Drip irrigation of onions

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Abstract. From 2017 to 2020, research was conducted in the Volgograd region in order to improve the efficiency of water and mineral nutrition management of onions by justifying the calculated layer of soil moisture and agrotechnical methods of cultivation on light chestnut soils to obtain 110 t/ha of marketable products. The main objectives of the research include the rationale for the formation of the water regime of the soil and drip irrigation regimes depending on the wetted soil, the study of patterns of growth, development and yield formation of onion depending on the studied factors, economic and environmental assessment of drip irrigation technology, the quality of the bulbs, depending on the studied factors. The field experience included the following options: water regime of the soil (factor A), mineral nutrition regime (factor B), promising onion hybrids (factor C). The studies were carried out on onion crops C1 – Migros F1; C2 – Dragon F1; C3 - Dammica F1. Against the background of the introduction of N₁₈₀P₈₀K₇₀, the Migros F1 hybrid provides an average of 94.3 t/ha of onions in 3 years of research, which is 16.6 t/ha more in comparison with the Dragon F1 onion; and 2.2 t/ha more in the Dammica F1 hybrid.

1. Introduction
According to the FAO, the world onion production is at the level of 98 million tons. The main leaders in onion production are China (24.8%), India (22.8%), the United States (4%), Egypt (2.5%), and Iran (2.5%). According to annual statistics, about 24.3 million tons are produced in China, 22.4 million tons in India, and 3.7 million tons in the United States.

In the Russian Federation, the area of onion sowing in recent years ranges from 23.8 to 28.1 thousand hectares. In 2018, the total volume of onion harvesting in Russia amounted to 103.3 thousand tons. The largest areas under onions are occupied in the Volgograd region, where 6.48 thousand hectares were sown in 2018, which is 24.7% of the total area. Farmers of the Astrakhan region sow an average of 3.83 thousand hectares. Two times less is allocated for onion crops in the Stavropol Territory, about 3.37 thousand hectares, and in the Rostov region the area of crops under spring onions does not exceed 2.89 thousand hectares [1, 2].

The Volgograd region is a leader in the growth of onions. The industry employs about 50 large agricultural organizations and almost 700 farms. Analysis of onion production in the Volgograd region shows that the average yield is 23 t/ha, although the best farms grow from 40 to 85 t/ha. Therefore, to increase the productivity of onions, it is necessary to further improve the technology of cultivation on
irrigated lands, taking into account the biology of the crop, the patterns of growth and crop formation [3, 4, 5].

The issues of managing the water regime of the soil and mineral nutrition of plants are very relevant. Obtaining new experimental data will allow us to develop not only a program for fertigation of crops under drip irrigation, but also a program for managing the water regime of the most common light chestnut soils in the region. Long-term research conducted by us in the period from 2004 to 2016 confirmed the need for further research using promising onion hybrids [6, 7, 8].

2. Materials and methods
Since 2017, new studies have been conducted by us in the farm of the Leninsky district of the Volgograd region in order to improve the efficiency of water and mineral nutrition management of onions by justifying the calculated layer of soil moisture and agrotechnical methods of cultivation on light chestnut soils to obtain 110 t/ha of marketable products. The main objectives of the research include the rationale for the formation of the water regime of the soil and drip irrigation regimes depending on the wetted soil, the study of patterns of growth, development and yield formation of onion depending on the studied factors, economic and environmental assessment of technology ka-pelny irrigation of onions, the quality of the bulbs, depending on the studied factors. Special attention is paid to the preparation of the soil for sowing.

During the research, a set of equipment from the company "Eurodrip" was used, the total area of the experimental site is 30 hectares, the area of one organized repetition is 0.25 hectares. For the area of the land plot, the experiment was laid by the method of split plots. The variants of the water regime of the soil and the regime of mineral nutrition were located across the experimental site. The placement of options within the factor is randomized. The shape and direction of the strips, as well as the size of the protective strips, were adopted in accordance with the requirements of generally accepted methods. To exclude the influence of soil differences, the experiments were carried out in four-fold repetition [9, 10].

3. Results and discussion
The experimental irrigated area, located on the territory of the farm, is located in a subzone of light chestnut soils. The soils of this subzone are characterized by low humus horizons of 0.15-0.25 m and low humus content (1.6-2.3%) in the surface layer. The reaction of the soil solution is slightly alkaline (pH 7.0-8.3). The absorption capacity is low, the amount of absorbed bases reaches 28.5 mg/eq. per 100 g of soil. In the composition of exchange cations, 70-80% is accounted for by calcium. The percentage of sodium in the total absorbed bases ranges from 2.4 to 3.3% on non-saline soils and from 5 to 10% on saline soils. According to the content of available forms of nutrients, the soils are characterized by low nitrogen supply, medium mobile phosphorus and high exchange potassium. The content of total nitrogen is 0.11-0.15%, hydrolyzed 2.12-14.16 mg per 100 g of soil. The amount of total phosphorus reaches 0.08-0.09%, and available - 2.5-12 mg per 100 g of soil, total potassium according to Milwich – 1.45%, and exchange – more than 25 mg per 100 g of soil.

According to the average long-term data, in the conditions of unstable moisture in the Lower Volga region, the replenishment of soil moisture reserves due to precipitation during the growing season is not enough to obtain high and stable onion yields.

The field experiment was based on the plan of a complete factorial experiment, which included the following options: water regime of the soil (factor A), mineral nutrition regime (factor B), promising onion hybrids (factor C).

The experimental setup for factor A was to provide three levels of maintenance of pre-irrigation soil moisture using a drip irrigation system for different horizons of soil drenching:

A1 – maintenance threshold pre-irrigation soil moisture 70% of the lowest moisture capacity (LMC) during the period from sowing of seeds to the formation of 5 sheet in a layer of 0.3 m, the period of 5 sheet before starting the technical ripeness of bulbs in the layer 0.5 m;

A2 – maintenance threshold pre-irrigation soil moisture 80% of LMC during the period from sowing of seeds to the formation of 5 sheet in a layer of 0.3 m, the period of 5 sheet until the formation of
follicles in the layer of 0.5 m and at 70% of LMC in the layer of 0.5 m during the period from the formation before the start of the technical maturity of the follicles; 

A3 – maintenance threshold pre-irrigation soil moisture 90% of LMC in the period from sowing of seeds to the formation of 5 sheet in a layer of 0.3 m, the period of 5 sheet until the formation of follicles in the layer of 0.5 m and at 70% of LMC in the layer of 0.5 m during the period from the formation before the start of the technical maturity of the follicles.

Diagram of experience in the food regime of the soil (factor) was the doses of fertilizer application, designed to receive trehubova onion yield: B1 – внесениеN₁₄₀P₄₀K₃₀ on the planned harvest onions 70 t/ha; B₂ – внесениеN₁₈₀P₈₀K₇₀ on the planned harvest onions 90 t/ha; B₃ – внесениеN₂₂₀P₁₂₀K₁₁₀ on the planned harvest onions 110 t/ha;

The scheme of experience for the study of promising onion hybrids (factor C) included the following variants: C₁ – Migros F₁; C₂ – Dragon F₁; C₃ - Dammica F₁.

At the experimental site, the seasonal stationary mobile drip irrigation system consists of three blocks. Each block (Figure 1) includes 18 modules with an area of 1.2 hectares. The total area of one block is 22.5 hectares. The total area of the drip irrigation system is 67.5 hectares. The system is designed in such a way as to ensure maximum water consumption of plants under the most arid conditions. The order of watering the modules is as follows: 1–4, 2–5, 3–6, 7–8, 9–16, 10–13, 11–14, 12–15, 17–18.

The weather conditions during the growing season were as follows. From the sowing of onions on April 21 to the beginning of harvesting, 117.8 mm of precipitation fell on September 1, which was extremely unevenly distributed. Most precipitation fell in May (28.8 mm) and July (71.5 mm). June was very dry, with precipitation below the long-term average of 21.2 mm (15.3 mm) and August. In August, 1.7 mm of precipitation fell, which is less than the long-term average of 31 mm.

During the growing season of onions, crops accumulated an average of 2925.7 °C: April - 146 °C, May - 774 °C, June - 774 °C, August - 706.8 °C. The lowest average monthly relative humidity was observed in June - 31% and in August - 39%.

All this significantly affected the irrigation regime and onion yield. In the conditions of the Volgograd region, soil and climatic resources combined with the management of the water regime of the soil, drip irrigation and fertigation of crops allowed the formation of 70-94.3 t/ha of standard onion products. Depending on the supported pre-irrigation threshold of soil moisture for the periods of plant growth and development and the depth of wetting of the calculated soil layer, the water consumption according to the experimental variants varied from 3200 to 4300 m³/ha. The average daily water consumption of onion crops varied from 8 to 63 m³/ha. The share of irrigation water in the water balance of the irrigated onion field varied from 57.6 to 65.3% according to the experimental variants. Irrigation norms for drip irrigation varied depending on the maintained pre-irrigation threshold of soil moisture and the depth of moisture from 120 to 310 m³. The obtained data for accounting for the yield of bulbs according to the experimental variants are statistically reliable (Figure 1).
Figure 1. Unit of mobile drip irrigation system includes 18 modules at 1.2 hectares each: 1 - water intake unit from the canal; 2 – pump station K 100/250; 3 - filter station; 4 – hydraulic feeder; 5 - layflat with a diameter of 150 mm; 6 – layflat 100 mm diameter; 7 - connection node; 8, 9 – distribution crane; 10 - connectors; 11 – dropper (emitters); 12 – drip line; 13 - number of modules; 14 - outdoor channel (outflow channel, Volgograd region). The arrows indicate the direction of water movement in the cable lines.

For the hybrid Migros F1 the Lowest Significant Difference (LSD_{0.05}) on factors A and B is 1.24 t/ha, for private averages 2.14 t/ha. For the hybrid Dragon F1 LSD_{0.05} on factors A and B 1.51 t/ha, for private averages 2.62 t/ha. According to the hybrid Dammica F1 LSD_{0.05} on factors A and B 1.46 t/ha, for private averages 2.54 t/ha.
Figure 2. Yield of promising onion hybrids depending on the water regime of the soil and the level of mineral nutrition, 2018-2020.

The yield of standard bulbs, hybrid Migros F1 depending on the studied factors is described by an equation of the form:

\[ Y = a + b \cdot W + c \cdot [NPK] + d \cdot W^2 + e \cdot [NPK]^2 + f \cdot W \cdot [NPK], \]

where \( Y \) is the yield of onions, t/ha; \( W \) – level pre-irrigation soil moisture under-derisively during the period from sowing of seeds to the formation of the fifth sheet, % of LMC; \([NPK]\) – planned level onion yield, which is calculated on the total dose of NPK; the parameters of the equation \( a = -405.6, b = 7.8, c = 2.37, d = -0.033, e = -0.0099, f = 0.0075 \) determined by regression analysis. The coefficient of determination of the dependence is 0.90.
Figure 3. Dependence of the Migros F1 hybrid yield on the level of water supply and mineral nutrition conditions under drip irrigation.

The dependence parameters for all onion hybrids studied in the experiment are shown in Table 1.

Table 1. Parameters of the dependence of the yield of promising onion hybrids on the level of water supply and mineral nutrition conditions under drip irrigation.

| Hybrid    | Dependency Parameters | R²  |
|-----------|-----------------------|-----|
|           | a    | b    | c    | d    | e    | f    |
| Migros F1 | -405.6 | 7.8  | 2.37 | -0.033 | -0.0099 | -0.0075 |
| Dragon F1 | -437.6 | 8.5  | 2.36 | -0.039 | -0.011  | -0.0055 |
| Dammica F1| -417.1 | 7.85 | 2.56 | -0.034 | -0.011  | -0.0077 |

4. Conclusion
Taking into account the typical features of the soil cover on the territory of the Volgograd region (mainly light chestnut type of soil), the yield of onions of marketable quality is directly dependent on the technological functions of drip irrigation. First of all, this is a differentiated regulation of soil moisture at different depths, depending on the specific phase of the plant growth period, fertilizing by applying mineral fertilizers to the planned crop. It is proved that under the condition of regulating the threshold of pre-irrigation soil moisture according to the presented scheme (in the period from seed sowing to the formation of 5 leaves in a layer of 0.3 m - not less than 90% of LMC; in the period from the formation to the beginning of technical ripeness of bulbs in a layer of 0.5 m - 80% of LMC) against the background of the introduction of $N_{180}P_{80}K_{70}$, the Migros F1 hybrid provides an average of 94.3 t/ha of onions over 3 years of research, which is 16.6 t/ha more than the Dragon F1 onion; and 2.2 t/ha more than the Dammica F1 hybrid. The planned yield of 110 t/ha for the studied onion hybrids was not obtained.

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