The plant growth regulators influence on the growth, crop productivity and quality of tomato under a climate warming conditions in the south of Russia

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Abstract. The plant growth regulators application will increase the stimulating effect on the plant, its growth activity, physiological functions and organism protective reactions involved with metabolism increasing, stress resistance to unfavorable conditions (diseases, pests, freezing, dry period and others). It was proved that the studied Energia-M and Biodux preparations stimulated the plants growth and development, increased the productivity of tomato in hyperarid conditions of the southern Russia. The productivity potential of the tomato hybrid Fokker F1 was obtained using the option with the pre-sowing seed treatment, as well as foliar treatment of plants during the period of growth and development with Energia-M and Biodux preparations. It is recommended for producers of high-quality vegetable products to use extensively these preparations against the background of sufficient mineral nutrition by seeds soaking before sowing and treatment plants during the vegetation development.

1. Introduction

Long-term climatological temperatures data indicate a serious environmental problem - global warming [1-4].

According to the most severe scenario RCP 8.5 during compiling forecast changes in the average sums of active temperatures and the sums of precipitation of the agricultural crops vegetation season, further dramatic warming of the climate in southern Russia can be observed [4].

Therefore, the contradictory picture of the modern development of agro-agricultural production predetermines the requirement for the new techniques development, adapted to the current conditions of land management that is providing plants with optimal conditions for moisture supply and nutrient regime of the soil [6, 7]. Of particular importance in this regard is the application of various plant growth regulators. These preparations have a stimulating effect on the plant, increase its growth activity, physiological functions and protective reactions of the organism involved with metabolism increasing, stress resistance to unfavorable conditions (diseases, pests, freezing, dry period and others). Based on the study of the compounds effect on plant development, scientists from various countries note a number of practical methods of plant life management recommended for use in agriculture - these are low consumption rates, ecological safety, organic origin and reducing the toxins load on living and nonliving objects [8, 9].
Depending on the biological effects nature caused by preparations, the range of plant growth regulators is diverse. In the world, more than 100 companies are currently working on research and implementation of new preparations - «Bayer Crop Science» (Germany), «Valagro SpA» (Italy), «Arysta Life Science Corporation» (Japan), «Biostadt India Limited» (India), «Koppert BV» (Netherlands), etc.

Innovative plant protection products in our country for 2019 are more than 95 trade names of plant growth regulators based on 49 different preparations compounds included in «The state catalog of pesticides and agrochemicals permitted for application in the Russian Federation».

The modern agrobiological science presents a choice of a large preparations line such as Energia-M, Mival-Agro, Cresolan, Vigor Forte (based on orthoresoxyacetic acid of triethanolammonium salt and its compositions with 1-chloromethylsilatrane or macro- and microelements), Obereg, Bioduks, Prorostok, Immunocytophyte (based on arachidonic acid).

It was revealed that the scientifically grounded application of plant growth regulators is an expedient technique for the agricultural crops cultivation, including vegetal ones [10].

The purpose of the research work is the scientific substantiation of the growth regulators effect with a stress resistance increase to environmental factors on the growth activity and protective reactions of tomato plants, their crop productivity and quality in conditions of the hydrothermal vulnerability of the climate of southern Russia.

2. Materials and methods

The studies were carried out in the conditions of laboratory and field experiments in the south of Russia in the period from 2014 to 2019. The object was tomato plants of the Fokker F1 hybrid. Experimental plants were treated with growth regulators Energia-M and Bioduks against the background of N\textsubscript{250}P\textsubscript{100}K\textsubscript{125} addition.

Control plants were sprayed with water. Before sowing, the seeds of tomato plants were soaked: in a solution of the growth regulator Energia-M for 30-40 minutes, in a solution of Biodux - for 1 hour (the consumption of the working solution is 2 l/kg), followed by drying to flowability and sowing with an Agroikola-1,4 seeder. The treatment of plants was carried out during the vegetation season with Energia-M preparation (15 g / ha / 300 g of water - plants spraying in the phase of 3-4 leaves and in the budding phase - the beginning of flowering of the 1st truss), with Biodux preparation (5 ml per 400 g of water - plants spraying in the flowering phase of the 1st, 2nd, 3rd truss). Crop care was carried out in accordance with generally accepted agricultural techniques.

3. Results and discussion

In our experiments aimed at studying the influence of growth regulators Energia-M and Biodux on the tomato plants development, we had the opportunity to make sure that the stimulated plants are resistant to unfavorable environmental factors.

The research area climate is distinctly continental, with hot, dry summer, warm and dry autumn. The average annual air temperature is positive and is in the range of 7.5-8.2 °C. The hottest month is July with an average monthly air temperature of 24.5-26.3 °C. The average air temperature during the three summer months is 23.5-26.8 °C. In September, the temperature decreases, but it is still quite high and equals 14.8-17.4 °C (Figure 1).

The number of frost-free days varies from 160 to 170, the duration of the warm period with a stable average air temperature above 0°C comprises 220-245 days. The annual sum of this indicator is 3200-3400 °C.
During the warm period, the highest relative air humidity (65-70%) is observed in spring (April-May), the lowest - less than 30-50% - in summer (July-August).

The precipitation amount in some years differs from the average norm by 1.5-2.0 times. On average, 200-239 mm falls during the growing season. An insignificant amount of snow and spring-summer precipitation, general thermal stress and high evaporation in summer lead to an acute deficiency of soil moisture. More than half of the precipitation falls during the warm period from April to October.

According to the hydrothermal coefficient, 2014 year was characterized as a dry, 2015 as very dry, 2016 and 2017 as slightly arid, 2018 and 2019 as very dry years.

The climatic conditions of the dry steppe zone of southern Russia are favorable for the cultivation of vegetable crops at the irrigated vegetable growing. Plants constantly need to maintain the pre-irrigation soil moisture at a high level in the initial and subsequent periods of development and only in the phase of biological and technical ripeness the plants need high temperatures.

High temperatures influenced the formation of flowers and ovaries in tomato plants treated with regulators. The largest percentage of butters and ovaries shed fell on plants without treatment, which is explained by unfavorable temperature conditions. The smallest percentage of ovary shedding (18.7%) occurred during the formation of the first tomato truss, in the variant where the seeds were soaked in a solution of the growth regulator Biodux with combined treatment of plants during the vegetation development (Table 1).

In this variant, the flowers and ovaries shedding occurred to a much lesser extent - by 16.1% than in the control (34.8%), which, obviously, caused an increase in the productivity of tomato fruits.

The tomato plants flowering fell on the hottest and driest period, which negatively affected the plants fruits setting in the control variant - 34.8 and 59.3%, respectively, during the first and the second trusses formation, while causing them the highest percentage of flowers drying and ovaries shedding.
Table 1. The growth regulators influence on the flowers and ovaries formation in tomato plants during the high temperatures exposure in the period May-July, (average for 2014 ... 2019 years)

| Experience variant                        | Flower bud number | Fruits number | % flower bud shedding | Flower number | Fruits number | % flower bud shedding |
|-------------------------------------------|-------------------|---------------|-----------------------|---------------|---------------|----------------------|
| Control (soaking in water)                | 36                | 28            | 34.8                  | 31            | 14            | 59.3                 |
| Seed soaking (Energy-M)                   | 42                | 32            | 27.6                  | 39            | 18            | 41.0                 |
| Seed Soaking (Biodux)                     | 43                | 39            | 21.6                  | 46            | 24            | 34.1                 |
| Plant treatment (Energia-M)               | 66                | 45            | 31.8                  | 50            | 32            | 31.1                 |
| Plant treatment (Biodux)                  | 67                | 48            | 23.3                  | 51            | 37            | 29.2                 |
| Seed Soaking + Plant Treatment (Energy-M) | 69                | 50            | 19.3                  | 53            | 39            | 28.5                 |
| Seed Soaking + Plant Treatment (Energy-M) / Seed Soaking + Plant Treatment (Energy-M) | 72                | 53            | 18.7                  | 55            | 41            | 27.3                 |

In relation to low temperatures, the manifestation of resistance was recorded in the plants treated with preparations. We performed an experiment in a greenhouse in the period January-March to study the effect of growth regulators Energia-M and Biodux on the tomato plants development of the Fokker F1 hybrid. The freezing caused great damage to our experiment, almost destroying it. In the most severe frosts, the heating in the greenhouse was turned off. The temperature dropped to +2 - +3°C and even to -1°C. This led, obviously, to the suspension of all life processes in tomato plants. As a result, plants that were not treated with growth regulators (the trusses that had formed at that time did not even bloom) suffered greatly from low temperatures, while the treated ones soon took their normal appearance and continued to bloom and bear fruits. By the time the fruit ripened, the picture was very bright and striking. The stimulated plants were covered with relatively large ripe fruits (average weight 45-50 g (Energia-M) and 47-51 g (Biodux)), while the plants of the control variant had only single ripe fruits, very small (average weight 10-12 g). Thus, plants treated with growth regulators turned out to be more resistant to low temperatures than control ones. Provided that these plants were exposed to low temperatures for a short period of time.

Table 2. Tomatoes productivity when growth regulators application at high temperatures exposure in the May-July period, (+26 - +35°C, average for 2014 ... 2019 years).

| Experience option                        | Total weight of fruits from 4 plants, g | Average weight of fruits from 1 plant, g | % of control |
|-------------------------------------------|-----------------------------------------|-----------------------------------------|--------------|
| Control (soaking in water)                | 1357                                    | 339.25                                  | 100          |
| Seed soaking (Energy-M)                   | 1802                                    | 450.50                                  | 32.79        |
| Seed Soaking (Biodux)                     | 2063                                    | 515.75                                  | 52.03        |
| Plant treatment (Energia-M)               | 2104                                    | 526.00                                  | 55.05        |
| Plant processing (Biodux)                 | 2673                                    | 668.25                                  | 96.98        |
| Seed Soaking + Plant Treatment (Energy-M) / Seed Soaking + Plant Treatment (Energy-M) | 2898                                    | 724.50                                  | 113.56       |
| Seed Soaking + Plant Treatment (Biodux)   | 2915                                    | 746.74                                  | 120.12       |

Least significant difference 05 1.54
Consequently, the growth regulator effect was closely dependent on the external environment conditions. Changes in temperature conditions upward or downward did not affect adversely the development and productivity of plants treated with growth regulators. On the contrary, the latter showed an increase in resistance to the unfavorable environmental factors.

From the data in Table 2 it can be seen that the smallest potential of fruit productivity was obtained in the control variant without the growth regulators application. Treated with preparations plants gave high productivity rates under these unfavorable conditions.

On the variant of the complex application of the Energria-M preparation, the plants formed an increased number of buds and fruits, a low percentage of ovaries shedding on the plant were observed, thereby contributing to an increase in the average weight of fruits from 1 plant by 113.56 % relative to the control. The Biodux preparation application promoted the formation of the largest weight of fruits per plant - 746.74 g (120.12 %).

We carried out biochemical analyzes of fruits for the content of vitamin C, dry matter, sugars and nitrates (Table 3).

| Experience option                                           | Dry matter, % | Vitamin C, mg/100 g | The amount of sugars | Acidity, % | Nitrates, mg/kg |
|-------------------------------------------------------------|---------------|---------------------|----------------------|------------|-----------------|
| Control (soaking in water)                                  | 3.7           | 15.2                | 2.5                  | 0.53       | 90.2            |
| Seed soaking (Energia-M)                                    | 4.2           | 15.6                | 2.9                  | 0.54       | 91.5            |
| Seed Soaking (Biodux)                                       | 4.8           | 15.8                | 3.0                  | 0.56       | 95.8            |
| Plant treatment (Energia-M)                                 | 5.3           | 16.3                | 3.1                  | 0.57       | 96.3            |
| Plant treatment (Biodux)                                    | 5.7           | 16.4                | 3.2                  | 0.59       | 98.6            |
| Seed soaking + Plant treatment (Energia-M) Seed soaking + Plant treatment (Energia-M) | 6.1           | 16.5                | 3.2                  | 0.59       | 103.3           |
| Seed Soaking + Plant Treatment (Biodux)                     | 6.0           | 16.5                | 3.2                  | 0.60       | 106.2           |

Analysis of biochemical parameters proved the advantage of fruits obtained on variants with the pre-sowing seed soaking in preparations and treatment of plants during the vegetation development.

The nitrates content in all experiment options was significantly lower than the LOC (150 mg/kg). Thus, the growth regulators application is an environmentally safe method of the crop productivity and vegetable products quality increasing.

The experimental plants researches have shown that stimulation of tomato plants with growth regulators led to a significant increase in the quality of this crop fruits. The productivity potential of the Fokker F1 hybrid tomato was noted in the variant with pre-sowing seed treatment with Biodux preparation, as well as foliar treatment of plants during the period of growth and development.

4. Conclusion

Analyzing the obtained data, we can talk about the growth regulators application usefulness, confirms the competitiveness of tomato plants. The growth regulators Energia-M and Biodux application on tomato culture is an effective measure for obtaining environmentally safe products. Thus, taking into account the test results, the introduction of Energia-M and Bioduxs preparations into the tomato cultivation technology under conditions of reduced moisture supply of the vegetable development period and high air temperature in the south of Russia, refers to the highly effective means of agricultural crops stress resistance increasing. It is recommended for producers of high-quality...
vegetable products to use extensively these preparations against the background of sufficient mineral nutrition by seeds soaking before sowing and treatment the plant during the vegetation development.

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