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Specific Features of the Mist Sprinkling Technology

Alexander Afanasyevich Kalashnikov,
Bolat Mazhitovich Kurtebaev,
Aigul Eltaevna Baizakova
Pavel Alexandrovich Kalashnikov

"Kazakh Scientific Research Institute of Water Economy" LLP
Kazakhstan Republic, 080003, Taraz city, Koigeldy St., 12

Abstract.

With the growing acute shortage of water resources in the Republic of Kazakhstan, where the main water sources are of a transboundary nature, an untimely transfer of irrigated agriculture to water-saving technologies in irrigation can negatively affect the national food security. Therefore, effective water resources management, introduction of new water-saving irrigation technologies, provision of irrigation water to regular irrigation lands necessary for the development of agriculture, improvement of the reclamative condition and restoration of the irrigation infrastructure, and effective use of land resources will allow including extra 610 thousand hectares of land of regular irrigation in the national irrigation area by 2021. The paper developed the basic scheme of a modular set of mist sprinkling, with nozzles designed by the "Kazakh Scientific Research Institute of Water Economy" LLP. The technological parameters of the operation of each module were identified: the range of the nozzles, the average intensity of the rain, and the effective irrigation coefficient.

Keywords: irrigation methods, sprinkling nozzle, rain intensity, irrigation coefficients, mist sprinkling, modular set.

INTRODUCTION.

With the growing scarcity of water resources, the application of new water-saving irrigation technologies that allow increasing the productivity of irrigation water use is an urgent field for the development of competitive agricultural output in the volumes sufficient to cover the needs of the domestic market, as well as to effectively develop the water sector of the economy and water policy.

The analysis of promising technologies that save irrigation water and create favorable phytoclimatic parameters in the environment of plant growth indicates that they are particularly effective at high air temperatures (more than 25-30 °C) and low humidity (less than 30%).

The development of the mist sprinkling technology and technical facilities solves the urgent problem: it creates favorable conditions for the growth and development of plants in areas with complex relief of arbitrary configuration, reduces the impact of unfavorable factors of the habitat during the vegetation period and prevents the occurrence of water erosion of soils.

A modular system is being developed for the application of the mist sprinkling technology, which will contribute to raising the technical level in irrigated agriculture, efficient use of water and land resources in the foothill zone, maintaining high crop yields even under unfavorable growing conditions and preventing the formation of water erosion.

METHODS

For the field testing of the technical mist sprinkling facilities, various schemes for placing sprinkler sets and nozzles have been developed at a field testing site of the experimental range of the Committee for Water Resources (CWR) of the Republic of Kazakhstan. The studies were carried out in accordance with the provisions on field tests, manuals on meteorological observations (temperature and humidity, wind direction and speed, precipitation) [1-6]. The values of watering rates and uniformity of moisture were identified by the rain-cups installed in the square and radial circuits; the working pressure in the pipeline network and the water flow – by the technical specifications of the pump, manometers, water meters; possible infiltration of irrigation water – by the moisture content of soils before and after irrigation; the microclimate of the habitat of plants (a 2-year-old apple orchard) – by the recorders (thermograph, hygrograph, barograph) installed in two meteorological booths.

RESULTS

The application of the mist sprinkling irrigation method provides optimal soil moisture regime, increased humidity of air, moisturized aboveground parts of plants and, as a result of enhanced evaporation of water, reduced temperature of air and plants.

Based on the analysis of patent information retrieval materials [7-14], a classification of technical sprinkling devices, such as the existing types of sprinklers and nozzles according to their main distinctive features (Table 1) has been made.

The application of sprinkling, especially in hot hours of the day to reduce the negative impact of high air temperatures on the growth and development of plants, is effective [15-21].

Table 1 – Classification of technical facilities of sprinkling (devices and nozzles)

Types	Rate, l/s	Range, m	Nozzle diameter, mm	Upstream pressure, MPa	Root-mean-cube diameter of drop, mm	Average rain intensity, mm/min	Application
Long range	5-85	35-100 and over	16-52	0.6-0.7	2-5.8	0.09-0.413	Stationary, seasonal sprinkling sets
Middle range	0.45-9.5	10-35	6-18	0.2-0.6	0.9-2.5	0.059-0.51	Wide coverage sprinkling machines for irrigation of garden plots, decorative gardening
Short range (deflector type)	0.05-0.7	under 10	0.5-7.5	under 0.2	under 1.5	0.098-0.6 and lower	Small sprinkling machines and sets for garden plots, kitchen gardens, lawns

For modular mist sprinkling sets, as sprinkler nozzles providing water distribution and the rain structure, compliant with the necessary requirements, the sprinkling nozzles developed in KazSRIWE LLP were adopted. Spray nozzle is in Figure 1, carousel nozzle – in Figure 2.

Figure 1 – Spray nozzle

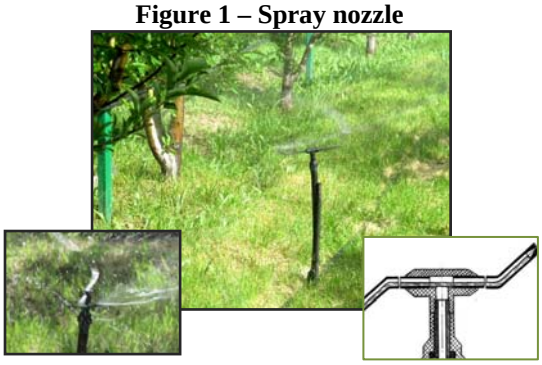

Figure 2 – Carousel nozzle

These nozzles have a rain structure of less than 1 mm and ensure the uniform distribution of water over the irrigation area, which does not adversely affect the soil and ensures the quality of irrigation.

The schematic diagram of a modular set of finely dispersed sprinkling was formed, consisting of two irrigation sections and equipped with sprinkler nozzles of various designs developed by KazSRIWE LLP. The technology of irrigation by modular irrigation sets allows alternating watering by sections. For modular sets, a hydraulic automation scheme has been developed that automatically switches the water outlets by the watering areas.

To test and identify the basic parameters of the modular mist sprinkling set, the stand shown in Figure 3 was designed.

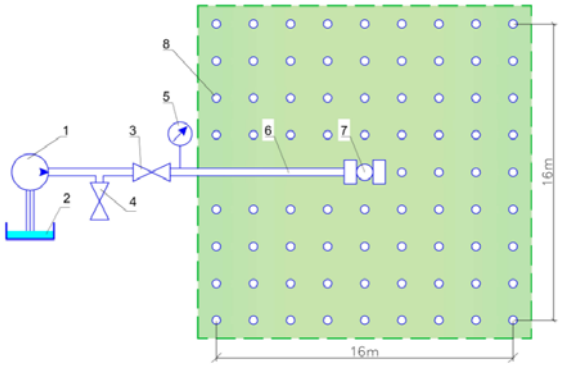

Figure 3 –Principal diagram of the stand for identification of the parameters of sprinkling nozzles: 1 – pump; 2 – accumulation tank; 3 – tap; 4 – pressure regulation valve; 5 – manometer; 6 – piping section; 7 – sprinkling nozzle; 8 – rain-cups

The stand for testing the mist sprinkling equipment is provided with connectors for installation of sprinkling nozzles and measuring gauges.

To identify the distribution uniformity of the rain layer over the irrigation area, a bench area has been prepared that allows testing the sprinkler nozzles taking into account the overlap of their ranges (Figure 4).

In the bench area, special fixators are provided for adjusting the installation angle of the piping in order to simulate the slope of the irrigated field surface.

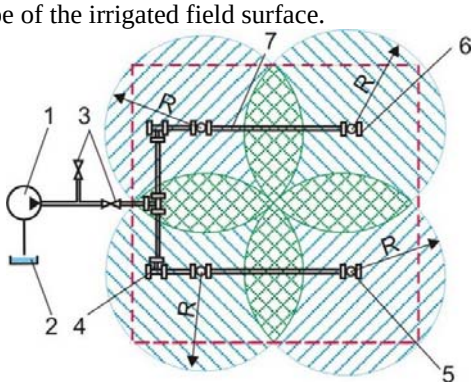

Figure 4 – Bench area for testing sprinkling nozzles: 1– pump; 2 – accumulation tank; 3 – tap; 4 – T-joint; 5 – riser with sprinkling nozzle; 6 – blank plug; 7 – piping section

The process of preparing for the bench tests of the elements and units of the modular sprinkling set began with the check on the quality of its components.

The check was done by visual inspection of the surface of all parts. Sealing rubbers were subjected to extra temporary compression during inspection to identify cracks or other defects. The parts of the set that had defects were replaced. The timing for checking the quality of the parts of the set is given in Table 2.

Table 2 – Timing of the quality control of parts and components of the mist sprinkling set

No.	Parts and elements	Quantity, pcs.	Checking time, s	Note
1	T-joint	9	72	
2	Nut	24	192	
3	Plug	10	60	
4	Rubber bushing *d* 15 mm	22	330	
5	Rubber bushing *d* 20 mm	6	90	
6	Sprinkling nozzle (carousel):			
	- connector	6	54	
	- bushing	6	48	
	- body	6	60	
	- T-joint	6	48	
	- nozzle	12	70	
	- ring	12	20	
	- PE (polyethylene) tube *d* 8 mm	12	45	
Total:			1,089	0.3 h

Table 3 – Timing of operations of assembling the sprinkling set

No.	Operations	Number of elements, units, sections of piping, pcs.	Time for operation, s	Note
1	Cutting PE piping risers for sprinkling nozzles *l*=0.6 m	6	300	
2	Welding riser with connector for nozzle	6	480	
3	Cutting fixing wires for nozzles and end-parts grinding	6	330	
4	Cutting PE pipes *d* 8 mm for nozzles	12	120	
5	Assembling nozzles (carousel)	6	1,680	
6	Cutting piping sections *l*=10 m	6	1,080	
7	Cutting fixing rings for attachments	12	60	
8	Connecting riser with T-joint with nuts and rubber bushings	6	480	
9	Assembling unit of set's connection with pressure-forming unit (tap, connector, nut, rubber bushing)	1	360	
10	Installation of bushings and nuts at piping sections	6	360	
	Total:		5,250	1.46 hr

Upon completion of the quality control of the elements, preparatory work, assembly of assemblies and cutting of PE piping sections were carried out. The timing of the operations is shown in Table 3. On the bench (Figure 3), one sprinkler was initially tested to identify its operational parameters, and then a modular sprinkling set was installed at the site to identify its technical and operational parameters (Figure 3). The pressure in the pipeline network was changed by the tap 4 (3), allowing the pressure to be relieved to the required values.

On the bench site, the following were set depending on the pressure in the piping network: the flow characteristics of the sprinkler nozzles, the range of operation with/without overlap (with several nozzles operating), the irrigation efficiency coefficients, the rain intensity, the water supply per unit time and other parameters.

The rate of the nozzles was identified by the volumetric method by collecting water in the measuring tank with a simultaneous time countdown with a stopwatch and was set according to the formula:

$$q_i = \frac{V_i}{t_i}, \text{ l/s, (1)}$$

where

q_i was the nozzle rate, l/s;

V_i was the water volume, l;

t_i was the time, s.

The total consumption of water by nozzles in the set was calculated by summing the rates of all nozzles.

$$Q = \sum q_i, \text{ l/s (2)}$$

where Q was the water consumption of the sprinkling set.

The range of the nozzles was found by a measuring tape at the extreme drops. The intensity of rain and the uniformity of its distribution over the area of irrigation were found with the aid of rain-cups of 0.8 liters capacity and 78.5 cm^2 receiving area. The duration of the experiments in 3-4-fold replicates was limited by the time of filling the rain gauges by 60-70% in the places with the highest intensity.

The volume of water by the rain gauges was determined by the formula:

$$W_d = \sum \frac{W_{d_i} \cdot F_{d_i}}{f_d}, \text{ l (3)}$$

where

W_d was the water volume in the rain gauges, l;

W_{d_i} was the water volume in the *i*-th rain gauge, l;

F_{d_i} was the area covered by one rain gauge, m^2;

f_d was the rain gauge area, m^2.

The nozzle and the carousel nozzle (Figures 1, 2) were tested, being by their parameters recommended for mist sprinkling.

When testing the sprinkler nozzle, it was found that it could be used to irrigate small areas (the irrigation range being up to 1.35 m depending on the pressure) in combination with drip irrigation to create a microclimate in the irrigation zone. The technical specifications of the sprinkler nozzle are given in Table 4, and the carousel nozzle – in Table 5.
On the carousel nozzle, during the tests, two nozzles were provided for long-range and short-range irrigation – with a slit cut. The nozzle outlets were made with a diameter of 1.0, 1.5 and 2.0 mm. The bench checking of the parts required the improvement of the components, such as: bushing, body and nozzles (the dimensions of mold parts were changed). Checking different nozzle combinations revealed that the nozzle for long and short irrigation with outlet holes of 2.0 mm in diameter was the best.

Table 4 – Technical characteristics of the sprinkler nozzle

Parameters	Pressure, MPa		
	0.15	**0.20**	**0.25**
Type	continuous operation		
Nozzle diameter, mm	2		
Rate, l/s	0.041	0.05	0.055
Sprinkling range, m	1.18	1.25	1.35
Coefficients:			
- effective sprinkling	0.86	0.87	0.82
- insufficient sprinkling	0.08	0.07	0.10
- oversprinkling	0.06	0.06	0.08

Table 5 – Technical characteristics of the carousel nozzle

Parameters	Pressure, MPa		
	0.15	**0.20**	**0.25**
Nozzle diameter, mm - long range - short range	 2 2		
Rate, l/s	0.083	0.10	0.11
Sprinkling range without overlap, m:	6.5	7.0	7.2
Coefficients:	0.81	0.82	0.80
- effective sprinkling	0.11	0.10	0.13
- insufficient sprinkling	0.08	0.08	0.07
- oversprinkling			

Upon the bench tests of the modular mist sprinkling system, its technical and operational specifications were obtained (Table 6).

Table 6 – Technical and operational specifications of the modular mist sprinkling set

Parameters	Pressure, MPa		
	0.15	**0.20**	**0.25**
1	**2**	**3**	**4**
Modular mist sprinkling set:			
- type	easily disassembling		
- operation mode	semi-automatic (manual adjustment of water supply rate)		
- pump brand	Kama-10		
- pump capacity, KW	0.4		
- nozzles per set, pcs.	6		
- nozzles layout	square		
- distance between nozzles, m	9.2	9.9	10.0
- mist sprinkling area, hectares	0.051	0.059	0.061
- total water consumption, l/s	0.050	0.061	0.065
- water supply per day of operation (not including evaporation loss), m^3/hectare	850	878	936
- mass of set without pump and risers for fixing nozzles, kg:			
pipes Ø 20 mm	9.72		
pipes Ø 25 mm	12.91		
Sprinkling nozzle (carousel):			
- type	continuous operation		
- nozzle diameter, mm:			
long range	2		
short range	2		
- rate, l/s	0.083	0.10	0.11
- sprinkling range without overlap, m	6.5	7.0	7.2
- mass, kg	0.074		
Piping network:			
- material	PE		
- diameter, mm	20 (25)		
- total length, m	60		
- number of sections, pcs.	6		
pipes Ø 20 mm	7.38		
pipes Ø 25 mm	10.56		
Coefficients:			
- effective sprinkling	0.81	0.82	0.80
- insufficient sprinkling	0.11	0.10	0.13
- over sprinkling	0.08	0.08	0.07

The data in Table 6 show that, at an operating pressure of 0.25 MPa, the carousel type sprinkling nozzles used have a considerable range (up to 7.2 m), which allows them to be placed at a distance in case of square location at the irrigat-

ed area, equal to 1.41*R*, that is, 10 m from each other. The irrigated area of one nozzle is 0.01 ha. A set of 6 nozzles can irrigate 0.06 ha using a low-flow Kama-10 pump with little energy per unit time (0.4 kW/h). For sections exceeding 0.06 ha, it is possible to use several modules with interchangeable parts. For considerable irrigated areas (1 ha and more), the supply and distribution pipelines of large diameters and a pump with a large flow rate are necessary if rationalized.

DISCUSSION

To test the results obtained, group tests of the mist sprinkling systems were carried out. At the experimental range in KazSRIWE LLP for testing the modular mist sprinkling systems, a pilot site with the necessary equipment was provided (pumping and power equipment, shut-off valves, control and measuring devices, main, distribution and irrigation pipelines, sprinkler nozzles, etc.). The diagram of the pilot site is shown in Figure 5.

The test results of simultaneously operating 2, 3, 4 and 8 mist sprinkling modules with 12 sprinkler nozzles and 6 carousel nozzles in each module, which have worked 220 and 240 hours, respectively, are shown in Table 7 and in Figures 6 and 7

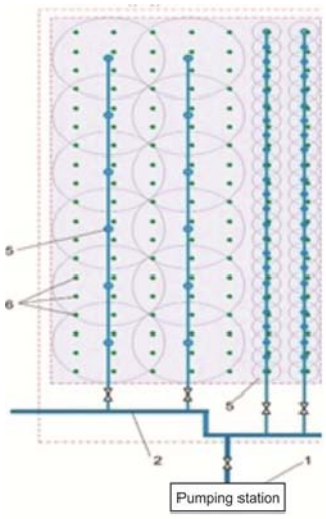

Figure 5 – Diagram of the bench site for testing the modular mist sprinkling systems: 1– pumping station; 2 – distribution piping; 3 – sprinkling piping; 4; 5 – sprinkling nozzles; 6 – fruit trees

Table 7 – Technical characteristics of the operation of modules with various types nozzles tested at the experimental bench site

Parameters	Number of simultaneously operating modules	Sprinkling nozzles					
		Spray nozzle			Carousel nozzle		
		Pressure in piping network, MPa					
		0.15	0.20	0.25	0.15	0.20	0.25
Sprinkling area, ha	2	0.0074	0.008	0.0085	0.0098	0.116	0.124
Network rate, l/s		0.034	0.038	0.044	0.98	1.16	1.28
Piping diameter, mm		15	15	15	20	20	20
Nozzle rate, l/s		0.0014	0.0016	0.0018	0.082	0.096	0.107
Sprinkling range, m		1.22	1.26	1.31	6.4	6.9	7.1
Number of nozzles, pcs.		24	24	24	12	12	12
Average rain intensity, mm/min		0.028	0.03	0.032	0.055	0.058	0.064
Coefficient of effective irrigation, K_{ef}		0.82	0.84	0.83	0.81	0.84	0.82
Sprinkling area, ha	3	0.0111	0.012	0.0129	0.147	0.174	0.186
Network rate, l/s		0.051	0.057	0.066	1.47	1.74	1.86
Piping diameter, mm		15	15	15	20	20	20
Nozzle rate, l/s		0.0014	0.0016	0.0018	0.082	0.096	0.107
Sprinkling range, m		1.22	1.26	1.31	6.4	6.9	7.1
Number of nozzles, pcs.		36	36	36	18	18	18
Average rain intensity, mm/min		0.028	0.03	0.032	0.055	0.058	0.064
Coefficient of effective irrigation, K_{ef}		0.83	0.85	0.84	0.82	0.85	0.83
Sprinkling area, ha	4	0.0148	0.016	0.0172	0.196	0.232	0.248
Network rate, l/s		0.068	0.076	0.088	1.96	2.32	2.56
Piping diameter, mm		15	15	15	20	20	20
Nozzle rate, l/s		0.0014	0.0016	0.0018	0.082	0.096	0.107
Sprinkling range, m		1.22	1.26	1.31	6.4	6.9	7.1
Number of nozzles, pcs.		48	48	48	24	24	24
Average rain intensity, mm/min		0.028	0.03	0.032	0.055	0.058	0.064
Coefficient of effective irrigation, K_{ef}		0.83	0.85	0.84	0.82	0.85	0.83
Sprinkling area, ha	8	0.0296	0.032	0.0344	0.392	0.464	0.496
Network rate, l/s		0.136	0.152	0.176	3.92	4.64	5.12
Piping diameter, mm		15	15	15	20	20	20
Nozzle rate, l/s		0.0014	0.0016	0.0018	0.082	0.096	0.107
Sprinkling range, m		1.22	1.26	1.31	6.4	6.9	7.1
Number of nozzles, pcs.		96	96	96	48	48	48
Average rain intensity, mm/min		0.028	0.03	0.032	0.055	0.058	0.064
Coefficient of effective irrigation, K_{ef}		0.83	0.85	0.84	0.82	0.85	0.83

Table 8 – The average layer of rain (mm) for different operating times of modules with sprinkler nozzles and carousel nozzles

Operating time, min	Sprinkling nozzles					
	Spray			Carousel		
	Pressure in piping network, MPa					
	0.15	0.20	0.25	0.15	0.20	0.25
60	1.68	1.80	1.92	3.3	3.48	3.84
120	3.36	3.60	3.84	6.60	6.96	7.68
180	5.04	5.40	5.76	9.90	10.44	11.52
240	6.72	7.20	7.68	13.20	13.92	15.36
300	8.40	9.00	9.60	16.50	17.40	19.20
360	10.08	10.80	11.52	19.80	20.88	23.04
420	11.76	12.60	13.44	23.10	24.36	26.88
480	13.44	14.40	15.36	26.40	27.84	30.72
540	15.12	16.20	17.28	29.70	31.52	34.56
600	16.80	18.00	19.00	33.00	34.80	38.4

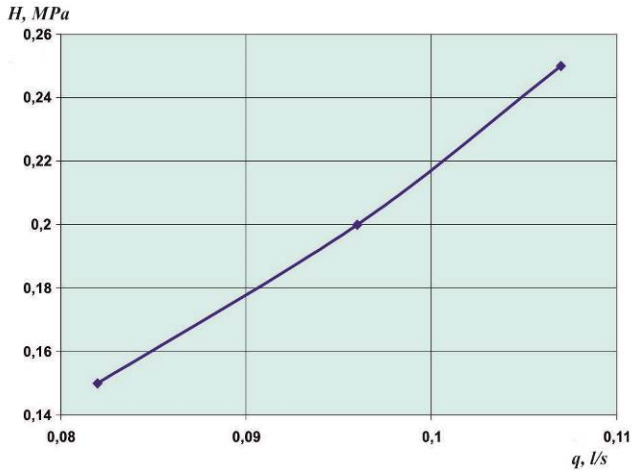

Figure 6 – Rate and head-flow characteristic of carousel nozzle

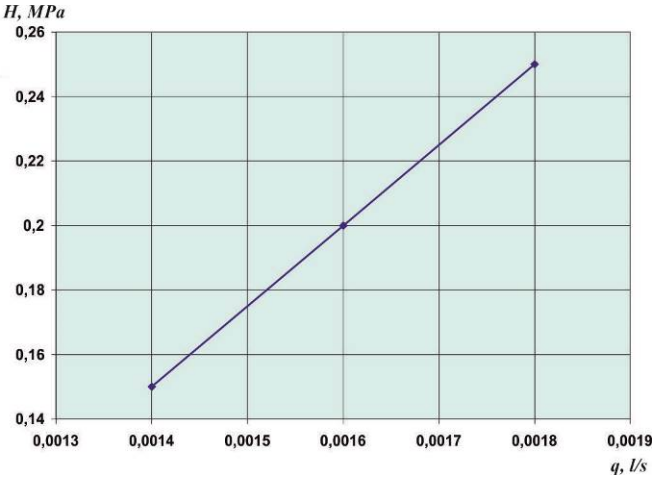

Figure 7 – Rate and head-flow characteristic of sprinkler nozzle

The average irrigation rate for sprinkling duration of 6-8 hours is 20.0-30.0 mm with the use of carousel nozzles and 10.0-15.0 mm – with sprinkler nozzles (Figures 8, 9). The standard deviation varies from 0.4 to 1.4 mm; the coefficient of variation is from 3.7 to 6.0%. With a relative error of the average weighted irrigation rate of 0.6-2.1%, the coefficient of effective irrigation is 0.81-0.84 (Table 8).

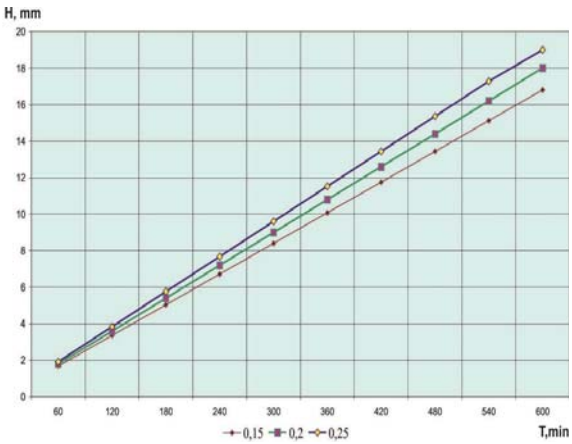

Figure 8 – Dependence of the precipitation layer on sprinkling duration with sprinkler nozzles

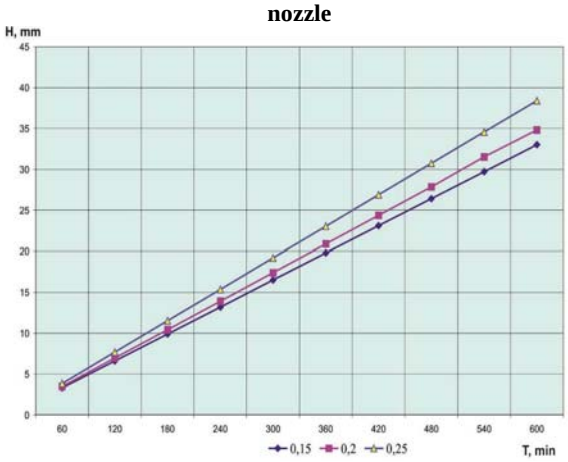

Figure 9 – Dependence of the precipitation layer on sprinkling duration with carrousel nozzles

CONCLUSION

1 The basic scheme of a modular mist sprinkling set, consisting of two sections of irrigation and equipped with sprinkler nozzles of various designs, has been developed. The technology of irrigation with modular mist sprinkling sets allows alternating watering by sections. For modular sets, a hydraulic automation scheme has been developed that automatically switches the water outlets between the watering areas.

2 For modular mist sprinkling sets, as the sprinkler nozzles providing water distribution and the structure of the rain, corresponding to the necessary requirements, the design of KazSRIWE LLP has been adopted: a spray nozzle and a carousel nozzle that have a rain structure of less than 1 mm.

3 As a result of the tests, the following has been identified: the flow characteristics of the sprinkler nozzles depending on the pressure in the pipeline network, the range of watering of the spray and carousel nozzles with and without overlap, the optimal diameters of the outlets, the irrigation efficiency coefficients, the rain intensity, the water supply per unit time and other indicators.

4 The technical and operating characteristics of the modular mist sprinkling system have been found. They show that the irrigated area of one nozzle is 0.01 hectares with an irrigation range of 7.2 m. A set consisting of 6 nozzles can irrigate a section of 0.06 hectares with the use of a low-flow Kama-10 pump with a small amount of energy per unit of time being 0.4 kW/h.

5 The technological operating parameters of a separate module: the range of the nozzles at pressures of 0.15-0.25 MPa is 1.2-1.3 m for mist sprinkling and 6.4-7.1 m for carousel nozzles; the average rain intensity is 0.028-0.032 and 0.055-0.064 mm/min; the coefficient of effective irrigation – 0.81-0.85.

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REFERENCES

1 Grammatikati, O.G., & Kuznetsova, E.I. (1998). *Patent RF No. 2113110. Sposob opredeleniya srokov poliva pri melkodispersnom dozhdevanii* [Patent of the Russian Federation No. 2113110. Method for Identification of the Timing of Irrigation during Mist sprinkling].

2 Kwan, R.A., Gershunov, E.V., Konstantinov, A.V. et al. (2001). *Zatraty vody pri razlichnykh sposobakh oroshe-niya selskokhozyaistvennykh kultur. Rekomendatsii* [Water Expenditures for various methods of Irrigation of Agricultural Crops. Recommendations]. Taraz. (p. 38).

3 Otraslevye normativy udelnykh zatrat vody pri regulyarnom i limannom oroshenii po vodokho-zyaistvennym basseinam respubliki Kazakhstan [Sectoral Norms of Specific Water Consumption for Regular and Liminal Irrigation in the Water Basins of the Republic of Kazakhstan]. (2008). In *Normativno-metodicheskoe obespechenie razvitiya otraslei agropromyshlennogo kompleksa* [Regulatory and Methodological Support for the Development of the Branches of the Agro-Industrial Sector]. Astana: Ministry of Agriculture of the RK. (p. 70).

4 Angold, Ye.V., & Zharkov, V.A. (2014). Special Features of Drip-Sprinkler Irrigation Technology. *Water Science and Technology: Water Supply, 14*(5), 841-849.

5 Angold, Ye.V., Zharkov, V.A., Kalashnikov, A.A., & Balgabaev, N.N. (2016). Features of Impulse Sprinkling Technology. *Water Science & Technology: Water Supply, 16*(5), 1178-1184. doi: 10.2166/ws.2016.037

6 Balgabayev, N.N., Kalashnikov, A.A., & Baizakova, A.E. (2016). Elaboration of Subsurface Irrigation Technique of Onions. *Research Journal of Pharmaceutical, Biological and Chemical Sciences, 7*(2), 738-751.

7 Zharkov, V.A. (1989). Impulsnoe dozhdevanie sadov na yuge Kazakhstana [Impulse Sprinkling of Gardens in the South of Kazakhstan]. *Sadovodstvo i vinogradarstvo, 8*, 19-21.

8 Zharkov, V.A. (2000). Primenenie impulsnogo dozhdevaniya dlya orosheniya selskokhozyaistvennykh kultur v predgornoi zone yuga Kazakhstana [Application of Impulse Sprinkling for the Irrigation of Agricultural Crops in the Foothill Zone of the South of Kazakhstan]. In *Nauchnye issledovaniya v oblasti melioratsii i vodnogo khozyaistva: sb. nauch. tr. KazNIIVKh* [Scientific Research on Land Reclamation and Water Management: Collection of Scientific Papers of KazSRIWE] (pp. 198-204). Taraz.

9 Konstantinov, A.V., Kalashnikov, V.A., & Zharkov, V.A. (1988). Vnedrenie resursosberegayushchei tekhnologii poliva v plodovykh pitomnikakh [The Introduction of Resource-Saving Irrigation Technology in Fruit Nurseries]. In *Kompleksnaya rekonstruktsiya gidromeliorativnykh sistem Kazakhstana: sb. nauch. tr. KazNIIVKh* [Complex Reconstruction of Irrigation and Drainage Systems in Kazakhstan: Collection of Scientific Papers of KazSRIWE] (pp. 142-151). Tashkent: SANIIRI.

10 Gershunov, E.V., Zhuiko, Yu.D., & Zhunusov, R.S. (1988). *Perspektivnye sposoby i tekhnika poliva na oroshaemykh zemlyakh Kazakhstana* [Prospective Irrigation Methods and Techniques on Irrigated Lands of Kazakhstan]. Alma-Ata: KazNIINTI. (p. 64).

11 Bochkarev, Ya.V., Gankin, M.Z., & Ovcharov, E.E. (1969). *Osnovy avtomatiki i avtomatizatsii protsessov v gidromelioratsii* [Fundamentals of Automatics and Automation of Processes in Hydromelioration]. Moscow: Kolos. (p. 392).

12 Kraesov, I.N. (1967). *Gidravlicheskie elementy v sistemakh upravleniya* [Hydraulic Elements in Control Systems]. Moscow: Mashinostroenie. (p. 255).

13 Shmarko, A.M. et al. (1972). *Avtorskoe svidetelstvo 355390 (SSSR). Generator komandnykh impulsov dlya zakrytykh orositelnykh sistem s dozhdevalnymi apparatami preryvistogo deistviya*. [Author's Certificate 355390 (USSR). Command Pulse Generator for Closed Irrigation Systems with Intermittent Sprinklers]. Bul. No. 31.

14 Kaganov, M.A., Khvoles, S.B. et al. (1953). Vliyanie orosheniya na mikroklimat pochvy i prizemnogo sloya vozdukha [Influence of Irrigation on the Microclimate of Soil and Surface Air Layer]. *Gidrotekhnika i mekhanizatsiya, 1*, 52-63.

15 Sapunkov, A.P. (1991). *Primenenie dozhdevalnoi tekhniki: sovremennye tendentsii* [Application of Sprinkler Technology: Current Trends]. Moscow: VO Agropromizdat. (p. 126).

16 Babaev, N.Kh. (1968). Uvyazka dlitelnosti poliva dozhdevaniem s vodno-fizicheskimi svoistvami pochv [Linking the Duration of Irrigation Sprinkling with Water-Physical Properties of Soils]. *Vestnik selskokhozyaistvennykh nauk, 5*, 55-57.

17 Boldyrev, A.P. (1978). *Vodopronitsaemost pochv i primenimost nekotorykh dozhdevalnykh ustroistv dlya poliva na sklonovykh zemlyakh Moldavii: Avtoreferat dissertatsii na soiskanie uchenoi stepeni kandidata tekhnicheskikh nauk* [Water Permeability of Soils and the Applicability of Some Sprinkling Devices for Irrigation on Sloping Lands of Moldova (Ph.D. Thesis Abstract)]. Moscow. (p. 24).

18 Erkhov, N.S., & Kantor, O.V. (1977). Vodopronitsaemost suglinistykh pochv i dopustimaya intensivnost dozhdya [Water Permeability of Loamy Soils and Permissible Rain Intensity]. *Gidrotekhnika i melioratsiya, 7*, 48-55.

19 Shekachev, Yu.A., Khazhmetov, L.M., & Zherukov, A.Kh. (2005). Optimizatsiya parametrov dozhdevalnogo apparata dlya poliva plodovykh nasazhdenii na gornykh sklonakh [Optimization of the Sprinkler's Parameters for Irrigation of Fruit Plantations on Mountain Slopes]. *Mekhanizatsiya i elektrifikatsiya selskogo khozyaistva, 9*, 14-16.

20 Olgarenko, G.V., & Gorodnichev, V.I. (2006). Dozhdevalnaya tekhnika novogo pokoleniya [Sprinkling Devices of the New Generation]. *Melioratsiya i vodnoe khozyaistvo, 2*, 34-36.

21 Balgabayev, N., Kalashnikov, P., Baizakova, A., & Kalashnikov, A. (2017). The Technology of Cultivating Lump Crops with Mist Sprinkling in the Conditions of the Zhambyl Region. *OnLine Journal of Biological Sciences, 17*(2), 110-120.