Results of application of water-saving technologies in rice farming

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Abstract. The article presents the results of field studies on the application of sprinkling and drip irrigation technologies in the cultivation of rice in the soil and climatic conditions of the Republic of Karakalpakstan based on the tasks defined in the Decree of the President of the Republic of Uzbekistan dated February 2, 2021, No. PD-4973 "On measures for the further development of rice growing". This article presents the results of field and laboratory studies on the application of rain and drip irrigation technologies in the cultivation of rice, primary irrigation regimes suitable for the soil and climatic conditions of the research object, the mechanical composition of the soil, salinity levels, salinity of irrigation water and the use of water-saving technologies in the cultivation of rice in experimental versions. The influence of the hydrochemical state of water on the soil and the yield of rice and its quality indicators were determined in the field conditions of the experiment.

1 Introduction

In recent years, special attention has been paid to growing agricultural products, increasing export potential, introducing modern innovative technologies, and rationally using water resources.

It is necessary to improve the well-established and efficient system of rice cultivation, storage, and processing in the republic, provide the domestic consumer market with rice products and increase export potential, strengthen research work in this direction, and widely use water-saving technologies in rice cultivation.

In the soil and climatic conditions of the Republic of Karakalpakstan, much scientific research has been carried out to improve the equipment and technology for irrigating crops, mainly cotton. However, studies on developing water-saving technologies for growing rice in low water conditions have not been conducted.

As a result of global climate change observed in recent years, in the conditions of frequent water shortages in our region, particularly in our republic, rice cultivation areas are shrinking. In most cases, the lack of approbation of water-saving irrigation technologies in practice or the lack of scientifically based recommendations on the irrigation method in rice cultivation is an obstacle to introducing water-saving irrigation technologies into practice over large areas. Most of the zoned rice varieties cultivated over large areas of our republic are considered very demanding on water and have high productivity compared to flooding

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in arid conditions. Therefore, it is very important to test effective water-saving irrigation technologies that save water when growing rice, which is a relatively water-intensive crop.

2 Used materials and methods

In field experiments, phonological observations and biometric measurements were carried out, and analyses of phonological, soil, and plant samples for the growth and development of rice were based on the "Methodological guidelines for growing rice in Uzbekistan". Statistical processing of data on rice yield was carried out according to the method of B.A. Dospekhov "Methodology of the field experiment" (1979; 1985) [7].

3 Literature review

Although rice always grows in water, its water requirements change during periods of growth and development. In our republic, rice is grown mainly in engineering and semi-engineering systems. In engineering and semi-engineering systems, the area of rice fields is, on average, 1.5-3.5 ha, and their alternative area is 2.5-3.0 ha, which has been proven in practice [4].

Today, in our republic, rice is grown traditionally, that is, from the day the seeds are sown in the ground until they ripen, the water level in the rice fields is 25 cm for 3-4 months (due to uneven ground in places 30-35 cm), the crop is grown at watering.

In Uzbekistan, rice seeds are scattered on the soil surface, and irrigation is carried out before sowing (under conditions of water tillage) and after sowing (when sowing on the surface of dry soil with seeders). The rice irrigation period lasts from the day of sowing to the first decade of September, considering the varieties' biological characteristics and the growing season.

In rice growing, a delay in the initial timing of water quenching of checks leads to a lengthening of the growing season, clogging of the field with starling, and decreasing rice yield. Some researchers believe that rice should be watered from the earing period to the period of wax ripeness and maintain soil moisture at two-thirds of the maximum moisture capacity in the remaining periods of vegetation. I.V.Abad 1931; N.S.Goryunov 1966, G.Voropaev 1970. P.S.Erygin and V.B.Zaitsev believe that the best conditions for rice from the germination phase are provided in waterlogged soil [6].

Field studies of the frequency of flooding of rice crops during its growing season, based on studies conducted in all rice-growing regions of our republic, can reduce periodic flooding to a certain extent (K.I.Savich, 1928; G.G.Gushchin, 1942; B.S.Konkov, 1948; V.M.Legostaev, 1971; K.Saparaliev, 1974). Some researchers believe that in the Far East and the Krasnodar Territory conditions, periodic drainage and irrigation in checks reduce rice yield compared to constant flooding. In our opinion, conflicting opinions about the timing of flooding of rice crops during the growing season are associated with climatic conditions and biological characteristics of varieties, various rice cultivation technologies, and research methodology [8].

The most common method of irrigating rice in the world is continuous flooding with the preservation of a layer of water even until the period of wax ripeness (L.V.Skripchinskaya, 1962). And here is another irrigation method, for example, reduced water suppression, which is used in sowing and straightening rice seeds by machine (S.K. Kondrashov, 1948). Such irrigation was called the "California" irrigation method [8].

Rice with reduced water suppression according to the method of prof. Under the leadership of Witte (1930), research was carried out in the experimental regions of the North Caucasus. Currently, rice is grown mainly in the CIS countries with reduced irrigation (V.A.Popov, 1991). In the rice-growing systems of the Central Asian republics, continuous irrigation is still widely used for sowing rice. Such irrigation is widespread in Vietnam and the countries of Southeast Asia (Dinh Van Li, 1978) [5].

Optimal growth and development of rice can be ensured with continuous flooding with a layer of water in checks until the period of wax ripeness and flooding with reduced rates (P.S. Erygin, 1950; P.M. Tsapko, 1955; K.S. Kirichenko, 1958; N.V. Natalina, 1965; Julai A.P., 1968) [6].

Research conducted by scientists in the area on maintaining a certain layer of water in rice fields from the germination of rice to the period of wax ripeness emphasizes the need to constantly maintain a 10-15 cm layer of water before the start of wax ripeness of rice and corn. As a result of constant water retention in such an aquifer, the highest yield of rice and the death of weeds are ensured (M.V. Borodin, 1935; D.S. Tinfrokk, 1958; I.E. Krivolapov, 1971; E.P. Aleshin, 1986) [17].

Based on the results of studies conducted at Mozdok (B.A. Neunylov, 1938) and Kizlyar (B.I. Korolev, 1934) experimental reclamation stations on the effect of continuous and periodic irrigation of rice paddies on productivity (Table 1.1.2).

Similar results were obtained by A. Kruzhilin (1938, 1944) when testing varieties from the Far East Sholi Experimental Station of the Saratov Region. The yield of different rice varieties under periodic flooding compared with continuous flooding was 40-76% [11].

E. B. Velichko, L. Dmitrieva (1930), A. T. Shchadrin (1930), K. P. Shumakova (1931), S. A. Dalinikaitnis (1935), K. N. Tarkov (1935), I .I.Khatuntsev (1938), S.A.Knapp (1910), P.K.Sen (1937), J.Lamis and A.Davis (1944) conducted studies [15, 16].

According to G.G.Gushchin (1938), when comparing 600 rice varieties under conditions of soaking (flooding) and constant flooding, 10 varieties achieved higher yields during flooding. This indicates that, in nature, there are rice varieties that can grow well in the absence of a groundwater level in the field and are capable of producing higher yields under such conditions than with constant flooding [19].

In studies conducted by E.V.Uspenskaya (1937) on the fields of the Uzbek rice experimental station, the number of weeds (mainly Kurmak-Echinochloa crus galli; Echinochloa coarctata) in the experimental field was 100 or more per 1 m2 [9].

In studies conducted by A.V.Nesterov (1938) at the rice-breeding experimental station of Uzbekistan, it was noted that an increase in the number of field desiccations increases the contamination of rice plants with weeds and adversely affects the rice yield. This can be seen from the following data: At the same time, the yield of rice with 7-fold drying is 37.1 t/ha; 44.6 c/ha when dried 4 times; 47.5 c/ha with 2-fold drying; 46.4 c/ha for 1 drying [20].

In 1948, I.I.Chugrikov, based on his experiments in the conditions of the Tashkent region, came to the following conclusions: at a water temperature above 35°C, it is necessary to ensure a low flow rate in the rice fields. V.F.Shchupakovskiy (1958) came to the same conclusion; he says that it is necessary to ensure fluidity only in the daytime when the water temperature in the checks exceeds 35-40°C. In all other cases, without benefit, on the contrary, it leads to a decrease in yield since the temperature of the water in the check decreases, as a result of which the ripening of rice is prolonged. Other data are indicating that in large limited artificial irrigation systems of rice, the effect of water consumption on its temperature is insignificant (E.B.Velichko, 1965; K.Sergilbaev, 1969; M.T.Kogai, 1972; N.Ya.Vinogradnaya, 1977; V.B.Zaitsev, 1980) [13]. From the above analysis, it can be concluded that in modern conditions of rice cultivation technologies, the water temperature in the check cannot be reduced due to flow irrigation. Many authors and practicing rice growers emphasize that draining water in rice fields is necessary to prevent overheating and excessive water mineralization in rice fields and combat various algae that appear in large numbers in rice fields depending on the stage of development. (Pereskokov M.F., Uspenskaya E.V., 1928; Obod I.V., 1931; Erygin P.S., 1950; Grist, 1959; Pak A.D., 1970; Baraev F.A., 1990) [10].

To date, the issue of uniform water distribution in rice cultivation has been studied relatively little. In several literary sources, some authors (Christiansen 1941; A.N. Lyapin 1953; S.M. Krivovyaz 1957; A.N. Kostyakov 1960; D.T. sprinkling and drip irrigation. Most of them give a statistical description of uneven rainfall or irrigation rates in individual areas. Only D.T. Howell (1964) gave qualitative and quantitative relationships between the uneven distribution of water [2].

One of the works that shed light on the physiological need of the rice crop for water in its various phases is the work of the researcher M.I. Uklonskaya (1929). He conducted experiments to study the effect of changes in the water regime of the soil on rice during the growing season and at different stages of its development. More complete and systematic studies on the study of the water regime of rice in the CIS countries with the local variety "Arpa-shaly" were carried out by PS Erygin (1934, 1939, 1945, 1946, 1947, 1949). In studies conducted by P.S. Erygin (1934), it was shown that the rice varieties available in nature could be divided into two groups: periodically irrigated (upland) and water-suppressed, each of them having upland and water-depressing genotypes. In addition to the obvious representatives of these groups, it was mentioned that rice varieties with an intermediate trait, that is, with a strong and low need for water and drought, can also be found. This, in turn, depends on the centuries-old history of their cultivation in various natural conditions. In this regard, before embarking on physiological and biochemical studies of periodically irrigated and water-suppressed rice varieties depending on the conditions of the soil water regime, P.S. water consumption. The first part of his experiments made it possible to establish the following. Compared to rice growth without a water layer, the growth of rice seeds and seedlings under a water layer causes the following: The annual irrigation rate of rice is, on average, 25-35 thousand m^3 per hectare, depending on the texture of soils and types of agrotechnical activities carried out 30-40% of this amount is absorbed by the plant; the rest is spent on evaporation, absorption into the soil, and utilization [12].

In Uzbekistan, rice seeds are sown by spreading over the soil surface, and pre-sowing (under conditions of water tillage) and after-sowing (when sown on the surface of dry soil with seeders) are irrigated. The rice irrigation period lasted from the day of sowing to the first decade of September, considering the biological characteristics of varieties and the growing season.

Currently, the sholipoyas is watered in two ways: draining and non-draining. According to the analysis of the results of scientific research conducted in the conditions of the Republic of Karakalpakstan, it is scientifically substantiated that the water temperature in rice paddies remains at the same level even when both methods are used in rice cultivation technology. In addition, the no-flow method of irrigating rice prevents excess water from entering the ditches. As a result, it is possible to avoid wastewater treatment and labor costs and increase drivers' productivity. In addition, the germination of rice seeds, i.e., during the period of initial establishment and from the period of wax ripeness to the period of full maturity, does not require the maintenance of a water layer in rice plants.

Table 1. Experience system, Rice variety "Gulistan".

Options №	Watering method	Estimated daily rate of irrigation, (m^3/ha)	Irrigation period (interval), (days)
Grain and rice Scientific Production Association of the Nukus region of the Republic of Karakalpakstan			
1.	Conventional flood irrigation (control variant)		
2.	Drip irrigation	175	1
3.	Sprinkling	180	2
4.	Drip irrigation	110	1
5.	Sprinkling	125	2

Today, in our republic, rice is grown traditionally, that is, from the day the seeds are sown in the ground until they ripen, the water level in the rice fields is 25 cm for 3-4 months. (due to unevenness of the ground in some places 30-35 cm) the crop is grown when irrigated.

Currently, there are more than 20 released and cultivated varieties of rice in all regions, the patent indicates a yield of 60-70 centners per hectare of land, but in 2019-2020, the average yield of rice grown traditionally was 30-35 t/ha. Rice is imported into our country, the level of reference is growing (G.Rakhimov, A.Urazkeldiev 2021).

4 The results obtained and their analysis

Field experiments were carried out in 2022 on the fields of the Scientific and Production Association of Grain and Rice in the Nukus region of the Republic of Karakalpakstan. The area of designed and built sprinkling and drip irrigation systems in each research facility was 1.5 ha. The experimental system consisted of 2 variants with moderately saline soils and was arranged in 3 repetitions (Table 1).

According to the mechanical composition, the soil of the experimental field, located in the grain-rice research and production association, is medium and heavy loamy, and the occurrence of groundwater is at the level of 2-3 meters, irrigated for a long time.

In the Scientific Association of Grain and Rice Growing experimental field, studies were carried out on daily and inter-day irrigation of rice of the Gulistan variety with traditional pressure, drip, and rain irrigation. In the studies, all observations and analyzes were carried out based on methodological manuals adopted by the Rice Research Institute, and agrotechnical measures were carried out in the manner adopted on the farm.

At the same time, the experimental area located in the SPA of grain and rice amounted to 90x176=1.58 ha. When designing a drip and sprinkling irrigation system on the experimental site, drip irrigation was placed at intervals of 0.4 m. Drip irrigation hoses d=17 mm were used, droppers every 0.30 m, water consumption 1.6 l per hour, made in Turkey. Also, in the design of the sprinkler irrigation system, a sprinkler irrigation system is used, in which each sprinkler device is placed at an interval of 12x12 m.

Experimental drip and sprinkler irrigation systems were designed and built at the research center. Research on drip and sprinkler irrigation of rice was carried out on the fields of the Grain and Rice SPA. The mechanical composition of the soil of the research object is medium sand; seepage water is 2-3 meters, slope i=0.001-0.003, the area of water-saving irrigation is 1.5 ha, of which drip irrigation is 0.75 ha, sprinkling irrigation is organized 0.75 ha.

The rice variety "Gulistan" was planted on the experimental field of the SPA Grain and Rice experimental station, where water-saving irrigation technologies were introduced, and in the 1st variant of the study of rice irrigation, i.e., with traditional invasive irrigation.

Control options, the seasonal rate of water consumption of rice was 20465 m^3/ha; in the 2nd version of the research based on the results, the seasonal rate of water consumption of rice on drip irrigation is 12766 m^3/ha, the rate of one-time drip irrigation is 120-244 m^3/ha, the number of irrigations using drip technology irrigated 47 times, saving 37.6 percent of irrigation water per season compared to the control back-up irrigation. According to the results of the 4th version of the study, the seasonal water consumption rate of rice under drip irrigation is 15062 m^3/ha, the rate of one-time drip irrigation is 110-152 m^3/ha, the number of drip irrigations is 92 times compared to the control option with pressure irrigation, for the season 26.4% savings in irrigation water.

Also, according to the results of the 3rd option of rain irrigation studies in the experimental field, where water-saving irrigation technologies are introduced, the seasonal water consumption rate of rain rice is 13111 m^3/ha, the rate of one-time rain irrigation is 125-255 m^3/ha, and the number of rain irrigation is 47 times saved 35.9 percent of irrigation water compared to the control. According to the results of the 5th research option, the seasonal rate of water consumption of rice is 16204 m^3/ha, the rate of one-time sprinkling is 130-164 m^3/ha, the number of sprinkling irrigations is 92 times, and 20.8% of irrigation water is saved per season compared to the control option with forced irrigation. According to preliminary observations, the rice yield in this variant exceeded 43 centners (Table 2).

To conduct irrigation experiments on introducing drip and rain irrigation technologies in rice cultivation, calculations of one-time water consumption rates and field studies based on these rates were organized.

In the course of field experiments, since it is planned to irrigate rice using water-saving irrigation technologies, irrigation rates are determined before each irrigation and irrigation work is carried out[1].

The rate of pressure irrigation of rice is determined by the following formula [3]:

$$m = \alpha \cdot H \cdot (A - B) \cdot 100\text{; } m^3/hec \tag{1}$$

where α is volumetric mass of soil, g/cm^3; H is the calculated layer thickness, cm; A is total moisture capacity of the soil, % by weight; B is soil moisture before irrigation, in % of the total soil moisture capacity.

The following formula determines the water requirement of rice:

$$E = K \cdot 0.0018 \cdot (25 + t^{\circ})^2 \cdot (100 - \alpha) \tag{2}$$

where K is rice yield factor (1.0-1.2 for wet area and 0.85 for dry area); α is average monthly relative air humidity, %; to the average monthly air temperature, °C.

To determine the total moisture capacity of the soil, the following formula is used [3]:

$$W = H \cdot (A - \beta_H) \tag{3}$$

where for rice, the recommended depth of the first saturation of the H-root layer is 1.5 meters (for the pressure method of providing seed water), m; A is soil porosity in a meter layer, m^3/ha; β_H is moisture of the soil of the first irrigation for rice was taken equal to 85%.

$$\beta_H = 0.85 \cdot W_{ЧДНС} \tag{4}$$

where: $W_{ЧДНС}$ is limiting moisture capacity in the root layer, m^3/ha.

[1] A. Ramazanov. Rice on the saline lands of the lower reaches of the Amu Darya. Tashkent-1983. pp. 27-64.

Seasonal water consumption is estimated at 23.000 m^3/day in rice fields under continuous flood conditions. Taking into account filtration losses due to the mechanical composition of the soil of the root layer under pressure irrigation, the seasonal water consumption of rice can reach up to 30.000 m^3/ha.

In the conducted field experiments, the first irrigation, that is, with rice sowing water, was carried out on the fields where water-saving irrigation technologies were introduced during the cultivation of rice. The method for determining daily rice irrigation rates was used to calculate the irrigation rate for irrigating rice seeds with water-saving irrigation technologies. In areas where water-saving irrigation technologies were introduced in rice cultivation, the sowing water of rice, that is, the first irrigation rates, was calculated using the following formula:

$$m_1 = W + 100 \cdot h_1 + E_1 \cdot t_1 \tag{5}$$

where: W is 85% of the total moisture capacity of the soil of the calculated layer, calculated for the first flood, is taken, m^3/ha; h_1 is calculated layer thickness for irrigation conditions using water-saving irrigation technology, cm; E_1 is average monthly evaporation from the rice field, m^3/ha; t_1 is duration of watering, hour.

Rice irrigation rates with water-saving irrigation technologies for rice cultivation were calculated using the following formula:

$$m_n = (E_n + f_n) \cdot t_n - 10 \cdot P_n \tag{6}$$

where E_n is amount of daily evaporation from the rice field during the flood period (n-irrigation number), m^3/ha; f_n is amount of daily filtration from the field during f_n is irrigation period, m^3/ha; tn is the duration of the irrigation interval, days; The sum of atmospheric precipitation for P_n is irrigation period, mm/day.

Table 2. Norms of seasonal water consumption for varieties of rice "Gulistan" planted on experimental field of Grain and Rice SPA of Nukus region of Republic of Karakalpakstan

Options, №	Rice varieties	Vegetation period of rice varieties, days	Watering methods	Norm of pre-sowing pressure irrigation, m^3/ha	Irrigation rate, m^3/ha	Irrigation rate, average (m^3/ha)	Irrigation rate, m^3/ha	Cultivation, c/ha	Water consumption for growing 1 centner of crop, m^3/c
1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**
1	Gulistan	90-95	Conventional flood irrigation (control variant)	2265	1500-2000	1300	20465	47.9	427
2			Drip irrigation		120-244	224	12776	35.0	365
3			Sprinkling		125-255	231	13111	36.1	363
4			Drip irrigation		110-152	139	15062	43.0	351
5			Sprinkling		130-164	152	16204	43.4	373

Using this expression, it is possible to determine the calculated one-time irrigation rates when irrigated by water-saving irrigation technologies.

The results obtained in the experiments on the actual one-time and seasonal rates of rice water consumption and rice yield indicators are presented in detail below.

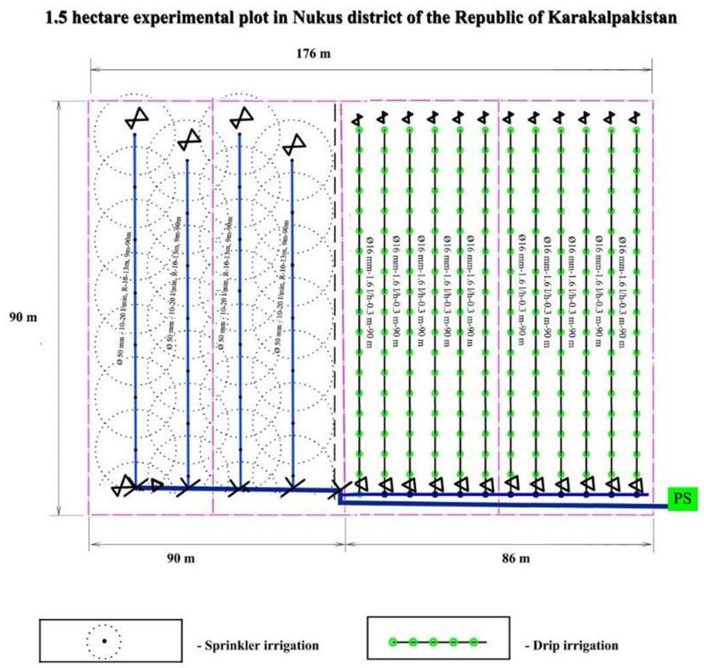

Fig. 1. Technological form of experimental system of drip and rain irrigation of rice at experimental site of Grain and Rice SPA in Nukus region of Republic of Karakalpakstan

The design of this drip and sprinkler irrigation system used main pipes with a medal connection. Main pipelines are intended for laying above the ground. The diameter of the main water supply pipe above the ground is 110 mm, the diameter of the distribution pipes is 75 mm, the diameter of the drip irrigation hoses is 17 mm, and the water flow rate of the droppers located every 30 cm is 1.6 l/h. Irrigation hoses are installed every 0.4 m.

The sprinkler irrigation system was designed using a fixed sprinkler system every 12 meters.

For each object, a scheme of a drip and sprinkling irrigation system was developed based on the R&D program for designing a drip and sprinkling irrigation system (Fig. 1).

Drip irrigation systems include a reservoir, water treatment, filters, water supply, water distribution, and irrigation, depending on the conditions of the area where they are implemented. The components of a drip irrigation system can vary in number, type, and number of elements depending on the location of the system, the chemical composition, and the turbidity of the water used in drip irrigation.

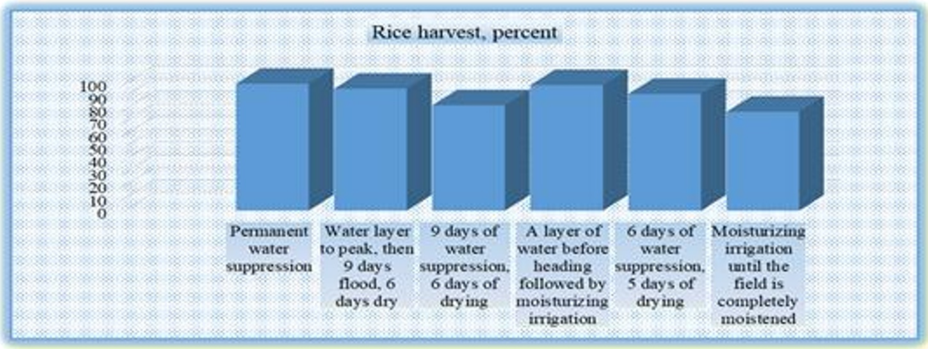

Fig. 2. Rice yield depends on irrigation regime

The main elements of the drip irrigation system, which are main elements of the drip irrigation system that serve to store or filter water, include a pool filter, mechanical, mesh, sand, and disc filters, water pumping devices, main and distribution pipes, pressure control equipment, valves of various sizes, valves, and fittings, the sprinkler part consists of drip hoses or tapes. In addition, a special fertilizing device for feeding crops and automatic control equipment can be included in the drip irrigation system. Fertilizers consist mainly of devices for dissolving and applying water-soluble mineral fertilizers that act as a mixer. During the design and construction of the rice drip and sprinkling irrigation system at the selected research sites, the components, elements, and materials used, as the quantity, size, and list of the drip irrigation system, were developed. When managing irrigation works by irrigation sectors, it was carried out based on irrigation regimes provided for in the experimental system.

5 Conclusions

On the introduction of water-saving irrigation technologies in rice cultivation, field studies were carried out based on the technology of sprinkling and drip irrigation of the Gulistan rice variety at the experimental site of the experimental station of the Grain-Rice SPA. The experimental system was carried out in 5 variants; variant 1 is the control variant, i.e., traditional pressure irrigation, option 2 - drip irrigation (intermittent irrigation), option 3 - rain irrigation (intermittent irrigation), option 4 - drip irrigation (every watering per day), option 5 rain irrigation (watering every day).

In the course of the studies, the control variant used the traditional rice flood method, i.e., in variant 1, the single flood rate during the growing season averaged 1300 m^3/ha, and the seasonal irrigation rate was 20465 m^3/ha.

In the 2nd variant of daily drip irrigation, the rate of one-time drip irrigation is 120-244 m^3/ha, the seasonal irrigation rate is 12776 m^3/ha, and in the 3rd variant, the rate of one-time drip irrigation is 125-255 m^3/ha, the seasonal irrigation rate is 13111 m^3/ha ha, in the 4th option, the daily rate of drip irrigation is 110-152 m^3/ha, the seasonal rate of irrigation is 15062 m^3/ha, in the 5th option, daily rain watering. The regular irrigation rate was 130-164 m^3/ha, and the seasonal irrigation rate was 16204 m^3/ha.

According to the results of the experiment, in terms of the amount of water used to grow 1 quintal of rice crop, there was a large difference in the options. At the same time, 427 m^3 of water was used to grow 1 ton of rice in traditional pressure irrigation options, 351-365 m^3 in drip irrigation options, and 363-373 m^3 in rain irrigation options.

According to the results of observations of the yield of row rice, it was 47.9 t/ha in the management options with traditional flooding, 35.0-43.0 t/ha in the drip irrigation options, and 36.1-43.4 t/ha in the rainwater options. Irrigation Rice crop is grown.

Water savings were 26.4-37.6% with drip irrigation and 20.8-35.9% with sprinkler irrigation compared to traditional flooding options.

According to the results obtained in the first year of the studies, it was noted that the water-saving coefficient was higher, and the yield was reduced in the options with the introduction of drip and rain irrigation technologies compared to the traditional flood method.

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