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# Determination of the dependence of the humidification circuit parameters during drip irrigation on the properties of irrigation water

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**Abstract**. To ensure the optimal water-air balance of the plant, agro-reclamation measures are required, including the organization of irrigation. The advantage of drip irrigation is the most rational consumption of irrigation water. To realize this advantage, it is necessary to calculate the irrigation rate taking into account the dynamics of moisture distribution in the soil. During irrigation, the humidification circuit takes on a semi-elliptical shape. To determine the geometrical parameters of the humidification circuit, one should take into account the physical and mechanical properties of the soil and irrigation water, the mineralization of which varies widely. Having identified the numerical dependences and the nature of the distribution of moisture in the soil and having calculated the parameters of the irrigation circuit, it is necessary to determine the flow rate per dripper and subsequently calculate the irrigation rate, taking into account all of the above factors. The proposed method for calculating the irrigation contour will make it possible to rationally use water for irrigation, minimizing losses due to filtration into deep soil layers. Optimizing the water regime of plants during the growing season will not only save water and energy resources, but also maintain an optimal water and air regime, which will increase the yield and improve the quality of grown products.

## 1. Introduction

The climate of the Moscow region is characterized by uneven precipitation both during the growing season of plants and throughout the year. High-water years alternate with water-deficient ones, the average annual value is 500 - 900 mm. During the summer period, rains are often torrential in nature, a significant part of the precipitation evaporates or goes into surface runoff without being absorbed into the soil. In this situation, obtaining a guaranteed harvest is possible with the use of agro-reclamation measures [1-3].

Sprinkler irrigation is predominantly common among irrigation melioration in the Moscow region. However, if among hose-drum machines, domestic new equipment entering farms accounts for about half of the total number of purchased machines, then among wide-cut machines, more than 90% of new arrivals are imported equipment. This contradicts the import substitution program adopted in the country, and the deteriorating political situation casts doubt on the timely repair of imported cars - the supply of spare parts and consumables [4-7].

The designs of most domestic sprinkling machines contain parts and assemblies supplied from abroad and having no domestic counterparts, so there is a high probability of suspension of production. Machines manufactured more than 20 years ago and still operating on farms have by now exhausted their resource and cannot compete with modern technology [8-12].

Under the current conditions, the solution of this problem may take several years. This may cast doubt on the fulfillment of the tasks set by the Government - to increase crop production by 25% compared to the 2017 harvest [13].

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To solve the tasks set by the Government, it is necessary to introduce more widely alternative methods of irrigation, including drip irrigation. Currently, territories using drip irrigation make up no more than 10% of all irrigated areas in the country. The production of drip tape, tubes and fittings has been established at domestic enterprises, in recent years there has been a steady increase in output, however, an increase in production capacity leads to an increase in the share of domestic materials in the construction of drip irrigation systems (in recent years from 30% to 65%), while increasing areas occupied by drip irrigation were not observed during the study period [14-18].

The undoubted advantage of drip irrigation is the delivery of irrigation water directly to the root zone of the plant. At the same time, there are practically no losses of irrigation water for evaporation and filtration into deep soil layers. However, the existing irrigation norms do not take into account the peculiarities of the delivery of irrigation water during drip irrigation and the process of forming an irrigation circuit, which does not allow the full use of the benefits of drip irrigation [19-21]. Recently, significant research material has been accumulated on this topic, but some questions still remain unresolved.

## 2. Materials and Methods

The movement of water in the soil is determined by the action of capillary and gravitational forces acting on the drop. The existing norms are based on the dependences obtained for surface irrigation, when a layer of water seeps into the soil under the influence of gravitational forces. For drip irrigation, the volume of non-irrigated soil, determined experimentally, is subtracted from the total volume of moistened soil:

$$m = 100 \cdot h \cdot a \cdot S(W_{HB} - W_N) \quad (1)$$

where: $h$ – active layer depth, m; $a$ – density of water, kg/m$^3$; $S$- proportion of area to be moistened; $W_{HB}$ – limiting field capacity, %; $W_N$ – moisture content of the active soil layer before watering, %.

The above formula does not take into account the shape of the contour formed during the movement of water in the pore space. This can lead to over-irrigation, as well as minimizing the benefits of using a drip irrigation system - significant savings in irrigation water and energy costs.

It is assumed that the movement of water in the soil is due to its interaction with the soil environment. Consequently, the nature of this interaction will be influenced by the properties of the soil and irrigation water. However, if the parameters of the soil medium were studied under various methods of moistening, then the properties of irrigation water and their influence on its distribution in the pore space were practically not studied. Meanwhile, if we consider such a parameter as mineralization, then depending on whether irrigation is carried out with rainwater, water from surface or underground sources, the values vary widely. The studies were carried out in the Dmitrovsky district of the Moscow region, in the floodplain of the river. Yakhroma (Table 1).

**Table 1.**General mineralization of natural waters in the Dmitrovsky district of the Moscow region

| Irrigationwatersource | Generalmineralization, mg/l |
|---|---|
| Rainwater | 40…80 |
| Riverwater (insummer) | 135…270 |
| Undergroundwater | 430…760 |

## 3. Results and Discussion

The studied waters are calcium-hydrocarbonate, the most common in the Moscow region, the iron content is increased in groundwater. It is assumed that mineralization affects the surface tension, and hence the rate of movement of water through the capillaries. The studies were carried out with water from a surface source (channel), mineralization was 216 mg/l, as well as tap water with a mineralization of 384 mg/l. An irrigation circuit was considered during irrigation with a single dropper at a flow rate of 2 l/h, measurements of the geometric parameters of the circuit were made at regular intervals (Figure 1).

*a)* *b)*

**Fig. 1.** Formation of a humidification contour during drip irrigation: a - tap water; b - water of atmospheric precipitation

For water from a surface water source, the rate of spread of water in the soil is lower than for tap water with a higher mineralization, and at the same time, the contour of the wetted and non-moistened zones is clearly marked, there is practically no transition zone. In this case, the pore space is filled gradually, up to the values of the limiting field moisture capacity, then the contour volume increases. In tap water, where the mineralization value is higher, the rate of water movement through the soil capillaries is faster; in this case, the pores are filled to the values of the limiting field capacity gradually, so the boundary of the moistened and non-moistened zones is blurred (Figure 2).

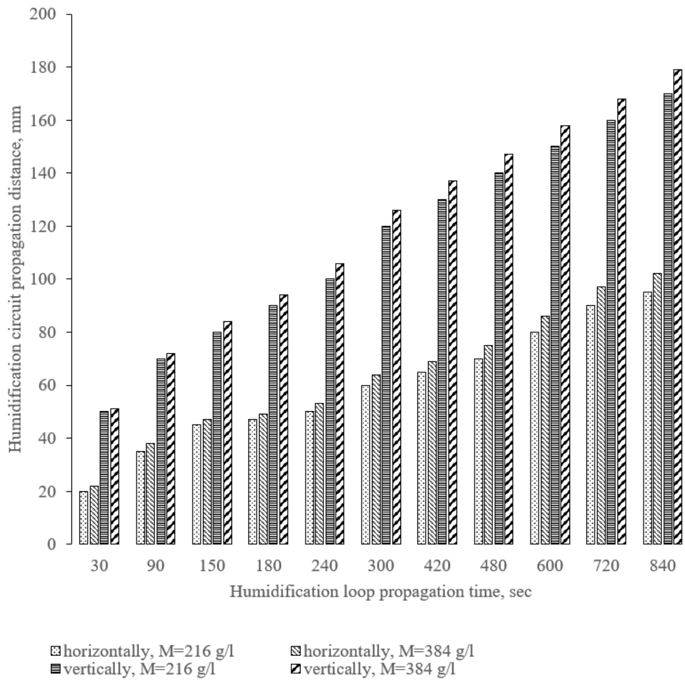


**Fig. 2.** Dynamics of moisture distribution during drip irrigation

In the course of further studies, the degree of influence of mineralization on the horizontal and vertical distribution of irrigation water in the pore space was determined.
The elliptical shape of the humidification contour is explained by the different influence of external forces on the droplet: with horizontal movement, the action of capillary forces should be considered, with vertical movement of the droplet in pores, under the action of capillary and gravitational forces. Therefore, when describing the movement of water, horizontal and vertical movement should be considered separately. So, the horizontal movement of a drop of water in the soil during drip irrigation should be determined:

$$x = \sqrt{4t \cdot \mathrm{M} \cdot \frac{\mathrm{K}_{\Phi} \Psi_{\mathrm{M}} W_{\mathrm{M}}}{\frac{(\mathrm{W}_1 - \mathrm{W}_0^2 \cdot W_{\mathrm{M}})}{\mathrm{W}_0^2 \cdot \mathrm{W}_1}} \cdot \left(\frac{\mathrm{W}_0 - W_{\mathrm{M}}}{\mathrm{W}_1 - W_{\mathrm{M}}}\right)^5} \quad (2)$$

where: $W_0$ – initial soil moisture; $W_1$ – limiting field capacity; $W_M$– maximum molecular moisture capacity; $\Psi_M$– soil moisture pressure value at maximum molecular water capacity; $K_\Phi$ – filtration coefficient, M – total mineralization, g/l; t – watering time, s.
To determine the vertical movement of moisture during drip irrigation, we use the formula:

$$z = \sqrt{4t \cdot \mathrm{M} \cdot \frac{\mathrm{K}_{\Phi} \Psi_{\mathrm{M}} W_{\mathrm{M}}}{1 - \frac{W_{\mathrm{M}}}{\mathrm{W}_1}} \cdot \left(\frac{\mathrm{W}_0 - W_{\mathrm{M}}}{\mathrm{W}_1 - W_{\mathrm{M}}}\right)^5 \cdot \left(\frac{1}{\mathrm{W}_0^2} + 2\frac{\mathrm{W}_0}{\mathrm{W}_1^3}\right)} \quad (3)$$

Knowing the vertical and horizontal coordinates of the circuit, taking into account its elliptical shape, we determine the flow rate per dripper:

$$Q_{\text{тр}} = \frac{2 \cdot 3{,}6 \cdot 10^{-3} \pi z x^2 (W_1 - W_0)}{3t} \quad (4)$$

Having determined the flow rate for the dripper, one should choose a drip tape based on the condition Qk≥Qtr. When choosing a drip tape, it is necessary to take into account the planting pattern.

According to the calculation data, a drip tape was selected with a flow rate per dropper of 1.6 l / h, with a distance between droppers of 0.3 m, with a tape diameter of 16 mm.

The drip tape was laid in a mechanized way at the experimental site of the Field Experimental Station of the RGAU-MSHA named after K.A. Timiryazev. Specialized equipment is mounted on the GrimmeGF-75/4 ridge former. Machine laying of drip tape allows not only to significantly increase the productivity of tape laying and reduce labor costs, but also to improve the laying quality. When using a special stacker, the tension of the drip tape remains constant during work, which eliminates twisting and breaking the tape during installation.

Upon completion of the laying work, a drip irrigation system was installed. Further calculations determined the irrigation rate:

$$m = \frac{7{,}2 \cdot 10^{-3} t \cdot \pi \cdot z \cdot x^2 \cdot (W_1 - W_0)}{l \cdot b} \quad (5)$$

where: $l$ – comb length, m; $b$ – distance between adjacent ridges, m.

Irrigation in the experimental plot was carried out at the calculated irrigation rate with the time between irrigations adjusted. Irrigation was carried out with tap water. The adjustment was carried out taking into account corrections for atmospheric precipitation, taking into account the salinity of water from atmospheric precipitation.

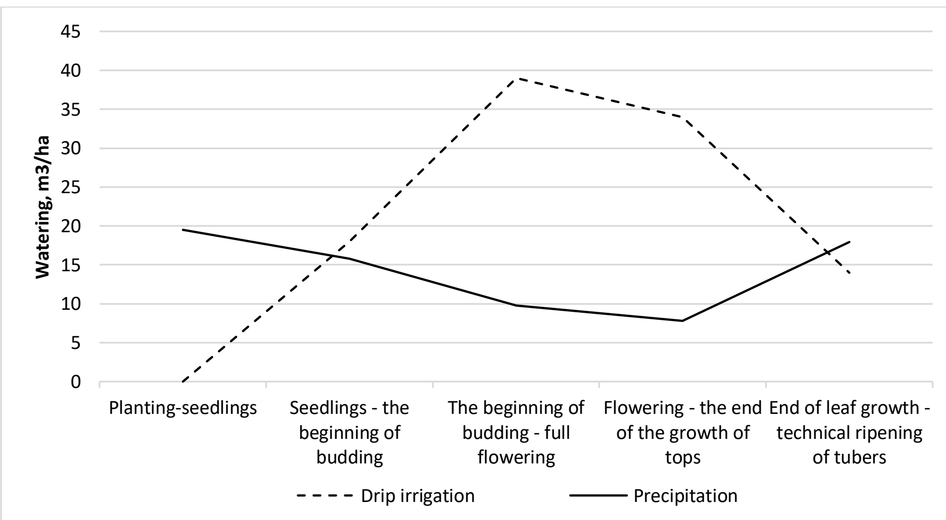


**Fig. 3.** Water consumption of potatoes at different stages of development

The experiments were carried out with early ripe potato varieties "Zhukovsky early" and "Luck". Irrigation was carried out according to the adjusted irrigation rate, and in the control plot, the irrigation rate calculated by formula (1). Irrigation water savings reached 18% due to reduced irrigation time, and the yield increase was 12...16% (Table 1). In addition, water consumption of potatoes at different stages of development is shown in Figure 3.

**Table 1.** Productivity of various varieties of potatoes when using drip irrigation

| Productivity, t/ha | «Zhykovskyranij» | «Udacha» |
|---|---|---|
| Determination of irrigation rate by known methods | 24,6 | 24,8 |
| Using an Adjusted Watering Rate | 28,5 | 27,8 |

The use of an adjusted irrigation rate, taking into account the shape of the moisturizing circuit, made it possible to fully use the advantages of drip irrigation, which makes it possible to deliver irrigation water directly to the root zone.

## 4. Conclusions

Creating an optimal water-air balance in order to obtain a guaranteed harvest involves the use of agro-reclamation measures. The undoubted advantage of drip irrigation is the delivery of water to the root zone, however, the methods for calculating the irrigation rate to realize this advantage should take into account the semi-elliptical shape of the humidification contour, as well as the salinity of irrigation water. The application of the proposed method for calculating the irrigation rate, taking into account the geometrical parameters of the humidification circuit, made it possible to reduce the consumption of irrigation water by 18%, and growing potatoes using the corrected irrigation scheme made it possible to obtain an increase in yield of 12...16%.

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