The influence of soil treatment and irrigation methods on tomato yield and quality in the lowlands of Dagestan

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Abstract. A positive effect of irrigation of meadow-chestnut soil on soil fertility was described for the dry-steppe zone of Dagestan. The object of research was tomatoes (Gift variety) planted on irrigated lands of Dagestan. The subject of research is tillage and irrigation methods. The influence of agrotechnical methods on agrophysical soil properties, level and quality of tomatoes was determined. Maintaining the moisture of the active soil layer within 80...100 % NV can optimize agrophysical fertility indicators of the meadow-chestnut soil. In combination with tillage at a depth of 0.23...0.25 m, it ensures the tomato yield of 80...86 t/ha.

1. Introduction
The problem of modern agriculture is preservation and reproduction of fertility of irrigated lands [1] affected by the methods of primary tillage [2–4].

In the farms of Dagestan (private farms and peasant farms) growing vegetables, a surface irrigation method – irrigation along furrows – predominates. This method leads to a strong soil compaction which damages the root system of plants, increasing clogging [5]. Therefore, for the destruction of the soil crust, a mandatory technique is post-irrigation loosening of row-spacing. With this irrigation method, the soil along the furrow length is moistened unevenly, water is consumed irrationally, and irrigation mechanization is difficult [6, 7].

Therefore, the search for tillage methods that contribute to the conservation and reproduction of soil fertility, optimization of the ecological state of irrigated lands is one of the urgent tasks of modern agriculture. In this regard, the goal of our experiments was to study the influence of tillage methods at various pre-irrigation thresholds under drip irrigation on the agrophysical properties of meadow chestnut soil.

2. Methods and materials
In 2016, we carried out three-factorial experiments on meadow-chestnut medium loamy soils of the farm “Magomedov Kamil Abdullaevich” in the Ba-Bajurt district of the Republic of Dagestan. According to the methods of primary tillage (factor A), there were the following options: A1 – dump tillage to a depth of 0.23–0.25 m (control); A2 – deep loosening to a depth of 0.23–0.25 m applying Zenkor Ultra herbicide in the spring under pre-sowing treatment. The following options of the irrigation method were compared (factor B): B1 – irrigation along furrows (control); B2 – drip irrigation. According to the water regime (factor C), the following options were compared: C1 – 70 % HB in the active layer of 0.5 m, control; C2 – 80 % HB in the active layer of 0.5 m; C3 – 90 % HB in the active layer of 0.5 m.
3. Results

Important parameters that determine the physical state of the soil are density and porosity [8]. The study of soil density with different methods of basic tillage showed that before planting tomato seedlings (dump tillage to a depth of 0.23...0.25 m), it was characterized by a lower density, and the volumetric mass values indicate a loose state of the arable layer (Table 1).

The research results showed that deep loosening leads to soil compaction by 0.02...0.03 t/m$^3$, but soil density is within optimal values.

Comparing the irrigation methods, it can be noted that the greatest soil compaction occurs during irrigation along the furrows, soil density increases by 0.09 t/m$^3$, approaching the values of soil density under deep loosening. The use of drip irrigation in both methods of primary tillage also leads to gradual self-compaction of the soil, but density increases by 0.06...0.07 t/m$^3$, which is 0.02 t/m$^3$ more than under dump tillage.

Table 1. The effect of primary tillage methods, irrigation methods and regimes on the agrophysical properties of the arable layer (2016-2018)

| Agrophysical properties | Tillage at a depth of 0.23...0.25 m, control | Deep loosening 0.23...0.25 m + Zenkor |
|-------------------------|---------------------------------------------|---------------------------------------|
|                         | 70 % NV                                     | 80 % NV                               | 90 % NV                               | 70 % NV                                     | 80 % NV                               | 90 % NV                               |
| Density /m$^3$           | 1.19                                          | 1.19                                   | 1.18                                   | 1.21                                          | 1.21                                   | 1.21                                   |
| Porosity, %              | 55.9                                         | 55.9                                   | 56.3                                   | 56.3                                          | 55.2                                   | 55.2                                   |
| Water permeability, mm/h | 180                                          | 181                                    | 179                                    | 180                                          | 186                                    | 184                                    |

* in the numerator – at the beginning of the growing season; in the denominator – at the end of the growing season

The pre-irrigation thresholds for soil moisture, the difference in irrigation rates and the number of irrigations affect the soil density. The greatest compaction occurs when the threshold of pre-irrigation soil moisture is not lower than 70 % of HB, at the highest irrigation rate of 225 m$^3$/ha. At this threshold, density increased by 0.06...0.08 t/m$^3$, the pre-irrigation threshold increased to 90 % HB. The application of irrigation rates at the level of 75 m$^3$/ha reduced an increase in bulk mass up to 0.04...0.06 t/m$^3$.

A very important soil property is its water permeability. The portion of water that enters the soil and can be used by plants depends on it [9]. Water permeability naturally decreases by the end of the growing season by 8.3...17.9 %. It has been noted that during sowing, it decreases by only 3.9...8.3 %, while with deep loosening it is already 11.4...17.8 %. Among the compared irrigation methods, it was noted that irrigation along the furrows leads to a decrease in water permeability during dump tillage by 3.4 %. Under deep loosening, a decrease is 8.6 %. This is due to differences in soil density and porosity. As for pre-irrigation thresholds of soil moisture, the greatest decrease in water permeability was observed at a pre-irrigation threshold of soil moisture of 70 % HB – an average of 13.1 %, with 80 % HB – by 10.0 %, and at 90 % HB – by 7.6 %. This is due to differences in irrigation norms. During the irrigation along furrows, water permeability decreases 1.4 times.

There is a tendency towards a decrease in porosity by the end of the growing season. The best air conditions are formed after dump tillage – 54.3 %, while after deep loosening it is 53.0 %. The transition to drip irrigation reduces the amplitude of oscillations in soil porosity due to the locality of moisture. Changes in the pre-irrigation moisture levels did not have a noticeable effect on soil porosity, although it was somewhat higher against the background of the dump cultivation.

The structure is the most important soil property determining water-air, thermal and biological regimes, provision of plants with water and nutrients, labor productivity in irrigated agriculture. Macroaggregates of 0.25–10 mm in size are most valuable [10]. The objective of our research was to study agrotechnical methods aimed at soil structuring (table 2).
Table 2. Parameters of the structural state of soil under different methods of primary tillage, methods and modes of irrigation (2016–2018)

| Parameters                               | Tillage at a depth of | Deep loosening          |
|------------------------------------------|-----------------------|-------------------------|
|                                          | 0.23...0.25 m, control| 0.23...0.25 m + Zenkor |
|                                          | 70 % NV KO NV NV     | 70 % NV KO NV NV       |
| Number of aggregates > 10 mm, %          | 32.5 29.6 28.5 28.2  | 30.1 28.3 27.8 27.6    |
| Number of aggregates 0.25–10 mm, %       | 58.6 60.7 62.2 61.9  | 60.4 62.4 63.5 63.6    |
| Number of aggregates < 0.25 mm, %        | 8.9 9.7 9.3 9.9      | 9.5 9.3 8.7 8.8        |
| Number of water-resistant aggregates, %   | 51.7 53.4 55.9 57.6  | 44.8 47.7 52.3 55.1    |
| Structure coefficient                     | 1.42 1.54 1.64 1.62  | 1.52 1.66 1.74 1.75    |
| Water resistance coefficient              | 1.07 1.14 1.27 1.36  | 0.81 0.91 1.10 1.23    |
| Water permeability coefficient            | 0.57 0.59 0.62 0.64  | 0.49 0.52 0.57 0.60    |

The determination of the aggregate composition of the arable soil layer showed that there were no significant differences in the content of structural aggregates. However, there was a slight decrease in clumpiness under deep loosening contributed to a slight increase in the number of valuable aggregates by 1.6 %. This is also confirmed by the structural coefficient, which increased from 1.56 to 1.67. In our opinion, this is due to the plant residues left after deep loosening.

But in conditions of irrigated agriculture, the most important soil property is the presence of water-resistant aggregates larger than 0.25 mm in size. Dump tillage contributes to an increase in the number of water-resistant aggregates by 3.9 %, which leads to an increase in the water resistance coefficient by 16.7 %.

The transition from irrigation along furrows to drip irrigation contributes to an increase in the number of water-resistant aggregates by 3.9 % after dump tillage and by 6.9 % after deep loosening. An increase in the level of pre-irrigation humidity from 70 to 90 % HB also contributes to the growth of water-resistant aggregates by 4.2 and 7.4 %, respectively. At the same time, water resistance of the meadow-chestnut soil after dump tillage and drip irrigation significantly exceeds water resistance of the aggregates after deep loosening.

The study of weeding of tomato plantings and potential weeding by weed seeds showed that deep loosening increases total weeding 1.3 times and potential weeding – by 46.3 %. The use of Zenkor Ultra (KS) herbicide at a dose of 1.5 l/ha allows you to abandon one cultivation in the system of pre-sowing tillage and reduce weeding by 66.7 %. Furrow irrigation compared to drip irrigation leads to an increase in total weeding by 19.1...28.6 % and potential weeding – by 16.4...19.0 %. A change in soil moisture pre-irrigation thresholds from 70 to 90 % HB leads to a decrease in total weeding by 19.6 %, and potential weeding by 8.9...9.4 million pcs/ha.

The irrigation regime depends on weather conditions, irrigation methods and thresholds of soil moisture. The transition from furrow irrigation to drip irrigation increases the number of irrigations by 8. Within one year, the transition from a moderate regime of irrigation (70 % HB) with an irrigation rate of 225 m$^3$/ha to a more humidified (80 % HB) one with an irrigation rate of 150 m$^3$/ha contributed to an increase in the number of irrigations by 7...8. An increase in soil moisture up to 90 % HB led to more frequent irrigation and an increase in their number compared to the pre-irrigation threshold of 70 % HB by 40...43. An increase in the number of irrigations occurs at the beginning of fruit formation. The method of primary tillage did not affect the number of irrigations.

An important indicator of the efficiency of irrigation water application is the application coefficient [8]. Irrigation water is used least efficiently when irrigating along furrows in both ways of primary tillage – 74.9...84.0 m$^3$/t. The transition from furrow irrigation to drip irrigation increases the efficiency of water use by 9.8...13.9 %. Raising the pre-irrigation threshold to 80 % HB contributes to a significant reduction in water consumption for 1 ton of crop and a decrease in the water use coefficient by 39.5...41.9 %. A further increase in soil pre-irrigation moisture to 90 % HB does not
contribute to the improvement of irrigation water use. The transition from dump tillage to deep loosening increases the average cost of irrigation water by 9.2%.

Crop yield is a general indicator of all processes occurring in a plant, and its value depends on the level of agricultural technology [10]. It was experimentally found that the transition from furrow irrigation to drip irrigation significantly affects the yield, but this is more evident at pre-irrigation thresholds of 80 and 90 % HB (table 3).

Table 3. The chemical composition of tomatoes depending on cultivation conditions (2016...2018)

| Parameters          | Tillage at a depth of 0.23...0.25 m, control | Deep loosening 0.23...0.25 m + Zenkor |
|---------------------|---------------------------------------------|--------------------------------------|
|                     | 70 % NV furrows                          | 70 % NV furrows                      |
| Yield, t/ha         | 57.4                                       | 51.2                                  |
| Dry matter, %       | 5.92                                       | 6.27                                  |
| Sugar, %            | 3.63                                       | 3.76                                  |
| Nitrates, mg/kg     | 61.9                                       | 61.7                                  |
| Vitamine C, mg/ %   | 16.8                                       | 17.1                                  |
|                     | 80 % NV KO                                | 80 % NV KO                           |
| Yield, t/ha         | 61.5                                       | 57.5                                  |
| Dry matter, %       | 6.10                                       | 6.35                                  |
| Sugar, %            | 3.55                                       | 3.40                                  |
| Nitrates, mg/kg     | 67.6                                       | 64.1                                  |
| Vitamine C, mg/ %   | 17.0                                       | 17.5                                  |
|                     | 90 % NV                                   | 90 % NV                               |
| Yield, t/ha         | 86.1                                       | 79.9                                  |
| Dry matter, %       | 6.35                                       | 6.50                                  |
| Sugar, %            | 3.40                                       | 3.25                                  |
| Nitrates, mg/kg     | 64.3                                       | 57.4                                  |
| Vitamine C, mg/ %   | 16.6                                       | 16.1                                  |

The research results show that the dump soil treatment under irrigation conditions has a positive effect on tomato yield, which is 5.9 t/ha higher than with deep loosening. The maximum tomato yield was obtained by combining dump treatment and maintaining a pre-irrigation moisture threshold of 80 % HB – 86.1 t/ha under drip irrigation.

The results of the analysis of the chemical composition showed that there were no significant differences in the quality indicators depending on soil treatment and irrigation methods, although there is a tendency to increase the dry matter content and vitamin C. To a greater extent, the quality is influenced by the moisture supply condition, since with an improvement in the level of pre-irrigation soil moisture, there is an increase in dry matter by 5.8 %, a decrease in the content of sugars and nitrates by 9.1 % and vitamin C by 4.1 %.

4. Conclusion

A comparative assessment of the impact of soil treatment methods on water-physical properties of meadow-chestnut soil indicates the best agrophysical values when applying the dump treatment method in combination with pre-irrigation thresholds of 80 and 90 % HB. Drip irrigation and dump treatment lead to a slight increase in soil density, a decrease in its water permeability and porosity. Pre-irrigation thresholds of 80 and 90 % HB contribute to a good structural state of the soil. The highest yield of tomatoes is observed when combining the dump treatment and a pre-irrigation moisture threshold of 80 % HB with drip irrigation.

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