

Determination of the main parameters of the mole irrigation network in the Lower Volga region

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Abstract. The article presents the results of studies to determine the main parameters of the irrigation network for the mole irrigation system on light chestnut soils of the Volgograd region, a typical region of the Lower Volga region. This method of irrigating crops will be used for the first time in this region. For this, 3 variants of the depth (0.3; 0.4 and 0.5 m) of the location of mole sprinklers - soil pipes with a diameter of 58 ... 63 mm for supplying water to plants were studied. Based on the study of moisture contours, it was found that the most effective was the location of molehills at a depth of 0.3 ... 0.4 m, since 99.3 ... 95.1% of the moisture in the zone of normal moistening (90...110% SMC the next day after watering) was within the active soil layer of 0.0-0.8 m in the absence of deep filtration into the underlying layers. Further study of the moisture contours showed that at a mole irrigation depth of 0.3...0.5 m, the zone of normal moisture (90...110% SMC) extended 40...51 cm to the left and 42...45 cm to the right, and the zone of low moisture (75 ...90% SMC) - 69...91 cm to the left and 63...68 cm to the right of the molehill axis, which allows soil sprinklers to be located at a distance of 1.0...1.5 m from each other if it is necessary to uniformly moisten the active soil layer throughout the irrigation area. The study was supported by a grant from the Russian Science Foundation and the Administration of the Volgograd Region under project No. 22-26-20070, <https://rscf.ru/project/22-26-20070>.

1 Introduction

Today, in many regions of our planet, there is a shortage of fresh water, including for the needs of irrigation of various crops. This imposes certain requirements on the irrigation methods used and forces us to look for more resource-saving ones. Subsoil irrigation (SIS) is the most water-saving method, however crop SIS has a rather narrow scope. Due to significant capital investments for the construction of an irrigation site, it is used only for irrigating orchards, vineyards, and less often for growing forage crops. But at the same time, long-term studies conducted at the Volgograd State Agrarian University on the study of the characteristics of subsoil irrigation of various vegetable crops [1-3] showed that this

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method of irrigation can freely compete with sprinkling and drip irrigation, and also be profitable despite high initial costs for putting the site into operation.

One of the most promising types of subsoil irrigation is mole subsoil irrigation (MSI). This method does not require capital construction, due to which the initial costs are minimized.

In the southern part of the Russian Federation, mole subsoil irrigation has been poorly studied; it was mainly used to irrigate crops with livestock waste. Abroad, mole irrigation was studied in Thailand [4], Iran [5], Argentina [6], China [7], Brazil [8], Great Britain [9], Portugal [10], the Netherlands [11], Australia [12], USA [13], Ireland [14], Egypt [15] and Canada [16].

On the light chestnut soils of the Volgograd region, as the most typical for the Lower Volga region, mole irrigation is studied for the first time, so one of the main tasks was to study the features of moisture distribution in the soil profile when using this method of irrigation.

2 Materials and methods

The experimental site is located between the Volga and Don rivers. The climate in this region is sharply continental. Summer is hot and dry with practically no rain in July and August. Winter is cold, with little snow. The article presents the results of field experiments performed at the Educational Research and Production Center "Gornaya Polyana" of the Volgograd State Agrarian University, carried out in 2022. The conducted studies are the basic part (initial stage) of many years of field experiments to develop a mole irrigation system for growing technical (on example of cotton) and leguminous crops (for example, soybeans), which will be planted in 2023.

The soils of the site are typical for the Lower Volga region, light chestnut, medium and heavy loamy. Ground waters were at a depth of more than 3 meters, so they did not affect the water-air regime of the active soil layer and were not monitored.

The presented article shows the results of field experiments that make it possible to determine the optimal depth of mole irrigation for the most efficient distribution of irrigation water in the soil section without deep filtration below the active soil layer (0.8 m).

In our experiments, 3 options for the depth of molehills were studied: 0.3, 0.4 and 0.5m.

All molehills were cut using a stand-knife with a front cutting edge and a coneparabolic flare (figure 1).

The diameter of the mole sprinklers was the same in all variants and amounted to 58...63 mm. The irrigation rate was 200 m³/ha, and the volume of water supply to 1 molehill with its length of 75 m was 2 m³.

The humidification contour was determined using the thermostatic-weight method the next day after watering. Sampling was carried out to the right and left of the molehill axis at a distance of 1 m with a step of 10 cm and to a depth of up to 1 m with the same step.

The initial soil moisture in the 0-1.0 m layer was 64...72% of the lowest moisture capacity (SMC).

Observations were carried out regularly during the field experiment in 2022. The article presents the most typical locations of moisture isopleths in the soil section.

Mathematical processing of the obtained results and construction of soil moisture isopleths were carried out using Microsoft Excel 2010 and Surfer 12

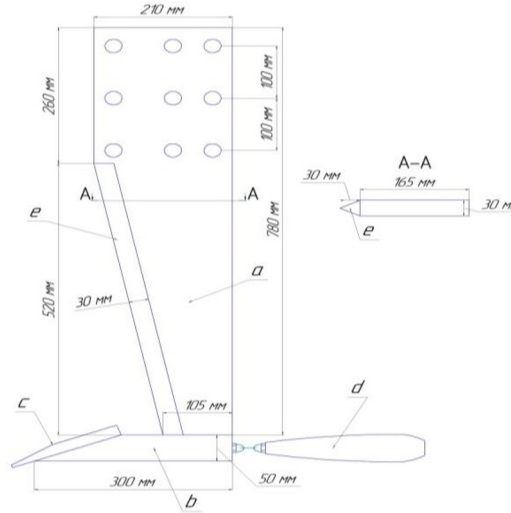


Fig. 1. The working body of the mole maker: a - stand, b - drainer, c - chisel, d - cone-parabolic flare, e - front cutting edge.

3 Results

After plotting soil moisture isopleths according to the experimental options (Figures 2 - 4), we evaluated the efficiency of distribution of irrigation water over the soil section. For convenience, 3 zones were identified with varying degrees of moisture: Waterlogged zone (> 110% SMC); Zone of normal humidification (90...110% SMC) Low moisture zone (75...90% SMC).

The boundaries of these zones clearly demonstrate the nature of soil moisture depending on the depth of mole irrigation.

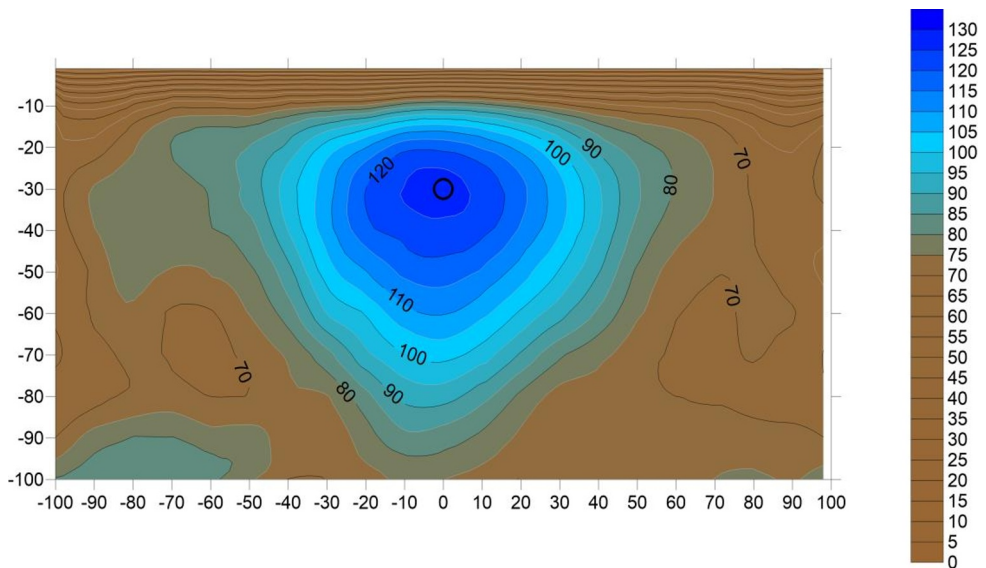


Fig. 2. Soil moisture isopleths (% SMC) at a mole irrigator depth of 0.3 m.

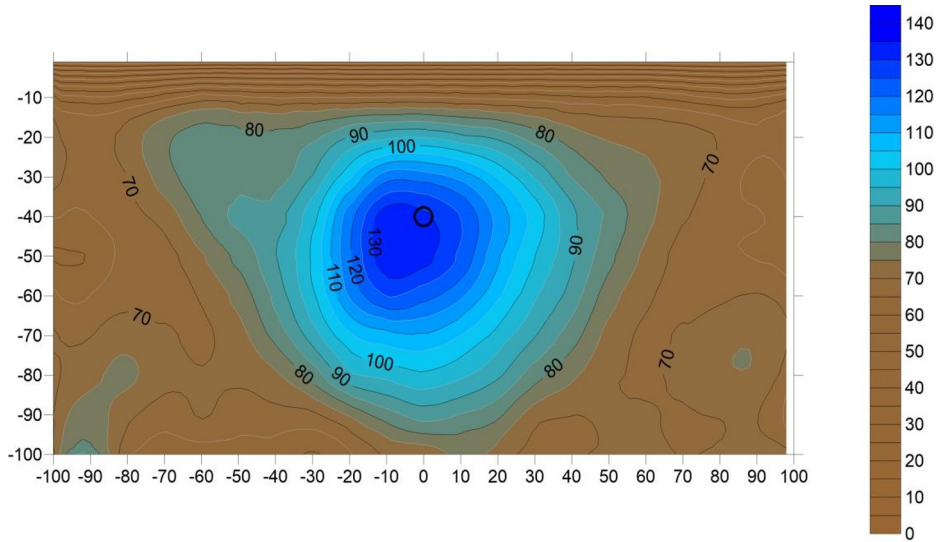


Fig. 3. Soil moisture isopleths (% SMC) at a mole irrigator depth of 0.4 m.

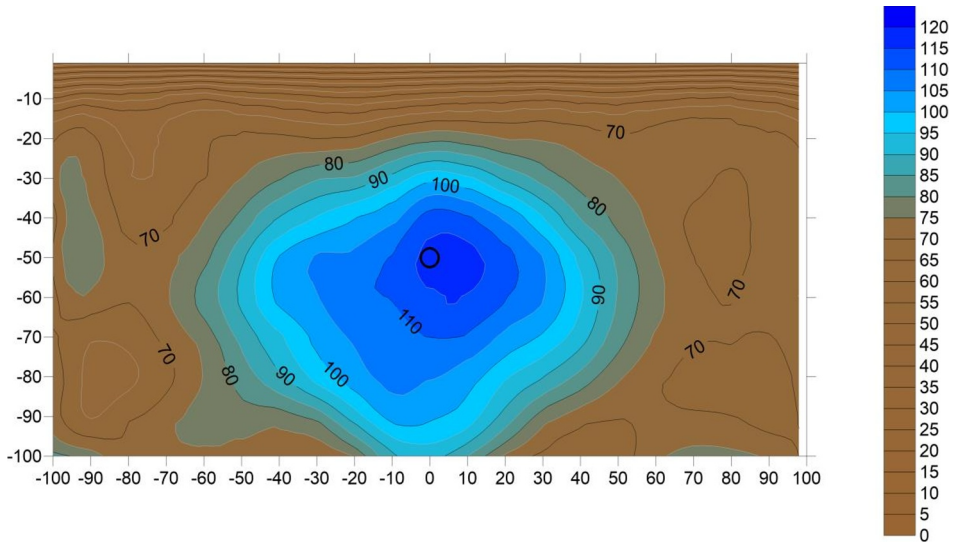


Fig. 4. Soil moisture isopleths (% SMC) at a mole irrigator depth of 0.5 m.

The outer boundaries of the humidification zones according to the variants of the experiment are shown in table 1.

Table 1. External boundaries of soil moisture zones at different depths of mole irrigation.

Depth of location of mole sprinklers, m	Above the molehill, cm from the ground	Below the molehill, cm from the ground	To the left of the molehill, cm from its axis	To the right of the molehill, cm from its axis
Outer boundary of waterlogged zone (location of 110 % SMC isopleth)				
0.3	- 17	- 61	- 28	26
0.4	- 26	- 70	- 25	23
0.5	- 38	- 70	- 15	24
Outer boundary of waterlogged zone (location of 90 % SMC isopleth)				
0.3	- 12	- 83	- 47	45
0.4	- 18	- 88	- 40	42
0.5	- 26	- 102	- 51	45
Outer boundary of waterlogged zone (location of 75 % SMC isopleth)				
0.3	- 9	- 101	- 91	68
0.4	- 13	- 103	- 76	64
0.5	- 19	- 111	- 69	63

4 Discussion

The results of field experiments showed that in the experiment with a humidifiers location depth of 0.3 m, the waterlogged zone above the molehill on the next day after irrigation reached -17 cm from the ground, and lowered to -61 cm below. To the left and to the right of the sprinkler axis this zone extended to 28 and 26 cm, respectively. The zone of normal moisture at the top of the molehill did not rise above the mark of -12 cm from the soil surface, but at the bottom — it dropped to -83 cm. To the sides of the molehill, the zone with soil moisture of 90–110% SMC extended 47 cm to the left and 45 cm to the right. The zone of low moisture at the top and bottom of the molehill reached -9 and -101 cm from the ground, respectively. To the left of the humidifier, the boundary of this zone was at a distance of 91 cm, and to the right -68 cm.

Similarly, the table shows the boundaries of the humidification zones on the remaining options for the location of the sprinklers in depth.

Evaluation of changes in soil moisture around the sprinklers showed that the distribution of moisture contours (up, down, to the left and right of the molehill) at all variants of the depth of the sprinklers was approximately the same. At a humidifier depth of 0.3...0.5 m, the waterlogged zone extended 12...14 cm up, 20...21 cm down, 15...28 cm to the left and 23...26 cm to the right. The outer boundaries of the zone of normal moisture from the molehill were at a distance of 18...24 cm up, 48...53 cm down, 40...51 cm to the left and 42...45 cm to the right. The zone with soil moisture of 75...90% SMC extended 21...31 cm up, 61...71 cm down, 69...91 cm to the left and 63...68 cm to the right of the humidifier.

With an increase in the depth of irrigation from 0.3 to 0.5 m, the upper and lower boundaries of the humidification zones shifted to deeper soil layers. So the upper limit of the waterlogged zone on the next day after irrigation shifted from -17 to -38 cm or 21 cm deep into the soil, and the lower — from -61 to -70 cm or 9 cm. The upper and lower boundaries of the normal moisture zone shifted deeper from the mark -12 to -26 and from -83 to -102 cm or 14 and 19 cm, respectively. The zone of low moisture also shifted from -9 to -19 cm along the upper boundary and from 101 to 111 cm along the lower boundary, or by 10 cm into the underlying horizons.

The increase in soil moisture down to the outer boundary of the waterlogged zone was on average 2.1 times greater than up. In the zone of normal moisture, these distances differed by 2.4 times, and in the zone of low moisture, by 2.6 times.

The distribution of moisture zones in the soil section (table 2) showed that in all variants of the experiment on the next day after irrigation, the waterlogged zone completely remained within the active soil layer. The movement of moisture in the soil of the zone of normal moisture at a depth of 0.3 ... 0.4 m of sprinklers below the active soil layer was insignificant, since it did not exceed 5%. With an increase in depth to 0.5 m, the movement of moisture in the soil was 16.5%, that is, deep filtration into the underlying horizons was observed. The zone of low moisture spread significantly below the active soil layer of 8.5-22.8%, which significantly exceeded the 5% limit.

Table 2. Distribution of moisture zones in the soil section, %.

Depth of location of mole sprinklers, m	Waterlogged zone (> 110% SMC)	Normal Humidity Zone (90...110% SMC)	Low moisture zone (75...90% SMC)
In the active soil layer (0-0.8 m)			
0.3	100	99.3	91.5
0.4	100	95.1	88.6
0.5	100	83.5	77.2
At a depth of more than 0.8 m			
0.3	0	0.7	8.5
0.4	0	4.9	11.4
0.5	0	16.5	22.8

An analysis of the distribution of contours to the sides of the molehill, depending on the depth of the sprinklers, made it possible to establish that no significant differences were observed here. The waterlogged zone at a depth of 0.3 m extended 28 cm to the left and 26 cm to the right of the axis of the molehill, in the variant with a depth of 0.4 m - 25 cm to the left and 23 cm to the right, and at a depth of 0.5 m - to 15 cm to the left and 24 cm to the right. The boundary of the zone of normal humidification at a molehill depth of 0.3, 0.4, and 0.5 m was located at a distance of 47, 40, and 51 cm from the humidifier to the left, and 45, 42, and 45 cm, respectively, to the right. The zone of low humidity according to the variants of the experiment extended to 91, 76 and 69 cm to the left and 68, 64 and 63 cm to the right.

5 Conclusion

Thus, the studies carried out on the light chestnut soils of the Lower Volga region in 2022 showed that the most effective depth of mole irrigation is 0.3 ... 0.4 m. Such a depth made it possible to more effectively moisten the active soil layer of 0-0.8 m, in the absence of deep filtration into layers below 0.8 m, since in these options, the next day after irrigation, the zone of normal moisture (90...110% SMC) was 99.3...95.1% in the active layer, and its boundaries spread from above to a depth of -12...-18 cm and -83...-88 cm below the ground.

Also in our studies, it was found that the depth of the location of the mole irrigators had no effect on the lateral distribution of the moisture contour. The zone of normal moisture (90...110% SMC) on average for the variants of the experiment extended to 46.0 cm to the left and 44.0 cm to the right, and the zone of low moisture (75...90% SMC) - to 78.7 cm to the left and 65.0 cm to the right of the molehill axis. Therefore, for uniform moistening of

the active soil layer, humidifiers should be located at a distance of 1 m or more from each other.

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