

Total water requirement and evaporation of tomato at different methods of showering and depth of calculated layer of soil in South region of Ukraine

The purpose. To investigate dynamics of evaporation according to growth phases and development of tomato, as well as the level of total water requirement, water use efficiency for forming unit of yield, dependence of daily consumption of soil moisture on daily average air temperature.

Methods. Field, laboratory, statistical.

Results. Total water requirement of tomato at drip irrigation for the season of probes was for 30,5% less than at sprinkling and micro-sprinkling irrigation. In the phase of mass formation of fruits daily average evaporation at drip irrigation was for 58,8-59,5% less than at sprinkling and micro-sprinkling irrigation. At drip irrigation quotients of water requirement were for 65,5% lower than at sprinkling irrigation, and for 56,8% lower than at micro-sprinkling irrigation.

Conclusions. Drip irrigation ensures more effective use of receiving part of water balance in comparison with sprinkling and micro-sprinkling irrigation in separate growth phases of development and as a whole for a vegetative period.

Key words: tomato, evaporation, water requirement, drip irrigation, sprinkling irrigation, micro-sprinkling irrigation.

The amount of soil moisture during vegetation depends on the natural and climatic conditions, location and biological features of the research object. Depending on the period of determining the cost of soil moisture transpiration and evaporation are divided into total water consumption - total moisture costs for the entire period of vegetation and total evaporation - the cost of moisture for separate segments of the growing season. They are determined by different methods, but the most widespread - the water balance [8, 11].

In the zone of inadequate moisture despite the rather large needs of most vegetable plants in moisture-proofing of the total evaporation and water consumption is a rather important task. They make it possible to establish a connection between water consumption of plants with meteorological factors and production processes and formalize it in the form of mathematical models for predicting the process as a whole or for calculating the elements. Therefore, studying this trend in vegetable irrigated agrocenoses is relevant.

Total water consumption and evaporation - the most important aggregate characteristics of the relationship of hydro meteorological conditions with growth processes for the vegetation and for its separate periods. The regularities of soil moisture costs for various agrocenosis productivity are fundamental principles for the development and improvement of irrigation regimes of agricultural crops [4, 5].

Steamability is the result of the complex influence of meteorological factors that cause the exchange of moisture in the soil-plant system, an atmosphere that equates to optimum water consumption of plants and is determined by various, in particular, calculated methods (SM Alpatyeva, DA Shtoiko, MM). Ivanova, GK Lgova, Penman-Monteite) [1, 3, 10]. Actually, it is a mathematical model for regulating the water regime of the soil and plants by meteorological indicators, which for local irrigation need to be refined on the basis of research results. Research methodology. The task of the research was to determine the 3 methods of irrigation - sprinkling, micro irrigation, drip irrigation - and 2 calculation layers of soil, the level of total water

consumption and evaporation, the efficiency of water use for the formation of the unit of harvest, the average daily cost of soil moisture at a different average daily temperature of air, and in developing a simplified model for determining the evaporation of tomato to control the soil moisture regime. The research was conducted in 2 factor field experiments according to the experimental research in irrigated agriculture and vegetable growing [2, 6]. The adaptation of the model was carried out in the production conditions of the FG "Seagull" of the Belozersky district of the Kherson region. Controlled the flow of moisture by the recommendations [9]. The model is based on field studies of 1993-1995, its development and field testing - 2012 - 2013. Research results. The study of total water consumption and evaporation by the methods of watering and the depth of the active layer of soil made it possible to determine the characteristics of soil moisture expenditure during the growth and development phases of tomatoes and in general for vegetation. Total water consumption can vary significantly enough, and the amplitude of oscillation is due to many factors, among which the technology of irrigation is a prominent place. Total water consumption was investigated using the water balance method. The water balance of tomato in different methods of watering was studied under the condition of maintaining the soil moisture in the calculation layers prior to the irrigation at the level of not less than 70% of the lowest moisture content (HB) during the ladder - fruiting, the beginning of ripeness - harvesting and 80% HB - in the phase of mass fetal formation. Analysis of the structure of the total water consumption by watering methods shows that it is formed mainly due to two components - the irrigated norm, the share of which is 54.5 - 72.3%, and precipitation, which accounts for 26.4 - 45.1 % of total water consumption. From the soil, the total water consumption consumes 10-64 m³ / ha of water, which in aggregate does not exceed 0.3 - 1.3% of the total water consumption and is a factor of insignificant influence on the total water consumption during the growing season.

By comparing the irrigated norm by the methods of watering and the depth of the calculated layer, it became clear that its value is more determined by the method of watering. This is confirmed by the results of statistical analysis. Thus, at a level of partial differences, the value of more than 1124 m³ / ha is reliable for comparison. This means that the difference in total water consumption for irrigation for spraying and micro irrigation is less than the threshold of reliability, therefore the values of the irrigated norm are almost one level and 43% larger than the rate of irrigation. Variation of the value of the irrigated norm for different methods of watering indicates that increasing the depth of the calculated layer from 0 to 30 to 0 to 50 cm promotes its steady growth, and for depths of the calculated layer 0 - 50 cm total water consumption for watering, on average, by the main factor B - the method of irrigation - at 667 m³ / ha exceed those that are formed at depths of the calculated layer 0 - 30 cm. In this case, the value of the irrigated norm increases significantly, but disproportionately to increase the depth of the calculated layer (27.4 and 67% respectively) (Table 1). For all methods of watering with an increase in the depth of the calculated layer to 0 - 50 cm, the proportion of precipitation in the total water consumption is reduced by 4.5 - 6.4%. It is also noteworthy that the share of precipitation in total water consumption by drop irrigation is 12.3 - 18.2% higher than other irrigation methods, which confirms the more efficient use of natural resources for this method of watering. Changes in the total water consumption of tomato for the studied set of factors fully correspond to the trends identified by the analysis of its structure. Thus, in case of spraying and micro irrigation, the total water consumption for harvesting reaches an average of 4600 m³ / ha, which is 30,5% more than for drip irrigation, - 3200 m³ / ha. Comparison of the level of total water consumption at the depth of the calculated layer shows that for depths of 0 - 50 cm it is 696 m³ / ha (15,5%) is greater than the depth of 0-30 cm. Thus, with increasing depth of the calculated layer, total water consumption on the formation of tomato crop is significantly increasing.

1. Total water consumption, structure of total water consumption, coefficients of water consumption for different methods of watering and depth of the calculated layer (average for 1993 - 1995 years)

Спосіб поливу	Розрахунковий шару ґрунту, см	Структура сумарного водоспоживання						Сумарне водоспоживання, м³/га	Коефіцієнт водоспоживання, т/м³
		опаді		зрошувана норма		волога ґрунту			
		м³/га	%	м³/га	%	м³/га	%		
Дощування	0–30	1333	31,4	2900	68,3	14	0,3	4247	94,0
	0–50	1333	26,9	3570	72,1	51	1,0	4954	107,2
Мікродощування	0–30	1333	32,1	2800	67,3	26	0,6	4159	87,7
	0–50	1333	26,4	3650	72,3	64	1,3	5047	103,0
Краплинне зрошення	0–30	1333	45,1	1610	54,5	10	0,3	2954	55,4
	0–50	1333	38,7	2090	60,6	24	0,7	3447	66,2
НІР ₀₅ часткових відмінностей (фактор А)				1124		30		1149	28,8
НІР ₀₅ головних ефектів (фактор А)				795		21		812	13,6
НІР ₀₅ головних ефектів (фактор В)				649		17		663	11,1

Efficiency of water use in irrigated agrocenoses is estimated by the coefficient of water consumption - the amount of water spent per unit of harvest. According to the calculations of the coefficients of water consumption of tomato for different methods of watering and depth of the calculated layer, to produce 1 ton of fruit, depending on the method of watering consumes 55.4 - 107.2 m³. Most of all - for spraying and for depths of the calculated layer 0 - 50 cm - 107,2 m³, the least - 55,4 m³ - for dropping irrigation and for depths of the calculated layer 0-30 cm. In general, on the basis of comparison of the coefficients of water consumption should recognize that in the average of the drop irrigation water consumption for the formation of the yield of 65.5 and 56.8% respectively, is less than for the spraying and micro irrigation, and for the depth of the calculated layer 0-30 cm per 1 ton of tomato harvest 16.6% less water, than at a depth of 0 - 50 cm. Thus, the coefficients of water consumption indicate that the depth Beans the calculated layer 0 - 30 cm water for harvesting is more efficient, and drip irrigation - the most effective of the studied methods of watering.

An important element of control and operational management of the irrigation regime is the average daily evaporation [8], which is determined by the calendar dates of the growing season or individual phases of plant growth and development. Average daily evaporation depends on the biological characteristics of plants, weather conditions of the vegetation period, physical and mechanical properties of the soil, the intensity of production processes, agrotechnical, reclamation and a number of other factors. Observation of the average daily evaporation of tomato shows that for the investigated factors, its absolute value is determined by the phase of plant development. The analysis of the moisture consumption shows that at the beginning of the vegetation they are relatively insignificant. Per day, depending on the watering method, 11.9 - 18.8 m³ / ha of soil moisture is used. Comparison of daily average moisture consumption at the level of main effects shows that for drip irrigation, they are 14,5 and 14,1% less, respectively, than for spraying and micro irrigation, and with the increase in the depth of the calculated layer from 0 to 30 to 0 to 50 cm, the daily average moisture losses of 5.2 m³ / ha (41.1%). In the period of fruit production, which is critical for water consumption, the average daily evaporation becomes the highest value for all methods of watering. The maximum daily flow of soil moisture (76.5 m³ / ha) arises from the micro irrigation and the depth of the calculated layer 0-50 cm, the smallest (42.8 m³ / ha) - for the drop irrigation and the depth of the calculated layer 0-30 cm. Analysis daily average costs The moisture content of the main effects of drip irrigation indicates a 58.8% decrease compared to the spray and 59.5% - by micro irrigation. As the depth of the

calculated layer increases from 0 to 30 to 0 to 50 cm, the average daily cost does not exceed 8.6%. The indicated trends in average daily evaporation are observed in the final stage of vegetation of tomatoes.

2. Average daily evaporation of tomato in different ways of watering and depth of the calculated layer of soil (average for 1993 - 1995 years), m³ / ha per day

Спосіб поливу (фактор А)	Зона зволоження, см (фактор В)	Фаза росту і розвитку		
		масові сходи — плодоутворення	плодоутворення — стиглість	стиглість — збирання
Дощування	0–30 см	13,0	71,3	53,3
	0–50 см	18,6	74,2	65,1
Мікродощування	0–30 см	12,7	69,6	52,6
	0–50 см	18,8	76,5	65,5
Краплинне зрошення	0–30 см	11,9	42,8	38,7
	0–50 см	15,7	48,8	41,7
НІР ₀₅ часткових відмінностей (фактор А)		2,5	15,9	10,3
НІР ₀₅ головних ефектів (фактор А)		1,8	11,3	7,3
НІР ₀₅ головних ефектів (фактор В)		2,3	2,4	5,6

Thus, for drip irrigation, the moisture consumption decreases by about 47% compared with other irrigation methods, and an increase in the depth of the active layer of soil from 0 to 30 to 0 to 50 cm causes an increase in the cost of soil moisture per day by 19.2%. In general, for average drop water irrigation, average daily moisture consumption in the development phases is 14.1 - 59.5% lower than in other irrigation methods, and by 8.6 - 41.2% less than the depth of the calculated layers compared with the spraying and micro irrigation (Table. 2).

According to the data, the largest difference in average daily evaporation over the depth of the calculated layer was observed during the stairs - the mass production of fruits - 31,9 - 48%, the least - 4,1 - 14% - during fruit production. That is, at the initial stage of vegetation, taking into account the biological features of tomato, it can be argued with high probability that the calculated layer 0 - 50 cm water is spent inefficiently, therefore, until the beginning of the fruiting phase, the calculated layer of 0 - 30 cm is sufficient to provide water to plants of tomatoes. In other phases of growth and development, it is more appropriate to form the soil moisture regime on the basis of a calculated layer of 0 to 50 cm. Analysis of average daily evaporation of tomato at different average temperatures during the day allowed to establish a connection between these indicators and determine the shape of the evaporation curves for the investigated factors. It turned out that the curves of the average daily evaporation in shape are similar to the growth curves. The dynamics of total moisture consumption for different watering methods and the depth of the calculated layer indicates that the average daily air temperature of 17.7 °C is the average daily evaporation for spraying and micro irrigation of roughly one level and depending on the depth of the calculated layer by 6.7-19.7% larger than a drop of irrigation. In the range of average daily temperatures of 17.7 - 21.2 °C, the average daily flow of moisture is rapidly increasing for all methods of watering. Thus, for spraying and micro irrigation for depths of the calculated layer 0-50 cm of moisture is spent on average 65.5 m³ / ha per day, and for depths of the dilution layer 0-30 cm - only 52.6 m³ / ha. For drip irrigation average daily moisture losses are 1.6 and 1.4 times lower than for other watering methods (Fig. 1). At the average daily temperature of 23.2 °C, the average daily evaporation of 76.6 m³ / ha is observed at micro irrigation at the depth of the calculated layer of 0-50 cm, the least - 42.8 m³ / ha for the drop irrigation and the depth of the calculated layer 0-30 cm. For the same the depth of the calculated layer, the difference between the average daily evaporation for spraying and micro irrigation does not exceed 3% and 34.2 and 40% respectively, higher than for drip irrigation. For

comparison of the limits of average daily evaporation by methods of irrigation for the first and second points of the bend (Fig. 1) it became clear that in the temperature range 17.7 - 23.2 ° C, the specific intensity of evaporation is rapidly increasing by 1 ° C, reaching 13.3 for sprinkling , for drip irrigation - 7.7 m3 / ha.

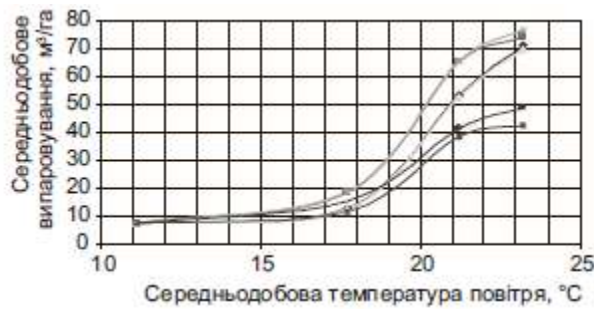


Fig. 1. Average daily evaporation of tomato by methods of watering and depth of the calculated layer, depending on the average daily temperature of air: - 0 - 30 cm, sprinkling; - 0-30 cm, microscopic; - 0-30 cm, drip irrigation; - 0 - 50 cm, sprinkling; - 0 - 50 cm, microscopic; - 0 - 50 cm, drop irrigation



Fig. 2. Schedule for determining the average daily evaporation of tomato in different ways of watering at the average daily temperature of air: - sprinkling; - micro-purchase; - drip irrigation

Consequently, for drip irrigation at 1oS, the moisture is consumed by 72.7% less than for watering. In the temperature range of 21.2-23.2 ° C, despite the overall growth of total evaporation, specific costs are reduced to 4.4 m3 / ha at 1 ° C for sprinkling and up to 2.1 m3 / ha at 1 ° C for drip irrigation. The intensity of evaporation in this temperature range is 3 and 3,7 times less than in the range 17.7 - 23.2 ° C. This confirms the presence of a temperature threshold, the excess of which significantly reduces the specific evaporation, probably due to the reduction of transpiration intensity, which is regulated by the size of leaf products, which depend on the temperature and humidity of the air. The temperature range in which the most intensive moisture exchange in tomato plants was observed in our conditions was in the range of 17.7 - 23.2 ° C, that is, in the range of 18 - 25 ° C, which according to the results of studies [7] is optimal for tomatoes. An attempt to approximate the average daily evaporation on the functions of B. Gompertz and P. Ferghults did not give satisfactory results in the range 10.9 - 17.7 ° C. Therefore, the average daily evaporation approximation by the average daily air temperature is carried out by a linear spline within each temperature regime:

$$E(t) = \begin{cases} a_1 + b_1 t, & 10,9 < t < 17,7 \\ a_2 + b_2 t, & 17,7 < t < 21,2, \\ a_3 + b_3 t, & 21,2 < t < 23,2 \end{cases}$$

where E (t) is the average daily evaporation for the corresponding average daily temperature of air, m3 / ha; ai, bi - coefficients of the equations, i = 1, 2, 3; t - average daily air temperature, oC. Within the studied factors and temperature regimes, the coefficients of the approximation equations for the average daily evaporation of tomato are determined (Table 3).

3. The coefficients of the linear spline equations for determining the average daily evaporation of $E(t)$ of tomato

Спосіб поливу	Зона зволоження, см	Коефіцієнт пропорційності					
		a_1	b_1	a_2	b_2	a_3	b_3
Дощування	0–30	0,55	0,77	–191,00	11,53	–136,84	8,97
	0–50	9,57	1,59	–216,29	13,27	–31,39	4,55
Мікродощування	0–30	0,06	0,72	–188,80	11,39	–128,61	8,55
	0–50	9,85	1,62	–217,40	13,35	–51,37	5,51
Краплинне зрошення	0–30	1,26	0,60	–123,68	7,66	–4,53	2,04
	0–50	4,89	1,16	–115,43	7,41	–34,31	3,58

Approximation by linear equations is a rather simplistic model of the evaporation process, but calculations show that the average daily evaporation calculated on this model is quite close to the experimental one. According to the calculations of daily daily evaporation of tomato, the equation (1) in the range 17 - 25 ° C is constructed with a graph whereby within the optimal range of average daily air temperatures one can determine the average daily evaporation level, which enables to control the daily average moisture consumption according to the average daily air temperature (Fig. 2)

The irrigation norms determined in this schedule in FG "Chajka" of Belozerskyi district of the Kherson region. in 2013, tomato spray irrigation was close to the recommended, and the irrigation rate in the end was 10% higher [9]. Consequently, in the absence of direct instrumental methods for monitoring soil moisture, the average daily evaporation and water regime of tomatoes in the southern region of Ukraine with a sufficient degree of reliability can be controlled by the average daily temperature.

Conclusions

Drop irrigation provides a reduction of 30.5% of water consumption for the total water consumption of tomato compared to the spray and micropropagation due to a reduction in the balance of total water consumption for watering and increasing the proportion of precipitation. The water consumption rate for drip irrigation is 58.3 - 61.9% lower than that for sprinkling and micropropagation, respectively, the water use efficiency per unit of yield for drip irrigation is higher in the same proportion. With the increase in the depth of the calculated layer from 0 to 30 to 0 to 50 cm, the efficiency of water use per unit of production is reduced by 16.6%. For drip irrigation, average daily moisture consumption during the growth and development phases is 14.1-59.5% lower than that in the case of spraying and micropropagation, which is the result of an increase in the humidity area during irrigation. In order to ensure the normal water regime of tomato plants, by the phases of development prior to the beginning of fruiting, the irrigation is sufficient in norm, calculated on wetting of the layer of soil 0-30 cm. In the range of average daily temperatures 17.7 - 21.2 ° C for droplet irrigation, the consumption of moisture at 1 ° C in 1, 7 times less than other watering methods. Determination of average daily moisture costs for tomato plants on the basis of the linear spline schedule, based on the average daily temperature of the air, makes it possible to regulate the water regime of the soil with an excess of water consumption within 10% compared with the instrumental methods of observation.

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