Methods for forming an irrigation network for a mole subsurface irrigation system

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Abstract. The article presents the results of field studies carried out in 2022 on light chestnut soils of the Lower Volga region, which were aimed at studying the methods of forming soil pipes for the mole irrigation system using various designs of the mole tine (a special working body for cutting molehills) and the speed of the tractor during the formation of the irrigation network. The considered method of irrigation in the soil and climatic conditions of this region has not been previously studied. As a result, it was found that the use of a trapezoidal stand with a "knife" (a front cutting edge 30 mm wide along the entire height of the stand) and a "chisel" (a rectangular cutting surface of the drainer) was the most effective for arranging an irrigation network of mole irrigators (molehills), since here, regardless of the shape and size of the expanders, the degree of their shedding was 5–38% lower than in the variants with a rectangular post with an ellipsoid shape of the cutting surface of the drainer. Also, our studies showed that when the tractor was moving at 0.9 ... 2.6 km / h, the degree of destruction of molehills was 42 ... 87%, and at 3.4 ... 4.3 km / h this figure decreased to 13 ... 18%, therefore, this speed allowed more efficient formation of soil pipes for the creation of mole subsoil irrigation systems. 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

In connection with the rapidly developing drip underground / subsoil irrigation, subsoil irrigation (SIS) through tubular humidifiers made of polymeric materials and its main variety, mole subsoil irrigation (MSI) through soil pipes to irrigators (molehills), which also contributes to significant water savings, has a significant prospect of application.

This irrigation method was well known in the Soviet Union and abroad. In the USSR, it was mainly used for irrigating crops with livestock waste. Abroad, mole irrigation was studied in Thailand [1], the Netherlands [2], Portugal [3], Ireland [4], Egypt [5], USA [6], China [7], Canada [8], Great Britain [9] and in other countries.

In the Volgograd region, as the most typical for the Lower Volga region, mole irrigation is being studied for the first time, therefore, one of the main tasks of scientific research conducted in 2022 on the experimental fields of the Volgograd State Agrarian

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University was to substantiate the methods and methods for forming the irrigation network of the mole subsoil irrigation system.

2 Materials and methods

The studies carried out in 2022 are the basis of many years of field experience on the development of a mole irrigation system for growing industrial (for example, cotton) and leguminous crops (for example, soybeans), which will be planted in 2023.

The soils of the experimental site, where the research on mole soil was carried out, are light chestnut, low-humus, medium and heavy loamy, widespread in the Lower Volga region. Nearby there was a site where, for almost 10 years, the Volgograd State Agrarian University successfully conducted field experiments on growing vegetable crops with subsurface irrigation using tubular humidifiers made of polymer materials [10]. The accumulated experience was used to develop a mole irrigation system and, first of all, to substantiate the methods and methods for forming an irrigation network for this irrigation method.

The irrigation network consists of mole sprinklers. Its device largely depends on the design of the equipment for cutting them - a special rack, as well as on the speed of the tractor in the process of creating a network of mole irrigators.

For cutting molehills, equipment for the formation of horizontal drainage systems (molehill drain systems) may well be suitable.

The study of manufactured products in Russia and abroad made it possible to choose two options for the working body (figure 1) for cutting mole irrigators in the soil, which is a stand (a) with a drainer (b) and an expander (d), fixed to a special frame behind the MTZ-tractor 82. The use of such a rack allows you to cut molehills - soil pipes in the direction of the tractor.

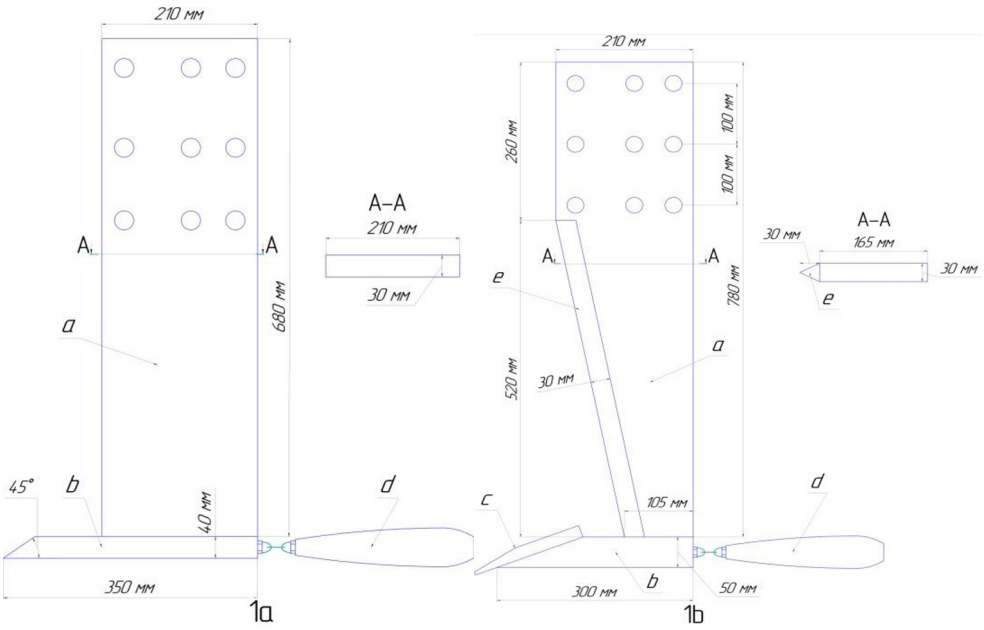

Fig. 1. Irrigation network rack options for mole irrigation: 1a. The stand is rectangular with an ellipsoid shape of the cutting surface of the drainer; 1b. Trapezoidal stand with "knife" and "chisel".

In the first version, the post had a flat vertical shape, a rectangular cross-section (A-A) and a drainer surface cut into the soil at an angle of 45o in the form of an ellipse.

In the second variant, the post had the shape of a 520 mm high trapezoid beveled back (along the tractor) with a 30 mm wide front cutting edge sharpened like a knife (e) and fixed to the drainer (b), a flat, rectangular cutting surface of the drainer cut into the soil - "chisel" (c).

All racks were tested with three extension options:

- Expander No. 1 of a cone-cylindrical shape (figure 2).
- Expander No. 2 cone-parabolic shape (figure 3).
- Expander No. 3 parabolaconic shape (figure 4).

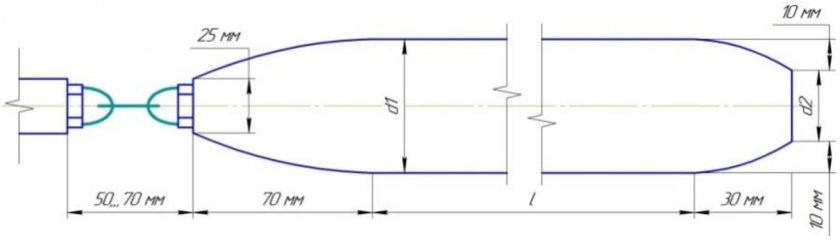

Fig. 2. Scheme of the expander for the mole maker No. 1 of a cone-cylindrical shape.

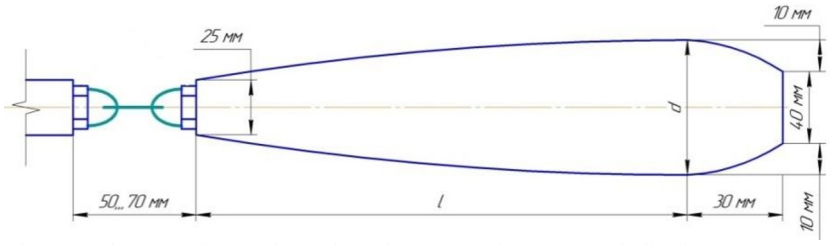

Fig. 3. Scheme of the expander for the mole maker No. 2 of a cone-parabolic shape.

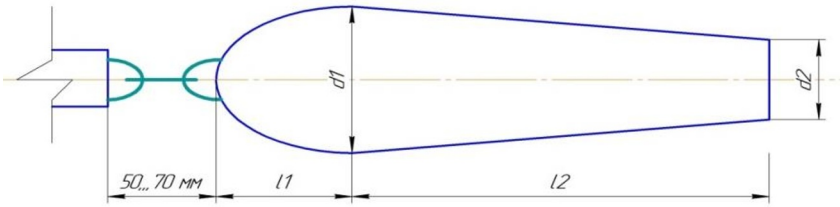

Fig. 4. Scheme of expander for mole maker No. 3 of parabolaconic shape.

All expanders had different shapes and sizes, which had a significant effect on the size of the formed molehills.

In the studies carried out, the issue of changing the speed of the tractor in the process of creating a network of mole sprinklers was specially studied, which changed in 5 modes.

The effectiveness of the use of racks of various designs and the use of different speeds of the MTZ-82 tractor was evaluated by the degree of shedding of molehills after they were cut.

Field experiments were carried out multiple times during the 2022 irrigation season. The article presents the most typical results.

3 Results

A study of the market for manufactured products showed that at present many companies around the world are engaged in the production of moles: in England, Australia, New Zealand, Ireland, Italy, Ukraine, Russia and other countries. As a result, today in the world there are many different designs of mole tines. They differ in both overall dimensions and design features.

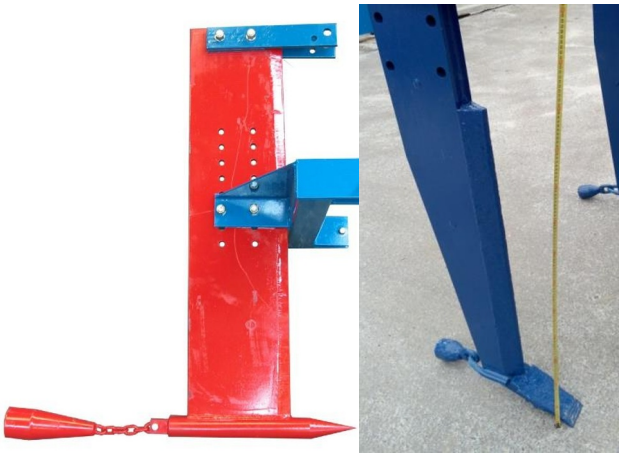

Fig. 5. Racks of the mole maker of "John Berends" (left) and the Krasnodar enterprise (right).

The most common design solution to improve work efficiency is the pointed front part of the rack - the knife. Typical examples of the mole keeper rack, in which such a solution is applied, are the products of the Australian company "John Berends" [11] and the Russian enterprise from Krasnodar [12] shown in figure 5.

But there are also racks on the market without a knife. As, for example, in the product of the English company "Beaconsfield Products" [13] shown in figure 6.

Fig. 6. "Beaconsfield Products" pole mole mower.

Also, to increase the efficiency of the mole maker, a replaceable chisel is provided in the front part of the drainer. This solution is applied in the mole makers of the Italian company AMA [14] and the Irish company R&M Buckets [15], shown in fgure 7.

Fig. 7. Mole keeper racks from "AMA" (left) and "R&M Buckets" (right).

However, a number of manufacturers do not use a chisel in their working bodies and produce mole-makers with a non-separable drainer, as in the products of the Russian company "Yugagromash" [16] and the English "Miles Drainage" [17] (figure 8).

Fig. 8. A mole rat with a "Yugagromash" stand (left) and a "Miles Drainage" stand (right).

The features of the manufactured structures were the determining factor for choosing the parameters of the two rack options in our studies (figure 6).

The test results of these rack options with expanders of three different shapes for the installation of mole sprinklers are shown in table 1.

Table 1. The results of testing racks with expanders of three different shapes for the installation of mole sprinklers.

Expander shape	Expander dimensions, mm			Degree of shedding of molehills, %	
	Length	Largest diameter	End Diameter	First stand option	Second rack option
cone-cylindrical	380	50	30	100	87
		60	40	85	66
		70	50	65	50
	300	60	40	100	85
cone-parabolic	380	50	40	45	40
		60	40	36	25
		70	40	21	11
	300	60	40	95	73
parabola-conic	300	56	50	100	65
		68	60	96	58
		80	70	77	51

The results of the study of the influence of the speed of the tractor on the degree of formation of mole irrigators are shown in table 2. Field experiments were carried out with a trapezoidal stand with a "knife" and a "chisel". A cone-parabolic expander 380 mm long, with a maximum diameter of 70 mm and a final diameter of 40 mm was attached to it.

Table 2. Study of the speeds of the tractor for cutting molehills.

Experience Variant (Speed Code)	Tractor speed, km/h	Molehill cutting depth, m	Molehill diameter, mm	Width of soil deformation along the top, m	Degree of shedding of molehills, %
U1	0.9	0.46	72	0.61	87
U2	1.8	0.47	72	0.55	69
U3	2.6	0.45	70	0.54	42
U4	3.4	0.43	71	0.60	18
U5	4.3	0.45	72	0.58	13

4 Discussion

Testing of various design options for the molehill rack (table 1) showed that the degree of their destruction is very high, reaching 100%. This was due to the fact that the thickness of the rack was 30 mm. In the future, it can be safely reduced by 2 times.

However, it was found that when using the second version of the rack, compared with the first, the destruction of molehills for cone-cylindrical expanders decreased by 13...19%, cone-parabolic shape - by 4...22%, parabolaconic shape - by 26...38%.

Studies of the effect of tractor speeds on the degree of formation of mole irrigators showed that, despite the wide range of changes in the speed of the tractor from 0.9 to 4.3 km/h, the use of a trapezoidal rack with a "knife" and a "chisel" made it possible to form molehills with a diameter 70 ... 72 mm at a depth of 0.43 ... 0.47 m. The width of soil deformation along the top was 0.54 ... 0.61 m. Then the network, all these parameters changed slightly, while the degree of molehill shedding sharply decreased with increasing speed tractor movement from 87 to 13 %.

5 Conclusion

Thus, the conducted studies have shown that, regardless of the shape of the expanders and their sizes, the use of a trapezoidal rack with a "knife" and a "chisel" was the most effective for arranging an irrigation network from mole irrigators.

The study of different speeds of the tractor showed that when using the speed options U1-U3, the degree of shedding of molehills was 42 ... 87%, and on options U4 U5 - 13 ... 18%. Consequently, the tractor speed of 3.4…4.3 km/h was the most effective for the formation of an irrigation network for mole irrigation.

Acknowledgments

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