The system of mineral nutrition of tomatoes in the Astrakhan region

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Abstract. The article considers the characteristics of tomato vegetable culture when growing it in the open ground in the soil and climatic conditions of the Astrakhan region. The total demand of tomatoes for macronutrients – nitrogen, phosphorus and potassium in the context of the planned yield from 40 to 100 tons per hectare, taking into account the availability of mobile forms of nutrients in the soil, is shown. The average doses of the main fertilizer application during the preparation of the soil for tomatoes, the timing and doses of fertilizing tomatoes with nitrogen fertilizers when they are applied with fertigation during sprinkling and the fertigation program for drip irrigation of tomatoes for processing are presented.

1. Introduction

Currently, tomato is one of the main vegetable crops in most countries of the world. In the open ground in the south of Russia, it began to be cultivated in the middle of the XIX century. Very quickly – by the beginning of the twentieth century – tomato, thanks to its excellent taste qualities, became one of the mandatory and priority vegetable crops in the gardens of the rural population. And now the leaders in growing tomatoes in the open ground in the Russian Federation are the Southern Federal District and the North Caucasus Federal District, which produce 55% and 37.6% of annual volumes, respectively [1, 2, 3].

Tomato belongs to heat-loving plants. Its seeds germinate together at a temperature of 20-25 °C, the decrease in temperature to 16-17 °C slows down their germination for 12-13 days. At a temperature of 8-10 °C, no more than 6-10% of seeds germinate for 30 days. For the photosynthetic activity of tomato plants, the optimum temperature is in the range of 20-25 °C. At a temperature below 15 °C, the tomato does not bloom, and at 10 °C, plant growth is suspended. The critical temperature for most tomato varieties is 1-2 °C [4, 5, 6].

Frequent sharp daily temperature fluctuations cause the fall of flowers, ovaries and delayed fruiting. The increased temperature also negatively affects the vital activity of the tomato plant. Already at a temperature of 30 °C, many pollen grains lose their ability to germinate, and a further increase in temperature leads to depression and rapid inhibition of photosynthesis, although the intensity of respiration continues to increase [7, 8, 9].

When assessing agro-climatic and weather conditions, it is customary to take into account the duration of a period favorable for the development of tomatoes with the temperature above 15 °C. It should be borne in mind that the ratio of tomatoes to the temperature regime depends on many factors: the biological characteristics of varieties and hybrids, the age of plants, the intensity of lighting, moisture...
The minimum temperature level for tomatoes in the seedling period is 17-19 °C during the day and 10-12 °C at night; for adult plants in the flowering phase, during fruiting and fruit ripening, it is 3-4 °C higher [10, 11].

Tomato is a very demanding plant for light. In low light, the absorption of nutrients by the root system of plants weakens, growth and development slow down. Light, which accelerates the processes of photosynthesis, and temperature, which controls the speed of enzymatic biochemical reactions, are closely interrelated and mutually dependent. The tomato shows the greatest demand for light in the phases of flowering and fruit formation. Cloudy weather during flowering, fruit formation and ripening lengthens this period by 10-15 days and significantly worsens the quality of commercial products [12, 13, 14].

Tomato is resistant to air and soil drought, but the decrease in the reserves of productive moisture in the root layer of the soil leads to a significant decrease in yield and causes a disease of plants with vertex rot. The lower limit of the optimal moisture content of the active soil layer is in the range of 75-80 % of minimum water capacity. Sudden changes in soil moisture during flowering cause the flowers to fall off, and during the filling period, the fruits of some varieties crack. Sharp fluctuations in air humidity also have a negative effect on tomato plants. The optimal relative humidity for tomatoes is in the range of 45-65%. The increased humidity of the air contributes to the spread of fungal and bacterial diseases of tomato (septoria, macrosporiosis, late blight, bacterial cancer, etc.) [15].

2. Materials and methods
The correct selection of tomato varieties and hybrids allows you to increase the yield, accelerate the ripening of fruits, improve their quality and marketability of the products produced.

For tomato cultivation, soils of various granulometric composition (from heavy loam to sandy loam) with a pH of 6.0-7.1 are suitable. Like other vegetable crops, tomato is demanding for effective soil fertility, the presence in the root layer of a sufficient number of nutrients in a form accessible to plants.

The removal of nutrients by tomato plants per 1 ton of fruits with the appropriate amount of vegetative mass at normal moisture supply during the growing season is, according to generalized data, 2.6-3.0 kg of nitrogen (N), 1.0-1.1 kg of phosphorus (P₂O₅) and 2.8-3.2 kg of potassium (K₂O).

The dynamics of the consumption of food elements is in good agreement with the rate of increase in the dry biomass of the whole plant and individual organs of the tomato. The maximum increase in dry matter is observed in July-August, when leaves and stems are formed and fruit formation processes are intensive. The consumption of phosphorus ends by the time the growth of the dry mass of leaves stops and the fruit sets. Active absorption of nitrogen and potassium is also observed during the period of the greatest increase in the organic matter of tomato plants. The consumption of these elements mostly ends long before the last harvest of fruits. The filling of fruits in tomatoes is carried out mainly due to reutilization – the movement of food elements from the vegetative organs. Calculations have shown that of the total amount of nutrients absorbed by tomatoes from the soil and fertilizers during the growing season in the open ground, the fruits contain 70% nitrogen (N), 70% phosphorus (P₂O₅) and 90% potassium (K₂O).

3. Results and discussion
The doses and composition of fertilizers used for tomato depend on the soil fertility, the degree of its cultivation and the planned yield. Table 1 shows the estimated annual doses of nitrogen, phosphorus and potash fertilizers for different levels of planned yield on the soils of the steppe and dry-steppe zones of the Astrakhan region under the optimal irrigation regime.
Table 1. Estimated annual doses of mineral fertilizers for different levels of planned tomato yield, kg of active substance/ha.

| Planned yield, t/ha | Provision of the soil with mobile forms of food elements | N    | P₂O₅ | K₂O |
|---------------------|--------------------------------------------------------|------|------|-----|
|                     | low–average                                            | low  | average | increased | high  | low  | average | increased | high  |
| 50                  | 100-140                                                | 75   | 60    | 50  | 25  | 185  | 150    | 110    | 35    |
| 60                  | 120-170                                                | 90   | 75    | 60  | 30  | 225  | 180    | 135    | 45    |
| 70                  | 140-195                                                | 105  | 90    | 70  | 35  | 260  | 210    | 160    | 55    |
| 80                  | 155-225                                                | 120  | 100   | 80  | 40  | 300  | 240    | 180    | 60    |
| 90                  | 175-250                                                | 135  | 115   | 90  | 45  | 335  | 270    | 200    | 65    |
| 100                 | 195-280                                                | 150  | 125   | 100 | 50  | 375  | 300    | 220    | 75    |

The system of tomato fertilization in the open ground includes two methods of applying mineral fertilizers: basic (pre-planting) and top dressing, most often and more effectively in the form of fertigation. The average doses of the main fertilizer application during the preparation of the soil for tomato in the conditions of the soil and climatic zones of the Astrakhan region are shown in Table 2.

Table 2. Average doses of the main fertilizer application when preparing the soil for tomato, kg of active substance/ha.

| Planned yield, t/ha | Provision of the soil with mobile forms of food elements | N    | P₂O₅ | K₂O |
|---------------------|--------------------------------------------------------|------|------|-----|
|                     | low–average                                            | low  | average | increased | high  | low  | average | increased | high  |
| 50                  | 70-50                                                  | 75   | 60    | 50  | 25  | 185  | 150    | 110    | 35    |
| 60                  | 85-60                                                  | 90   | 75    | 60  | 30  | 225  | 180    | 135    | 45    |
| 70                  | 95-70                                                  | 105  | 90    | 70  | 35  | 260  | 210    | 160    | 55    |
| 80                  | 110-80                                                 | 120  | 100   | 80  | 40  | 300  | 240    | 180    | 60    |
| 90                  | 125-90                                                 | 135  | 115   | 90  | 45  | 335  | 270    | 200    | 65    |
| 100                 | 140-100                                                | 150  | 125   | 100 | 50  | 375  | 300    | 220    | 75    |

The main fertilizer is designed to meet the nutritional needs of tomato plants from the planting of seedlings to the end of the growing season. At the same time, phosphorus and potash fertilizers are usually applied in autumn for deep plowing, and nitrogen fertilizers are applied in spring for pre-planting tillage (scattered or locally). With drip irrigation, the main fertilizer can be applied locally along the landing strip in the spring 15-20 days before planting tomato seedlings.

During the growing season of tomatoes in the open ground, 1–4 nitrogen fertilizing is carried out at intervals of 3 weeks with a dose of N₅₀. The terms, number and doses of fertilizing with various nitrogen fertilizers (urea, ammonium nitrate, urea-ammonia mixture) when applying them with irrigation water are shown in Table 3.
Table 3. Terms and doses of top dressing of tomatoes with nitrogen fertilizers when they are applied with fertigation during sprinkling (against the background of the main fertilizer (against the background of the main fertilizer (NPK) for the planned crops)).

| Planned yield, t/ha | The first top dressing after planting seedlings, weeks | Number of top-ups | Interval between fertilizing, weeks | Total fertilizers*, kg/ha |
|---------------------|-----------------------------------------------|------------------|-------------------------------|-----------------------------|
|                     |                                               |                  |                               | urea | ammonium nitrate | urea-ammonia mixture |
| 50                  | 2-3                                           | 1                | -                             | 110  | 150            | 155              |
| 60                  | 2-3                                           | 1                | -                             | 110  | 150            | 155              |
| 70                  | 2                                             | 2                | 3                             | 220  | 300            | 310              |
| 80                  | 2                                             | 3                | 3                             | 330  | 450            | 465              |
| 90                  | 2                                             | 3-4              | 3                             | 330-400 | 450-540     | 465-565           |
| 100                 | 2                                             | 3-4              | 3                             | 330-400 | 450-540     | 465-565           |

* The dose of each fertilizer for fertilizing is distributed between the number of planned fertigations (the form of nitrogen fertilizer is selected depending on the availability in the farm).

Optimization of nitrogen nutrition of tomatoes when grown in the open ground against the background of the main full fertilizer contributes to the formation of a larger leaf area, enhances the photosynthetic activity of plants, prolongs active fruiting, which significantly increases the yield of high-quality fruits.

Table 4. Fertigation program for drip irrigation of tomatoes for processing (against the background of the main fertilizer applied 2 weeks before planting seedlings with a dose of N\textsubscript{80}P\textsubscript{80}K\textsubscript{80}).

| Number of days from the date of planting | The phase of tomato growth and development | Tensiometer readings before watering, sbar | Irrigation rate, m\textsuperscript{3}/ha | Fertigation components (N) (P\textsubscript{2}O\textsubscript{5}) (K\textsubscript{2}O) | Fertigation components kg/ha for irrigation |
|----------------------------------------|-------------------------------------------|-------------------------------------------|------------------------------------------|-------------------------------------------|------------------------------------------|
| 0                                      | Planting seedlings                         |                                            | 300-500                                  |                                            |                                          |
| 5-6                                    | Survival                                   |                                            | 10-20                                    |                                            | 20                                       |
| 12                                     | Vegetative growth                          |                                            | 10-20                                    |                                            | 10 20                                    |
| 18                                     | -/-                                        |                                            | 10-20                                    |                                            | 10 20                                    |
| 24                                     | Flowering                                  | 30-35                                     | 20-30                                    |                                            | 15 20                                    |
| 30                                     | -/-                                        | 30-35                                     | 20-30                                    |                                            | 15 20                                    |
| 33                                     | -/-                                        | 30-35                                     | 30-40                                    |                                            | 20 20                                    |
| 36                                     | Fruit formation                            | 30-35                                     | 30-40                                    |                                            | 20 20                                    |
| 39                                     | -/-                                        | 30-35                                     | 40-50                                    |                                            | 20 20                                    |
| 42                                     | -/-                                        | 30-35                                     | 40-50                                    |                                            | 20 20                                    |
| 45                                     | Fruit growth                               | 25-35                                     | 50-60                                    |                                            | 20 20                                    |
| 48                                     | -/-                                        | 25-35                                     | 50-60                                    |                                            | 10 20                                    |
| 51                                     | -/-                                        | 25-35                                     | 60-70                                    |                                            | 10 20                                    |
| 54                                     | -/-                                        | 30-35                                     | 60-70                                    |                                            | 10 20                                    |
| 57                                     | -/-                                        | 30-35                                     | 70-80                                    |                                            | 10 20                                    |
| 60                                     | -/-                                        | 35-40                                     | 70-80                                    |                                            | 10 20                                    |
| 63                                     | -/-                                        | 35-40                                     | 70-80                                    |                                            | 10 20                                    |
| 66                                     | -/-                                        | 35-40                                     | 70-80                                    |                                            | 10 20                                    |
| 69                                     | Changing the color of fruits               | 35-40                                     | 60-70                                    |                                            | 10 20                                    |
| 72                                     | -/-                                        | 35-40                                     | 60-70                                    |                                            | 10 20                                    |
| 75                                     | -/-                                        | 40-45                                     | 60-70                                    |                                            | 10 20                                    |
| 78                                     | -/-                                        | 40-45                                     | 60-70                                    |                                            | 10 20                                    |
In case of drip irrigation, the terms and norms of irrigation and the doses of fertilizers applied are set taking into account the water regime of the soil and the phases of growth and development of tomato plants. An intensive tomato technology for industrial processing has been developed and is used in production for the Astrakhan Region, in which the control of the water regime of the soil using tensiometers evaporometers and plant nutrition using fertigation is used synchronously.

Irrigation and fertigation schedules for growing tomatoes for processing (for one-time mechanized harvesting) are approximate, since they are compiled without taking into account atmospheric precipitation, water-physical properties and soil parameters, NPK reserves in the soil, but their implementation provides a real possibility of obtaining a fruit harvest of at least 80-100 t/ha.

A special feature of the fertigation program is the introduction of only nitrogen fertilizer with irrigation water after planting seedlings (for a week), then regular fertilizing with nitrogen-phosphorus fertilizers (8 fertigations in 3 days). In the future, the tomato is fed with small doses of nitrogen fertilizer (up to 7 times N_10).

The irrigation schedule is designed to maintain soil moisture in the calculated layer of 0-0.4 m within the humidification circuit at the level of 80-90 % of minimum water capacity. Pre-planting irrigation is carried out at a rate of 300-500 m³/ha. All vegetation watering is carried out with the simultaneous supply of a fertilizer solution, which provides a higher coefficient of assimilation of nutrients by plants.

4. Conclusion

Depending on the intensity of evapotranspiration of tomato plantings, the water consumption for drip irrigation may vary in the first 4-5 weeks after planting within 10-30 m³/ha, and in subsequent periods of vegetation it may increase to 40-80 m³/ha.

The use of drip irrigation of tomatoes based on fertigation allows you to grow high yields of up to 80-100 t/ha and more high-quality commercial fruits in the agroclimatic and soil conditions of the Astrakhan region.

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