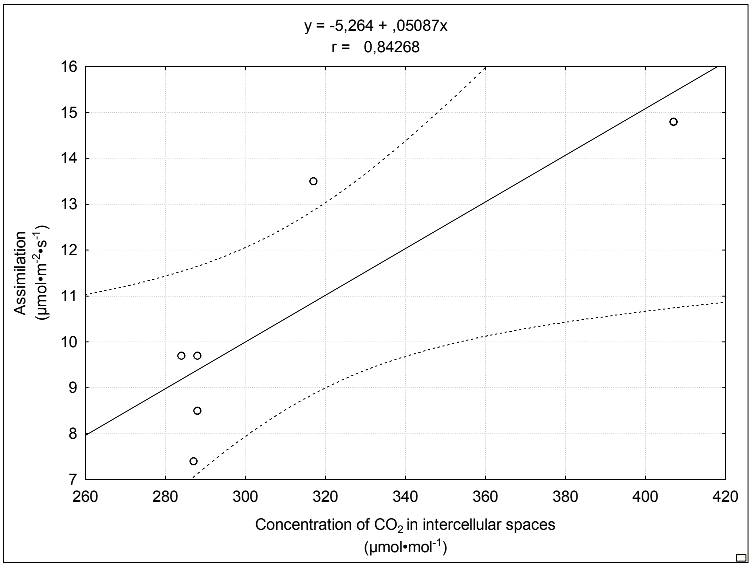

Fig. 3. Dependence of CO_2 assimilation on concentration of CO_2 in intercellular spaces of small-sized tomato cv. 'Bianka F_1' sprayed with Labimar 10S

The analysis of a straight line correlation between the determined variables that characterise the gas exchange of tomato showed a significant negative relationship between the intensity of assimilation and transpiration in plants treated with Labimar 10S. In the same plants, a significant positive relationship between the assimilation rate and the CO_2 concentration in the intercellular pores of leaves was also shown (fig. 2, 3). Also Starck et al. [1993] and Mikiciuk and Mikiciuk [2009] observed the relationship between these physiological features. In the case of plants sprayed with the remaining biostimulators and the control ones no significant correlation relationships between parameters of gas exchange were observed.

CONCLUSIONS

1. Three-time-treatment of the tomato with Acadian or Labimar 10S has significantly increased the total and the marketable yield of fruit in comparison to the plants sprayed with Bio-algeen S-90 and to the control plant. Application of preparation of see algae has increased the early yields of tomato fruit.

2. The tomatoes treated with preparations of sea algae made longer clusters and also greater number of fruits in the cluster.

3. Application of Bio-algeen S-90 increased the content of chlorophyll a, b, total and carotenoids in the leaves of small-sized tomato, cv. 'Bianka F_1'. Spraying with Labimar 10S increased in the content of chlorophyll b and total in leaves of the studied variety of tomato.

4. The plants treated with biostimulators were characterised by a significantly higher rate of CO_2 assimilation and a larger index of effectiveness of water use in the photosynthesis and no effected on stomatal conductance for water and CO_2 concentration in the intercellular pores of leaves. The rate of transpiration decreased after sprayed them with solutions of biostimulators Labimar 10S and Bio-algeen S-90.

5. The largest values of the relative water content index in the tissues were characteristic of the leaves of tomato treated with Labimar 10S and Bio-algeen S-90.

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http://www.polger-kido.pl/lab10s/lab10s.html
http://www.acadianagritech.com

OCENA PLONU ORAZ WSKAŹNIKÓW FIZJOLOGICZNYCH POMIDORA DROBNOOWOCOWEGO ODMIANY ‘BIANKA F$_1$’ POD WPŁYWEM BIOSTYMULATORÓW Z ALG MORSKICH

Streszczenie. W latach 2009–2011 rośliny pomidora drobnoowocowego odmiany ‘Bianka F$_1$’ były opryskiwane biostymulatorami na bazie ekstraktów z alg morskich: Acadian (w stężeniu 0,5%), Bio-algeen S-90 (0,5%) i Labimar 10S (0,3%). Preparaty stosowano trzykrotnie: w fazie 2–3 liści, przed sadzeniem oraz na początku kwitnienia. Celem badań była ocena zależności pomiędzy plonem pomidora, cechami gron i wskaźnikami fizjologicznymi pod wpływem różnych biostymulatorów z alg morskich. Doświadczenie przeprowadzono w wysokim tunelu foliowym w Warzywniczej Stacji Badawczej koło Szczecina. Opryskiwanie roślin preparatem Acadian i Labimar 10S zwiększyło plon ogółem i plon handlowy pomidora w porównaniu z roślinami traktowanymi preparatem Bio-algeen S-90 oraz roślinami kontrolnymi (opryskiwanymi wodą). Wszystkie stosowane preparaty miały korzystny wpływ na wielkość plonu wczesnego owoców pomidora, długość gron i liczbę owoców w gronie. Opryskiwanie liści preparatem Bio-algeen S-90 istotnie zwiększyło zawartość chlorofilu a, b, a + b oraz karotenoidów. Zastosowanie preparatu Labimar 10S zwiększyło poziom chlorofilu b oraz a + b. Rośliny pomidora opryskiwane biostymulatorami charakteryzowały się większym natężeniem asymilacji CO_2, większym wskaźnikiem efektywności wykorzystania wody w fotosyntezie. Nie stwierdzono wpływu preparatów na przewodność szparkową dla wody oraz na stężenie CO_2 w przestworach międzykomórkowych liści. Zastosowanie preparatów Labimar 10S i Bio-algeen S-90 zmniejszyło intensywność transpiracji oraz istotnie zwiększyło wartość wskaźnika względnej zawartości wody w tkankach liści.

Słowa kluczowe: *Lycopersicon esculentum* var. *cerasiforme* Alef., Acadian, Bio-algeen S-90, Labimar 10S, chlorofil, fotosynteza, transpiracja

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