The trace elements influence on the tomato plants heat resistance in arid climate

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Abstract. In the arid conditions of the Astrakhan region agricultural plants heat resistance is one of the important criteria of quality production getting. In this regard, and also taking into consideration the fact that the soils of our region are characterized by a very low content of trace elements in the form accessible to plants, researches were carried out to study the effect of trace elements of copper, manganese and zinc for tomato plants heat resistance. To exclude the trace elements rapid absorption by the soil, plants foliar treatments were used during the growing season with 0.05% solutions of zinc sulfate (ZnSO$_4$), manganese sulfate (MnSO$_4$) and copper sulfate (CuSO$_4$). In the control variant, the plants were sprayed with water. The results showed that tomato plants foliar feeding during the III-V organogenesis stages with 0.05% solutions of zinc sulfate, manganese sulfate and copper sulfate have not got a significant effect on tomatoes growth and productivity. However, the zinc and copper trace elements positively influenced such physiological parameters of plants as the leaf cells hydration, the bound water content in them, the protoplasm viscosity, thereby contributing to the increase in tomato resistance to the adverse effects of high temperatures in the arid climate.

1. Introduction

In the arid conditions of the Caspian Lowland and the intensively changing climatic environment, researches on the agricultural crop resistance to the high temperatures effects during the growing season are very relevant. One of the important ecological and physiological indicators of tomato plants cultivated in Astrakhan region arid conditions is resistance to high temperatures. Numerous studies proved the enormous importance of trace elements in plant metabolism. They are a part of some enzymes, affect the synthesis of RNA, individual amino acids, their implication helps to reduce the water unproductive loss in agricultural crops [1, 2]. The experiments carried out by Petinov and Molotkovsky, Slukhay and Tkachuk [3, 4] showed that with the mineral nutrition conditions improvement the water consumption for the crop dry matter unit formation sharply decreases. The researches range defined that under the trace elements influence in plant tissues, the colloids hydration degree, the content of strongly bound (colloidal and osmotically) water increases, which is important in the economical consumption of moisture by plants, especially during periods of high temperatures and unfavorable moisture conditions. According to the research data, a good supply of plants with mineral nutrition elements contributes to a significant increase in the osmotic potential in the leaves. Thus, trace elements have a huge effect on increasing drought and heat resistance of plants [5, 6, 7, 8, 9].
2. Materials and methods

The research was carried out in the field conditions of the Astrakhan region Privolzhsky district on the basis of the educational and experimental farm "Nachalo" of the Astrakhan State University. The research object was the Novichok pink tomato variety, which is most in demand for growing in production conditions in the open field [10, 11, 12].

According to the Federal State Budgetary Institution "Gossortkomissia" the mid-season variety is included in the State Register for the Nizhneje Povolzhje region. The number of days from the moment of seedlings to the formation of the crop is 110-130 days. Even sprouts and crop ripening characterize the variety. The plant is determinant, it has a compact, low bush up to 80 cm high. The fruit is elliptical, smooth, when ripe becomes pink, weighing 80-113 g. The marketable fruits yield is 318-588 dt/ha. The ripe marketable fruits yield is 81-89%. The variety is resistant to viral and fungal diseases, the effects of unfavorable external conditions, including top rot disease and high temperatures (drought-resistant), as well as overripening and mechanical damage, due to the strong and dense peel of the fruit, thereby having high transportability [13, 14].

Field experiments were carried out in the Privolzhsky district of the Astrakhan region, on alluvial floodplain-meadow soils, the thickness of the humus horizon is 45 cm, the humus content is 1.14%, hydrolyzable nitrogen (N) in an amount of 58 mg/kg, mobile phosphorus (P) - 47 mg/kg), exchangeable potassium (K) - 335 mg/kg, mobile forms of trace elements: Mn - 11.1 mg, Zn - 0.18 mg, Cu - 0.8 mg, B - 2.0 mg, Co - 0.05 mg per 1 kg of dry soil. Ground waters are located at a depth of 1.5-2 meters. Ph 7.6 (slightly alkaline) (according to FGBU SC Agrochemical Service "Astrakhanskoye").

Weather and climatic conditions in the years of research did not differ from the average for the area. Air temperature for the growing season is average long-term 22.5 °C. The sum of active temperatures is above +10 °C during the growing season was 3560-3600 °C, and the amount of total solar radiation is 118-120 kcal/cm². Plants during the growing season were adversely affected by high temperatures (up to +30 °C in July) under conditions of moisture deficit (the largest amount of precipitation occurred in May, June and averaged up to 22 mm) (according to the Astrakhan Center for Hydrometeorology and Environmental Monitoring) [15].

Field studies were carried out according to the generally accepted methodology of Dospekhov [16]. Agrotechnical methods of soil preparation, planting seedlings and caring for crops were carried out according to the generally accepted technology of growing tomato in the Astrakhan region.

In the experimental variants, the tomato plants seedlings during the III-V organogenesis stages were sprayed by a 0.05% solution of zinc sulfate (ZnSO₄); 0.05% manganese sulfate solution (MnSO₄) and 0.05% copper sulfate solution (CuSO₄). In the control variant, the plants were sprayed by water. The experiment was repeated four times. Foliar feeding of plants was carried out every 9 days according to the experiment variants. The organogenesis stages were determined by the growth cone of the main stem.

The tomatoes heat resistance evaluation was carried out according to the method of Matskov [17] in the fruit ripening beginning phase. To evaluate tomato heat resistance, leaves should be taken from plants with the same number of tiers, one (better than average) tier, having, if possible, the same orientation to the cardinal points. The leaves are kept in a water bath at the temperature of 55 °C, providing browning in a 0.2% solution of hydrochloric acid (HCl) about ½ of the leaf area, at a 20-minute exposure [18]. The damage degree to leaves by high temperatures was determined by scoring. In this case, the following heat resistance scale was used:

- 0 points - complete browning of the leaf;
- 1 point - browning ¼ of the leaf area;
- 2 points - browning ½ of the leaf area;
- 3 points - browning ¾ of the leaf area;
- 4 points - green leaf (no browning).
Indirect methods for studying heat resistance of plants include: determination of the viscosity of the protoplasm of leaf cells (plasmolytic method) and the content of bound water (according to the Okuntsov-Marinchik method) [19, 20].

3. Results and discussion

The research results on the tomato plants height (stem length, cm) of the experimental and control variants showed that in most cases the differences in the height of seedlings, as well as of tomato plants in the phase of the beginning of fruit ripening and at the end of the growing season were insignificant. The data are presented in the Table 1.

| The variants of the experiment | Seedling period | The phase of the fruit ripening beginning | Plants at the end of the growing season |
|-------------------------------|----------------|------------------------------------------|---------------------------------------|
| Control | 25.6 | 52.3 | 64.7 |
| 0.05% zinc sulfate solution (ZnSO₄) | 35.8 | 55.1 | 66.7 |
| Deviation from control | 10.2 | 2.8 | 2.0 |
| Significance criterion (t) | 24.2 | 1.19 | 0.52 |
| Significance level (P) | 0.01 | > 0.1 | > 0.1 |
| 0.05% manganese sulfate solution (MnSO₄) | 22.5 | 49.5 | 59.6 |
| Deviation from control | - 3.1 | - 0.1 | - 5.1 |
| Significance criterion (t) | 1.27 | 0.04 | 9.12 |
| Significance criterion (P) | > 0.1 | > 0.1 | 0.001 |
| 0.05% copper sulfate solution (CuSO₄) | 30.8 | 57.2 | 62.5 |
| Deviation from control | 5.2 | 4.9 | 0.5 |
| Significance criterion (t) | 1.74 | 14.0 | 0.16 |
| Significance criterion (P) | 0.1 | 0.001 | > 0.1 |

The influence of tomato seedlings foliar treatments with zinc sulfate on plants heat resistance in the phase of the onset of fruit ripening turned out to be the most effective in comparison with other variants of the experiment, where solutions of manganese sulfate and copper were used. The data is represented in the Table 2.

| The variants of the experiment | Heat resistance, score |
|-------------------------------|-----------------------|
| Control | 2.00 |
| 0.05% zinc sulfate solution (ZnSO₄) | 3.34 |
| Deviation from control | 1.34 |
| Significance criterion (t) | 3.27 |
| Significance criterion (P) | 0.01 |
| 0.05% manganese sulfate solution (MnSO₄) | 1.95 |
| Deviation from control | -0.05 |
| Significance criterion (t) | 0.09 |
| Significance criterion (P) | > 0.1 |
| 0.05% copper sulfate solution (CuSO₄) | 2.92 |
Presumably, the zinc trace element causes a shift in respiration towards an increase in the formation of organic acids, which are able to bind free ammonia that accumulates in plants at high temperatures. This fact, in its turn, can explain the positive effect of tomato plants foliar treatment with zinc sulfate on the plants thermal tolerance [10]. In addition, a significant increase in plants heat resistance was revealed in an experimental variant with seedlings foliar treatment with copper sulfate, which is due to the ability of this trace element to increase the plant cells protoplasm viscosity and the bound water content. The manganese implication did not significantly affect the tomato plants resistance to high temperatures.

Table 3 presents data on the cell protoplasm viscosity and the content of total and bound water in the control variant and experimental plants leaves using foliar treatments with 0.05% zinc sulfate and copper sulfate solutions.

**Table 3.** The influence of tomato seedlings foliar treatments by trace elements on physiological parameters contributing to an increase in plants heat resistance.

| The variants of the experiment | Water content in leaves, % of dry weight | Time of convex plasmolysis onset, min. |
|-------------------------------|------------------------------------------|----------------------------------------|
|                               | general bound                            |                                        |
| Control                       | 614 288                                  | 62                                     |
| 0.05% zinc sulfate solution(ZnSO₄) | 706 338                              | 89                                     |
| 0.05% copper sulfate solution (CuSO₄) | 684 308                              | 81                                     |

The researchers showed that trace elements zinc and copper significantly increased such important plants physiological indicators as the protoplasm viscosity and the bound water content in cells, which, in their turn, contribute to the increase in agricultural crops heat resistance in an arid climate. In addition, the water content of the leaf cells also increased in the experimental plants.

During the research, the copper, manganese and zinc trace elements influence on the productivity of tomato plants was studied. The data is represented in the Table 4.

**Table 4.** The influence of tomato seedlings foliar treatments by trace elements on plant productivity.

| The variants of the experiment | The weight of tomato fruit per plant, kg |
|-------------------------------|-----------------------------------------|
| Control                       | 1.78                                    |
| 0.05% zinc sulfate solution (ZnSO₄) | 1.83                                  |
| Deviation from control        | 0.05                                    |
| Significance criterion (t)    | 0.45                                    |
| Significance criterion (P)    | > 0.1                                   |
| 0.05% manganese sulfate solution (MnSO₄) | 1.70                                  |
| Deviation from control        | - 0.08                                  |
| Significance criterion (t)    | 0.34                                    |
| Significance criterion (P)    | > 0.1                                   |
| 0.05% copper sulfate solution (CuSO₄) | 1.85                                  |
| Deviation from control        | 0.07                                    |
| Significance criterion (t)    | 0.46                                    |
| Significance criterion (P)    | > 0.1                                   |
Tomato seedlings foliar feeding by trace elements did not have a significant effect on plant productivity. On average, the fruits weight from one experimental plant was 1.70 kg for the variant with manganese sulfate, 1.83 kg for the variant with zinc sulfate, and 1.85 kg for the variant with copper sulfate. For the control tomato plants, this indicator was 1.78 kg.

4. Conclusion
Tomato plants foliar treatment during the III-V organogenesis stages with 0.05% zinc sulfate solution (ZnSO₄), 0.05% manganese sulfate solution (MnSO₄) and 0.05% copper sulfate solution (CuSO₄) did not significantly affect the growth and productivity of the plant.

However, the zinc and copper trace elements positively influenced such physiological parameters of plants as the leaf cells hydration, the bound water content in them, the protoplasm viscosity, thereby contributing to the increase in tomato resistance to the adverse effects of high temperatures (heat resistance) in the arid climate of the Astrakhan region.

The application of the manganese trace element did not significantly affect the resistance of tomato plants to high temperatures.

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