Resource efficiency in ecological technologies of tomato production in the conditions of hydrothermal climate tension

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Abstract. The complex conditions of the modern period of agricultural production development determine the need to develop new elements of technologies adapted to modern conditions of land use. The article presents the results of studies of the growth regulator effect on obtaining high-quality tomato products. It is proved that the organosilicon preparation Energy-M stimulated the growth and development of plants, increased the productivity of tomatoes in the acutely arid conditions of the Lower Volga region. The object of the study was the tomato variety Hercules. The highest yield of tomatoes with the formation of a large number of large fruits with good taste indicators was obtained on the variety Hercules on the variant with pre-sowing seed treatment, as well as non-root treatment of plants in the initial growth period and in the budding-flowering phase. The use of the Energy-M growth regulator on tomato culture is an effective measure. It is recommended that producers of high-quality vegetable products widely use this drug against the background of sufficient mineral nutrition by soaking the seeds before sowing and processing the plant throughout the growing season.

1. Introduction

The main way to raise agriculture and meet the growing needs of the country in agricultural products is comprehensive mechanization and consistent intensification: achieving a high culture of agriculture on the basis of science and best practices at all enterprises, a sharp increase in the yield of all crops and an increase in the output of products from each hectare at the lowest cost of labor and money [1, 2, 3].

One of the most valuable types of vegetables is tomato. Their fruits are very rich in sugars, organic acids, vitamins, mineral salts and, therefore, bring great benefits to human health [4, 5, 6].

It is known that chemical growth regulators are very important in obtaining high yields of tomatoes with good taste indicators of fruits and an earlier period of their maturation [7, 8, 9].

Chemical growth regulators do not replace either nutrients or any other conditions of plant life. They only modify the nature of the transformation of substances, accelerate the course of physiological processes. The greatest economic effect from the regulator can be obtained with good care of plants. Therefore, when using this method of increasing plant yield, it is important to observe the basic rules of agricultural technology [10, 11, 12].

Obtaining high yields of fleshy fruits rich in nutrients under their influence is of great importance in the development of the food industry. And the ability to accelerate the ripening of fruits with the help
of these substances plays an equally important role in vegetable growing in both northern and southern regions of the country, where tomatoes suffer from early autumn frosts.

Thus, in the struggle for a high yield of agricultural crops, highly active chemical compounds are used with increasing effect every year. As an alternative to the use of mineral fertilizers, new-generation biological products have been introduced into agricultural technology, which differ in that they are used in small doses when applied and contribute to increasing crop yields [13, 14].

Energy-M is a silicon-protran regulator of plant growth and development, which is a composition of silatran with a synthetic analogue of phytohormones (auxins) - protran. The drug does not contain hormonal additives, does not have mutagenic, teratogenic and cumulative properties [15].

Despite the constantly emerging difficult weather conditions in various soil and climatic zones of Russia, the use of the drug Energy-M allows to get guaranteed yields of crop production with the increase of 15 to 45%.

The treatment by chloromethylsilatran (the active substance of the drug Energy-M) increases the content of hydrated water in plants by more than 2.5 times, and also increases the percentage of dry matter content.

Hydrated water does not crystallize, freezing, and thus preserves plant tissues from damage. During the dry period, it does not evaporate from the plant cell and allows it to more easily tolerate moisture deficiency during drought. This explains the drought and frost resistance.

A huge role in the development of plants under the influence of a growth regulator is played by temperature conditions, as well as soil and atmospheric humidity. It is known that tomatoes are a demanding crop to the temperature and humidity of the air and soil. If the temperature conditions are violated in the direction of decreasing or increasing, as well as when the air is dry, the fertilization process is disrupted, and as a result, the flowers fall off or the formation of sessile ovaries occurs. The lack of water in the soil suppresses the growth of plants, the tying and filling of fruits worsens. Violation of the water regime of plants, as well as temperature conditions, leads to fruit disease [16].

However, plants treated with stimulant solutions are more resistant to low and high temperatures, to a lack of moisture in the soil, to high dryness of the air. Since these drugs increase the water-retaining capacity of plant cells and weaken transpiration [17].

The purpose of the study is to substantiate the resource efficiency of using a growth regulator in the production of tomatoes to obtain high-quality products in conditions of hydrothermal climate tension.

2. Materials and methods
The experimental part of the work was carried out in the conditions of the agricultural organization of Gorodishchensky district, Volgograd region. In the period of 2014...2016, we conducted a number of experiments to establish the dependence of the action of the growth regulator Energy-M on the development of tomatoes on the conditions of mineral nutrition in open ground conditions. The research was carried out on plants of the tomato variety Hercules. The experimental plants were treated by spraying with a growth regulator solution against the background of N₂₅₀P₁₀₀K₁₂₅ application. The control plants were sprayed with water. Seeds of tomato plants were soaked in a solution of the growth regulator Energy-M for 30...40 minutes before sowing (the consumption of the working solution was 2 liters/kg). After that, the seeds were dried to flowability and sown with an Agroikol-1.4 seeder. Non-root treatments were carried out on an area of 1 ha with a dose of 15 g per 300 g of water during the growing season (spraying of plants during the initial growth period and in the budding-flowering phase). Research in the experiment was carried out according to the Methodology of field experience by Dospekhov.

3. Results and discussion
In our experiments conducted to study the effect of the growth regulator Energy-M on the development of tomatoes, we had the opportunity to verify the resistance of stimulated plants to adverse environmental factors – high temperature conditions (Figure 1).
The rapid increase in temperature contributes to the rapid evaporation of moisture from the upper horizons of the soil. Droughts that occur in May cover almost the entire Lower Volga region and continue with small interruptions throughout the spring and summer period. The onset of summer in the conditions of the Lower Volga region is observed not in the generally accepted June, but a few weeks earlier – by May 8...10, the average temperature reaches +17 °C. In June, hot, sunny weather is established, which lasts for three months. During this period, the average daily air temperature is +22...+26 °C. By the end of August, there is a gradual decrease in the thermometer readings below +20 °C.

The relative humidity of the air in July-August reaches less than 50%, in acute arid years – up to 20...30%, and on some days, it drops to 10...14%.

An insignificant amount of snow and spring-summer precipitation, general thermal stress and high evaporation in summer leads to an acute shortage of soil moisture.

In general, the agro-climatic conditions of the dry-steppe zone of the Lower Volga region can not be considered favorable for the cultivation of vegetable crops, whose plants need high moisture supply in the initial growth phases and subsequent periods of vegetation, and only high temperatures are required for the ripening of fruits.

High temperatures affected the formation of flowers and ovaries in tomatoes treated with regulators. The largest percentage of fallen buds and ovaries fell on plants without treatment, which is explained by unfavorable temperature conditions (Table 1).

**Figure 1.** Average monthly air temperature.
Table 1. Dependence of the action of the growth regulator Energy-M on the formation of flowers and ovaries in tomatoes from high temperatures (May-July 2014...2016).

| No. | Experience option                                                                 | I cluster | II cluster |
|-----|-----------------------------------------------------------------------------------|-----------|-----------|
|     | number of buds | number of fruit | % of buds falling | number of buds | number of fruit | % of buds falling |
| 1   | Control (soaking in water)             | 36        | 28        | 34.8           | 31        | 14        | 59.3          |
| 2   | Soaking seeds in Energy-M              | 42        | 32        | 27.6           | 39        | 18        | 41.0          |
| 3   | Processing plants in a period flowering period with Energy-M                       | 43        | 39        | 21.6           | 46        | 24        | 34.1          |
| 4   | Soaking seeds in the drug Energy-M + Processing of plants during the flowering period with Energy-M | 66        | 45        | 31.8           | 50        | 32        | 31.1          |
| 5   | Processing plants throughout the growing season with Energy-M                       | 69        | 50        | 19.3           | 53        | 39        | 28.5          |
| 6   | Soaking seeds in the drug Energy-M + Processing of the plant throughout the growing season with Energy-M | 72        | 53        | 18.7           | 55        | 41        | 27.3          |

As can be seen from the data of Table 1, the lowest percentage of ovaries fall (18.7%) it was in the first brushes of tomatoes, in the variant, where the seeds were soaked in a solution of the growth regulator when the plant was jointly processed during the entire vegetation. On this variant there was a fall of flowers and ovaries in a significant but less - by 16.1% than in control (34.8%), which, of course, caused an increase in the yield of tomato fruits.

Flowering of the second brushes was the hottest and driest period, which negatively affected the tying of fruits in plants on the control variant - 34.8 and 59.3%, respectively, on the first and second brush, causing them the highest percentage of drying of flowers and falling ovaries.

In relation to low temperatures, there was a manifestation of stability in processed plants. The temperature dropped to 2...3 °C and even to -1 °C. This led, of course, to the suspension of all life processes in tomato plants; the brushes formed at this time did not even bloom. Stimulated plants were covered with relatively large mature fruits (average weight 45...50 g), and on the plants of the control variant were only single mature fruits, very small (average weight of 10...12 g). Thus, in relation to low temperatures, plants treated by the growth regulator were more resilient than control plants. Provided these plants are exposed to low temperatures for a short period of time.

Consequently, the activity of the growth regulator was closely dependent on the conditions of the external environment. Changes in temperature conditions upwards or decreases did not adversely affect the development and productivity of plants treated by the growth regulator. On the contrary, the latter have experienced an increase in resilience to adverse environmental factors.

Analysis of Table 2 data showed that the lowest fruit yield was recorded on the control variant. Plants treated with the drug Energy-M, under these adverse conditions gave high yields. On option 6, plants formed an increased number of buds and fruits, had the lowest percentage of ovary fall on the plant, thus contributing to an increase of 113.56% relative to control.
Table 2. The dependence of the Energy-M growth regulator on the productivity of tomato plants and on high temperatures, (+26...+35 °C, May-July 2014...2016).

| No. | Experience option                                                                 | Total weight of fruits from 4 plants, g | Average weight of fruit with 1 plant, g | % of control |
|-----|-----------------------------------------------------------------------------------|----------------------------------------|----------------------------------------|--------------|
| 1   | Control (soaking in water)                                                        | 1357                                   | 339.25                                 | 100          |
| 2   | Soaking seeds in Energy-M                                                          | 1802                                   | 450.50                                 | 32.79        |
| 3   | Processing of the plant during the flowering period with Energy-M                 | 2063                                   | 515.75                                 | 52.03        |
| 4   | Soaking seeds in the drug Energy-M + Processing of plants during flowering period with Energy-M | 2104                                   | 526.00                                 | 55.05        |
| 5   | Processing of the plant throughout the growing season with Energy-M               | 2673                                   | 668.25                                 | 96.98        |
| 6   | Soaking seeds in the drug Energy-M + Processing plants throughout the growing season with Energy-M | 2898                                   | 724.50                                 | 113.56       |

LSD 0.05 1.54

We conducted biochemical analyses of fruits for vitamin C, dry substances, sugars and nitrates (Table 3).

The analyses showed an advantage in this respect of the fruit obtained on the variant with pre-planting soaking of seeds in the preparation Energy-M-the processing of the plant during the entire growing season.

Table 3. Effect of Energy-M growth regulator on the biochemical composition of tomato fruits, (average for 2014... 2016)

| No. | Experience option                                                                 | Dry substance, % | Vitamin C, mg/% | Amount of sugars, % | Acidity, % | nitrates mg/kg |
|-----|-----------------------------------------------------------------------------------|------------------|-----------------|--------------------|------------|----------------|
| 1   | Control (soaking in water)                                                        | 3.7              | 15.2            | 2.5                | 0.53       | 90.2           |
| 2   | Soaking seeds in Energy-M                                                          | 4.2              | 15.6            | 2.9                | 0.54       | 91.5           |
| 3   | Processing of the plant during the flowering period with Energy-M                 | 4.8              | 15.8            | 3.0                | 0.56       | 95.8           |
| 4   | Soaking seeds in the drug Energy-M + Processing of plants during flowering period with Energy-M | 5.3              | 16.3            | 3.1                | 0.57       | 96.3           |
| 5   | Processing of the plant throughout the growing season with Energy-M               | 5.7              | 16.4            | 3.2                | 0.59       | 98.6           |
| 6   | Soaking seeds in the drug Energy-M + Processing plants throughout the growing season with Energy-M | 6.1              | 16.5            | 3.2                | 0.59       | 103.3          |
The nitrate content on all test options was significantly lower than the maximum permissible concentration (150 mg/kg). The use of the Energy-M growth regulator is an environmentally friendly way to increase the yield and quality of vegetable products.

Studies of experimental plants have shown that the stimulation of tomato plants by the growth regulator led to a significant improvement in the quality of the fruits of this crop. The highest harvest of tomatoes with the formation of a large number of large fruits with good taste indicators was obtained on the Hercules variety on the variant with pre-seed processing, as well as non-root processing of plants in the initial period of growth and in the budding-flowering phase.

4. Conclusion
These experiments confirm the ability to increase the stability of tomatoes under the influence of the Energy-M growth regulator to adverse environmental conditions.

Thus, the biologic Energy-M, taking into account the results of the test, in conditions of reduced water availability of the growing season and high air temperature, refers to the highly effective means of drought control.

The application of the Energy-M growth regulator on tomato culture is an effective measure of obtaining environmentally friendly products. It is recommended that manufacturers of high-quality vegetable products widely use this drug against the background of sufficient mineral nutrition by soaking seeds before sowing and processing the plant during the entire growing season.

References
[1] Kalmykova E V and Petrov N Yu 2017 Effect of the Energy-M Growth Regulator on growth, development and tomato productivity Bulletin of Ryazan State Agricultural University named after P. A. Kostychev 4(36) 33-40
[2] Kalmykova E V, Petrov N Yu and Kalmykova O V 2018 Increase in the productivity and quality of tomato plants under the influence of the growth regulator Izvestiya of Timiryazev Agricultural Academy 6 109-118
[3] Kurbanov C A, Magomedova D S, Ibragimov A K and Nigmatulayev N M 2017 Effect of irrigation and basic soil processing on its agrophysical indicators and tomato yield Fertility 6(99) 38-40
[4] Koshman M E, Skorina B B and Bosak B N 2013 Yield and quality of different varieties of tomato in the conditions of the Belarusian Polesie Izvestia of the St. Petersburg State Agricultural University 30 12-15
[5] Mukhortov S Ya 2014 Dynamics of the adaptive ability of tomato agrocoenoses when using a growth regulator Fruit and Berry Growing in Russia 40(1) 217-220
[6] Pigorev I Ya, Soloshenko V M and Naumkin V N 2016 About innovative technologies in agriculture Bulletin of the Kursk State Agricultural Academy 3 32-36
[7] Gajc-Wolska J, Mazur K, Niedzińska M, Kowalczyk K and Zolnierczyk P 2018 The influence of foliar fertilizers on the quality and yield of sweet pepper (Capsicum annuum L.) Folia Horticulturae 30(2) 183-190
[8] Kimura S and Sinha N 2008 Tomato (Solanum lycopersicum): A Model Fruit-bearing Crop Emerging Model Organisms: a Laboratory Manual (New York: Cold Spring Harbor Laboratory Press) pp 119-138
[9] Shiva Kumar S and Bhaktavatchalu S 2017 Role of plant growth-promoting rhizobacteria (PGPR) in the improvement of vegetable crop production under stress conditions Microbial Strategies for Vegetable Production pp 81-97
[10] Venezian A, Dor E, Achdari G, Smirnov E and Hershenhorn J 2017 The influence of the plant growth regulator maleic hydrazide on Egyptian broomrape early developmental stages and its control efficacy in tomato under greenhouse and field conditions Frontiers in Plant Science 8691
[11] Pleskachev Yu N and Lukyanenko E A 2019 Increase in vegetable crop productivity by applying leaf feedings Int. Agricultural J. 5 22-27
[12] Pleskachev Yu N and Gubina L V 2017 The recipes to increase the productivity of carrot dining in the Volgo-Don Inter-River Agricultural Scientific J. 6 18-22

[13] Pleskachev Yu N, Tyutyuma N V and Gubina L V 2017 Innovative carrot-cultivation technologies in the Volgo-Don between the Rivers Theoretical and Applied Problems of the Agro-Industrial Complex 3(32) 22-25

[14] Puchkov M Yu and Mohamed M M A 2017 Study of the effects of regulatory growth in vegetable crops Natural Sciences 1(58) 13-22

[15] Saharchuk T N, Poliksenova V D, Naumova G V and Makarova N L 2012 Effect of huminum drugs on seed germination and tomato seedling growth Bulletin of the Bryansk State University 2(2) 53-57

[16] Sosnov V S and Yurov A I 2012 Growth regulators increase tomato plant productivity and resistance to diseases Potatoes and Vegetables 6 19-20

[17] Shibzukhov S G S, Ezaov A K and Shugushkhov A A 2016 Influence of growth regulators on the productivity of the tomato Proceedings of Kabardino-Balkar State Agricultural University named after V. M. Kokov 2 27-32