Biological features of growing tomatoes in closed agroecosystems

Oksana Vershinina*, *Inna* Knyazeva, and *Vladimir* Gudimo

Federal Scientific Agroengineering Center VIM, 109428, Russia

Abstract. Researches were conducted in 2019-2020 in the department of closed artificial agroecosystems for plant growing on the basis of Federal State Budgetary Scientific Institution "Federal Scientific Agroengineering Center VIM", Moscow. The object of the study was the seeds of tomatoes Solanum lycopersicum L. The aim of the research was to study the effect of a biostimulant (succinic acid) on biological characteristics and productivity of Solanum lycopersicum L. grown in the substrate hydroponics of a climatic chamber. As a result of conducted researches, there was identified the most effective method of using succinic acid as a biostimulator – inoculation of seeds, which contributed to an increase in yield with a significant rise in relation to the control – 64.1%. The average fruit weight in this variant was 114.1 g, which exceeds the control by 37.0%. The complex application of the biostimulator provided an increase in the average fruit weight in 18.6%, the addition of hydroponics to the nutrient solution is 4.1%.

1 Introduction

Soil-free cultivation of vegetable crops in closed agroecosystems is a promising and economical alternative to open lands due to high productivity, environmental safety and excellent quality of finished products. High performance is achieved by adapting the indoor climate in terms of controlling lighting, temperature, and relative humidity, as well as minimizing interaction with the outdoor climate [1, 2].

Tomatoes belong to the family Solanaceae and the genus Solanum. They are not only the most popular vegetable crop, but also the most cultivated vegetable in the world (4.7 million hectares) [3]. Tomatoes are widely used as a model culture for various physiological, cellular, biochemical, molecular and genetic studies. Tomatoes are grown in greenhouses or growth chambers in soil, substrates, or aeroponically, without a substrate [4].

Currently, due to the interest of consumers in environmentally friendly food products, the search for new highly effective ways of growing and improving the quality of finished vegetable products in closed agroecosystems is relevant.

* Corresponding author: tomasss1086@mail.ru

The aim of the research is to study the effect of the biostimulant (succinic acid) on biological characteristics and productivity of Solanum lycopersicum L. grown in the substrate hydroponics of a climatic chamber.

2 Materials and methods

Researches were conducted in 2019-2020 in the department of closed artificial agroecosystems for plant growing on the basis of the Federal State Budgetary Scientific Institution "Federal Scientific Agroengineering Center VIM", Moscow. As an object of research, we used tomato seeds (Solanum lycopersicum L.) of the variety 'Lyana', included in the State Register of Breeding (selection) Achievements, approved for use on the territory of the Russian Federation [5].

The dry matter was determined by drying the sample to a constant mass in a Memmert UN-450 drying chamber (Germany) according to GOST 31640-2012. The photosynthetic pigment content was determined by the Lichtentaller method. The total content of pigments was determined by the spectrophotometric method using the Speks SSP-705M spectrophotometer (Russia). 100% acetone was used as a solvent (for spectroscopy).

Succinic acid was used at the stage of seed inoculation and with constant drip watering of plants.

The experiment included the following treatment options:

I. Control-without inoculation (seeds soaked in water);

II. Seeds without inoculation with the introduction of succinic acid in a hydroponic solution;

III. Inoculation of seeds with succinic acid;

IV. Inoculation of seeds with succinic acid and its introduction into a hydroponic solution.

As a substrate, mineral wool mats with a horizontal fiber structure were used to ensure an optimal uniform distribution of water and necessary nutrients along the entire length of the mat.

The data analysis was evaluated by the method of variance analysis using the STADIA 8.0 program. The SSD (smallest significant difference) was used to check the significance of the obtained data at a probability level of $p < 0.05$.

3 Results and discussion

Phenological observations and signs of growth and development of the studied tomato plants in closed ground differed depending on the method of applying an aqueous solution of succinic acid. In the variants of the experiment with seed treatment, seedlings appeared 3 days earlier compared to the control and untreated seeds. The flowering phase of the first sprout occurred 5 days earlier (42 days from the beginning of germination) in the variants with seed treatment (option III) and the complex action of the preparation (option IV) compared to the control (45 days). The earliest fruit maturation was observed on tomato plants in variant IV. The average length of the growing season was 145 days.

Important morphological parameters include the height of plants and the intensity of daily growth, which subsequently determine the size of elements of the plant structure and its quality. The amount of plant growth depends on the biological characteristics of the cultivar, the diet and supported growing conditions. Observations in the experiment showed that the most intensive growth in tomato plants was observed in the flowering phase of 1.8-2.4 cm per day with the highest value in the variant with pre-sowing seed treatment and the addition of hydroponics to the nutrient solution (Fig. 1). Plants by the flowering phase had

a shoot length of 29.7-36.0 cm in the experimental versions relative to the control – 27.1 cm. The tallest plants were noted in the variants with the addition of a biostimulator to the hydroponic nutrient solution.

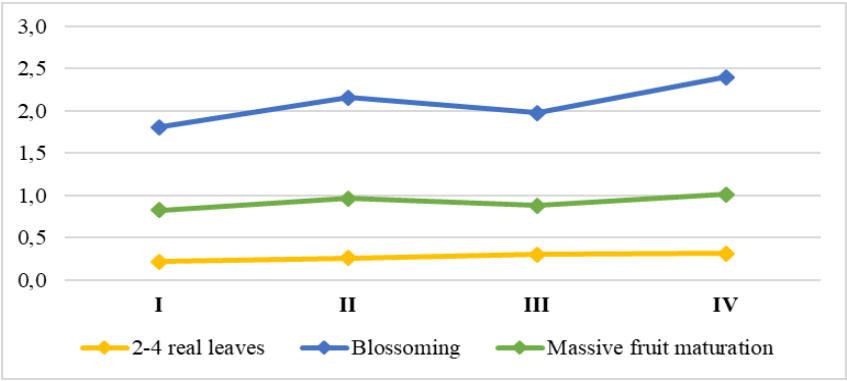

Fig. 1. Daily growth rate of tomato plants grown under controlled conditions of the climatic chamber during the growing season, cm

By the phase of mass maturation of fruits, the growth rate decreased and the length of shoots in plants grown with the use of succinic acid was 79.4-91.1 cm (Fig. 2). The highest height was recorded in the variant with the complex use of succinic acid (option IV) – 36.0 cm.

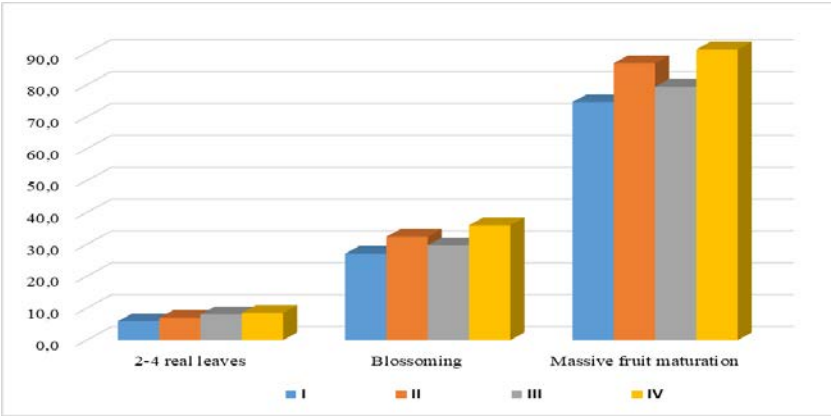

Fig. 2. Height of tomato plants of the 'Lyana' variety, cm

According to the content of photosynthetic pigments in tomato leaves, the highest values were found in the variants with the addition of succinic acid to the hydroponic solution. So, in the version without seed treatment, the content of chlorophyll is (*a*+*b*) was 8.63 mg/g, chlorophyll *a* –5.32 mg, chlorophyll *b* –3.31 mg/g and carotenoids –1.15 mg/g (Table 1).

Table 1. The content of main pigments in tomato plants of the variety 'Lyana' in the conditions of a closed agroecosystem, mg/g

№ of experiment variant	Chlorophyll *a*	Chlorophyll *b*	Chlorophyll (*a*+*b*)	Carotenoids
I	4,72	2,86	7,58	1,08
II	5,32	3,31	8,63	1,15
III	4,87	3,31	8,18	1,05
IV	5,68	3,74	9,41	1,24

It should be noted that in general, when using the biostimulator of succinic acid, there is a tendency to increase the content of main photosynthetic pigments in leaves of tomato plants, but it is worth noting that its complex use (option IV) leads to an increase in these parameters to 30.8%.

Crop yield is determined by the nature of development of reproductive organs of plants. When evaluating productivity, special attention should be paid to the characteristics of parameters of the crop structure. When analyzing the obtained experimental data, it was noted that the pre-sowing treatment of seeds with the studied biostimulator had a positive effect on the formation of fruits, due to which the maximum yield is formed.

Figure 3 shows a diagram of the number of shoots and the number of fruits on the plants. Thus, it should be noted that in variant III of the experiment, the largest number of flower shoots and formed fruits were observed – 5.6 and 13.9 pieces accordingly. With double biostimulation (option IV) with succinic acid, the parameter of the number of fruits per shoot in comparison with the other two options decreases to 5.0 and 9.4 pieces, provided that the size of fruits with an average weight of 98.8 g (with an increase of 18.6%) is preserved (Table 2, Fig. 3).

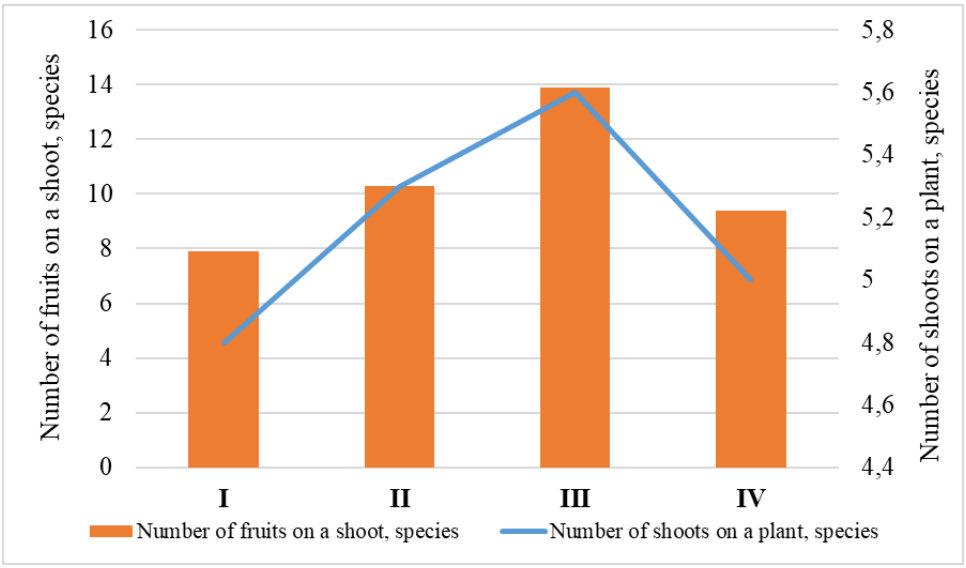

Fig. 3. Individual parameters of the structure of tomato plants

Table 2. Structure of crop productivity of tomato plants of the variety ‘Lyana’ depending on the use of succinic acid.

№ of experiment variant	Number of plants			Fruit weight, g
	shoots	sprouts	fruits on sprout	
I	3,8	4,8	7,9	83,3
II	3,8	5,3	10,3	86,7
III	3,7	5,6	13,9	114,1
IV	4,3	5	9,4	98,8

As can be seen from Figure 4, in variant III with pre-sowing seed treatment, the largest fruits weighing up to 174.7 g were observed, and in the other two variants: 130.5 g (variant II)...135.7 g (variant IV). The average fruit weight in the variant with seed inoculation was 114.1 g, which exceeds the control by 37.0%. The complex application of the biostimulator provides an increase in the average weight of fruits in 18.6%, the addition of hydroponics to the nutrient solution - 4.1%.

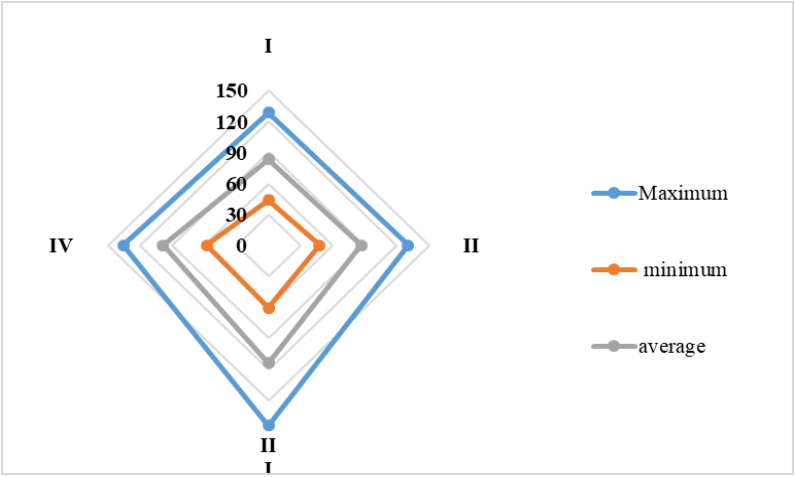

Fig. 4. Average weights of tomato fruits

Assessing the impact of the use of an aqueous solution of succinic acid in the cultivation of tomatoes of the variety ‘Lyana’, it is worth pointing out that the most effective way of its application is pre-sowing inoculation of seeds. In this version of the experiment, the yield reached a maximum of 3.84 kg/plant (Fig. 5).

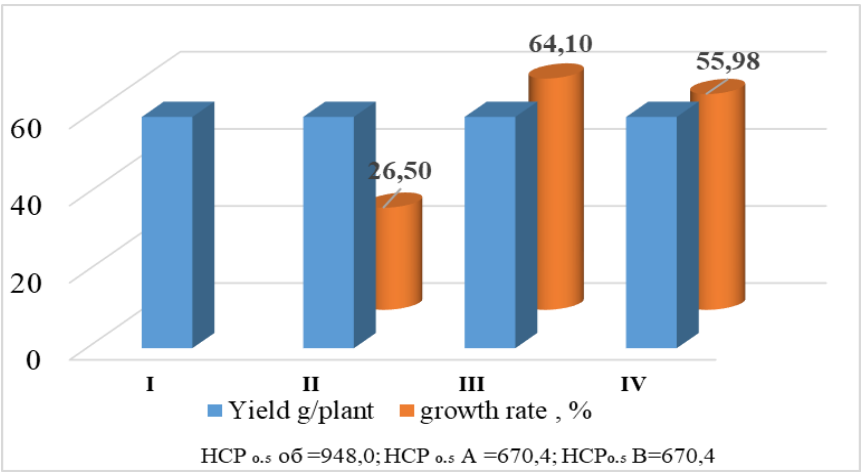

Fig. 5. Yield of tomatoes of the 'Liana' variety

The combination of methods of using the biostimulator (inoculation of seeds + application with irrigation) contributes to an increase in the yield of tomatoes by 56.0% in relation to the control – 3.65 kg/plant.

4 Conclusions

In a result of conducted studies on the influence of the biostimulator of succinic acid in the cultivation of tomatoes of the variety 'Lyana' under controlled conditions of the climatic chamber, it was revealed that the most effective method is inoculation of seeds with a significant increase in yield in relation to the control – 64.1%. In this version of the experiment, the largest number of buds and formed fruits were observed, differing in size by weight up to 174.7 g among other variants of the experiment and control. The complex application of the biostimulator of succinic acid provides an increase in the yield of tomatoes in 56.0%, the addition of hydroponics to the nutrient solution-25.6%. Thus, when growing tomatoes of the 'Lyana' variety in artificial agroecosystems, an aqueous solution of succinic acid is recommended to be used at the stage of pre-sowing seed treatment.

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