MODE OF RICE DRIP IRRIGATION

I. P. Kruzhilin[1], N. N. Dubenok[2], M. A. Ganiev[1], A. S. Ovchinnikov[3], V. V. Melikhov[1], N. M. Abdou[4], K. A. Rodin[1] and S. D. Fomin[3]
[1]All-Russian Research Institute of Irrigated Agriculture, Volgograd, Russia
[2]RussianTimiryazev State Agrarian University, Moscow, Russia
[3]Volgograd State Agrarian University, Volgograd, Russia
[4]Fayoum University, Al Fayoum, Egypt
E-Mail: fsd_58@mail.ru

ABSTRACT

The results of studies on the justification of the combination of controllable factors of growth and development of rice, providing the usage of drip irrigation to obtain yields 5, 6 and 7 t/ha of grain are observed. During the investigations were determined the reaction norms of periodically watered rice on the various options for the water regime of the soil and to ensure their regulations irrigation, fertilizer application rates. The proposed irrigation technology can reduce the cost of irrigation water in the cultivation of rice in the 2.0-5.6 times in comparison with the traditional, and bring the total water consumption of this culture to a biologically sound one.

Keywords: crop yields, drip irrigation, fertilizers, rice, irrigation regimes, water regime, water use.

INTRODUCTION

Rice refers to a group of basic crops of the planet and is the leading culture of irrigated agriculture. It is grown in 120 countries on more than 165 million ha. The main area of rice cultivation is South-East Asia. Here is concentrated more than 80% of the cultivated area (in Africa - 5.3%, in South and North America - 4.7% and Europe - 0.5%). In 2013, the production of unpolished rice has exceeded 700 million tons. Still, the demand for rice in connection with the growth of population and the increase in its consumption in countries outside of Southeast Asia continues to grow.

In the Russian Federation, as in most countries of the world, rice fields are irrigated by flooding water layer, to which the rate of 1 hectare is spent more than 20 thousand m^3 of irrigation water. This evapotranspiration hereby consumes 6-8 thousand m^3 (Abdou *et al.*, [1]; Velichko and Shumakova, [23]; Witte, [24]; Kruzhilin, [12]; Kruzhilin *et al.*, [11]; Kruzhilin *et al.*, [16]; Kruzhilin *et al.*, [15]; Rodin, [21]; Chamyshev and Kruzhilin, [5]; Aguilar and Borjas, [3]).

Due to the high cost of irrigation water in most rice-growing areas there is a problem of water shortage for irrigation and other needs. In our country from it suffer Krasnodar region, Rostov region, in the other - the countries of Southeast Asia, Spain, Italy, Egypt and others (Kruzhilin, [12]; Aguilar and Borjas, [3]; Parthasarathi*et al.*, [18]). All this has actualized the need to seek new water-saving irrigation technology of rice as the most water-consuming irrigated culture. One solution to this problem lies in the design and development of rice, as well as of other cultures from bluegrass family, irrigation technology that offers irrigation not by flood checks but by conducting periodic watering.

All-Russian Research Institute of irrigated agriculture (VNIIOZ) has been dealing with issues of scientific consideration of irrigation rice by periodic watering since 1999. Based on a synthesis of the research results in previous years (Velichko and Shumakova, [23]; Witte, [24]; Abramenko and Bagrov, [2]; Ganiev and Zhezmer, [7]; Subbotin, [22]), the main directions of our research were limited to the development of new varieties, tolerant to the presence of water-in checks layer, obtaining the so-called aerobic rice varieties (Kruzhilin, [12]; Aguilar and Borjas, [3]; Parthasarathi *et al.*, [18]; Jrassi *et al.*, [8]). At the same time we addressed questions assess the reaction norms periodically watered-direct rice on the water regime of the soil, fertilizer dosage, the combination of controllable factors of growth and development for different levels of productivity, irrigation schedules for different methods of irrigation in different years under the terms of moisture. The results of studies on rice irrigation surface irrigation of the bands and furrow irrigation are described in scientific articles (Witte, [24]; Velichko and Shumakova, [23]; Kruzhilin, [12]; Kruzhilin *et al.*, [13]; Kruzhilin *et al.*, [11]; Kruzhilin *et al.*, [16]; Kruzhilin *et al.*, [15]; Rodin, [21]; Subbotin, [22]). They claim to the possibility of sowing rice watered periodically at 4...6 t/ha grains at savings in the irrigation water 3...5 times compared with the irrigation water flooding layer checks. However, the use of drip irrigation systems for this culture remains unexplored. This article presents the results of studies on irrigation of rice on drip irrigation systems.

MATERIALS AND METHODS

The aim of research was limited to the justification of the possibility of periodic cultivation of watered rice on drip irrigation systems, differentiated by interphase periods of the water regime of the soil and provide for its regulation of irrigation, doses of soil fertilizing, promoting the production of the planned yield.

Experimental studies were carried out in 2013-2015 at the experimental plot of the Federal state budgetary scientific institutions VNIIOZ location "Oroshaemoje" within the land of the Federal State Unitary Enterprise.

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Soils of the experimental plot are light brown and loamy. They are characterized by a small thickness of the humus layer, 0.00-0.28 m, with a humus content of 1.29-1.87%. The reaction of the soil solution is slightly alkaline, the pH of the aqueous extracts 7.2-7.7. According to the content of the soil nutrition elements soils are characterized by low nitrogen security, medium - mobile phosphorus and exchange potassium. The density of the natural structure of the soil, on average for the calculated layers of 0.0-0.4 and 0.0-0.6 m are respectively 1.27 and 1.29 t/m^3, the lowest moisture capacity - 24.9 and 23.8% by weight dry soil. Indicators porosity in layers varies in the range of 46.64 to 51.59%, the density of solids - 2.52-2.72 t/m^3.

The studies were conducted on crops aerobic rice variety "Volgogradsky" (Ganiev *et al.*, [6]). Seeding planter SN-16 was used, while soil was warming up to 140°C in 2013 and 2014 on April 28 and in 2015 - on 8 May. Drip line irrigation system of the company "Netafim" was used. Water flow through the drop counter 2.2 l/h, the distance between droppers 0.4 m, between the humidifiers - 0.6 m.

The amount of precipitation for the period April-September 2013-2015 made accordingly 306.9, 104.9 and 235.4 mm, mean daily air temperatures - 3605.7; 3637.3 and 3574.7^{0}C. From the combination of hydrothermal indicators of the growing season during studies are characterized as follows: 2013 - moist, 2014 - medium-dry and 2015 - media-unsaturated.

Driving two-factor experiment included 3 different soil water regimes (the first factor):

a) Maintain moisture in the active (0.6 m) soil layer is not lower than 80% of field moisture capacity (FMC) during the growing season;

b) The same as in variant 1 until the end of tillering in a layer of 0.4 m, and the phase of the full ripeness upduct - 0.6 m;

c) Water regime before the wax ripeness scheme by variant 2 with following decline in the beginning phase of wax ripeness pre-irrigation moisture up to 70% FMC.

The second factor consisted of 3 different doses of fertilizer application, designed for a 5, 6 and 7 tons per 1 ha of grain. The doses of fertilizer were annually adjusted in view of the content in the soil of mobile forms of macro-elements (ME).

The experiment was laid by the split plots with single-stage systematic arrangement of options on the water regime and with randomizing by doses of fertilizers. The experiment was repeated three times, the discount plots area of 630 m^{2}of water regime and mineral nutrition - 203 m^2. Field experiments were accompanied by observation, recording and measurements carried out in compliance with the requirements of experimental work techniques (Armor, [4]; Nikitenko, [17]; Pleshakov, [19]). Water-physical and agro-physical properties of soil were defined by method offered by Kaczynski [9] and Rode [20], the total water consumption was defined by A.N. Kostyakov's method, irrigation rates under drip irrigation were defined by A.N. Kostyakov's method which was modified by I.P. Kruzhilin *et al.* (Kostyakov, [10]; Kruzhilin *et al.*, [14]).

RESULTS

To maintain the water regime of the soil in the first variant of the experiment the total number of irrigation norm of 370 m^3/ha each in 2013-2015 amounted to 12, 15 and 13, respectively irrigation norm made 4440, 5550 and 4610 m^3/ha. Duration of irrigation interval ranged from 2 to 26 days.

In the second variant of the watering regime in 2013 the number of irrigation rate of 250 m^3/ha amounted to 4, in 2014 - to 5 and in 2015 - to 2, the next phase 370 normal m^3/ha data respectively to 10, 13 and 13 with irrigation interval from 2 to 19 days.

In the third variant, the total number of irrigation rate of 250 m^3/ha was 4 years, 5 and 2 respectively, and the rate of 370 m^3/ha, 8, 10 and 10. Additionally, the waxy grain phase in these years, 9 August 6 and 19 needed a watering rate of 550 m^3/ha. The irrigation rate in this data there was 4510, 5500 and 4750 m^3/ha.

DISCUSSIONS

Analysis of the results showed that the earliest ripening grain crust fell on the rice crops of the first variant of the water regime of the soil. The cycle of the vegetation in this version was completed in 108 days. The most lasting 113 days, the period of rice vegetation formed in a second variant of the water regime, and in the third variant of the experiment was 3 days more than in the first and 2 days shorter than the second one. The decrease compared with the second variant is explained by the length of the growing season of rice lowering afore-watering threshold of humidity at the final stage of the growing season from 80 to 70% FMC, and an increase compared to the first - earlier periods beginning irrigation.

The rice plants reaction to levels of mineral nutrition are characterized by the healing period of harvesting grain maturity, through 107 days after sowing, against fertilizer designed to yield 5 t/ha grains ($N_{109}P_{62}K_{75}$). In an application of fertilizers under the yield of 7 t/ha ($N_{157}P_{90}K_{108}$) length of the rice vegetation increased to 7 days and was 114 days. This happened due to the increase of duration-interphase periods of the first half of the growing season, to phase of panicle-buttonholing. Against the background of applying fertilizers to produce 7 t/ha of grain, this phase came 5 days later as compared to the variant of fertilizer application under the yield of 5 t/ha. Increasing the length of the growing season of rice contributed to the formation of the more powerful of the photosynthetic apparatus and, as a consequence, increased productivity.

The highest yield of rice, 6.95 t/ha of grain on the average for 2013-2015, was formed in the second

VOL. 12, NO. 24, DECEMBER 2017 ISSN 1819-6608
ARPN Journal of Engineering and Applied Sciences

embodiment of the water regime in the background making $N_{157}P_{90}K_{108}$ (Table-1).

It was the lowest, 4.88 t/ha grains, in the first variant of watering regime with the background of fertilizing calculated to 5.0 t/ha grains. In the third variant, the rice water regime yields an average of 3, compared with the second variant decreased to 80 kg/ha, but was higher than in the first variant of water regime at 230 kg/ha.

Table-1. Effect of water regime and fertilizers on rice yield, t/ha.

Pre-irrigation moisture of the soil, % of humidity	Dose of fertilizer application, kg active ingredient/ha	2013	2014	2015	Average
80, h = 0.6 м	$N_{109}P_{62}K_{75}$ (5 t/ha)	4.82	4.79	5.04	4.88
	$N_{131}P_{74}K_{90}$ (6 t/ha)	5.71	5.59	6.05	5.78
	$N_{157}P_{90}K_{108}$ (7 t/ha)	6.64	6.54	6.74	6.64
80, h = 0.4 and 0.6 м	$N_{109}P_{62}K_{75}$ (5 t/ha)	5.26	5.14	5.47	5.29
	$N_{131}P_{74}K_{90}$ (6 t/ha)	6.17	6.12	6.41	6.23
	$N_{157}P_{90}K_{108}$ (7 t/ha)	6.92	6.88	7.06	6.95
80 and 70, h = 0.4 and 0.6 м	$N_{109}P_{62}K_{75}$ (5 t/ha)	5.10	5.02	5.28	5.13
	$N_{131}P_{74}K_{90}$ (6 t/ha)	6.05	6.02	6.26	6.11
	$N_{157}P_{90}K_{108}$ (7 t/ha)	6.85	6.81	6.96	6.87
Least Essential Difference $(LED)_{05}$: 2013 – 0.2563; 2014 – 0.1424; 2015 – 0.1767					

It should be noted that the first and second level rice yields, 5 and 6 t/ha grains formed in all three variants of soil water regime in conjunction with the introduction of convenient rhenium, designed to receive them, 5 t/ha ($N_{109}P_{62}K_{75}$) and 6 t/ha ($N_{131}P_{74}K_{90}$). With regard to the yield of 7 t/ha of grain, it is also formed on all three versions of an aqueous re-benching of the soil on the background of making the dose calculated on the level of productivity, $N_{157}P_{90}K_{108}$. However, the minimum deviation from the planned rice yield obtained in the WTO-set and third variant of the water regime (Table-2).

Table-2. The combination of controllable factors to obtain the planned rice yields (the average for 2013-2015).

Yield, t/ha		Deviation from the planned, %	The combination of irrigation rate factors		Irrigation norm, m^3/ha	Total water consumption, m^3/ha	Irrigation water costs m^3/t
planned	actual		pre-irrigation moisture of the soil, % FMC	doses of mineral fertilizers, kg active ingredient /ha			
5.00	4.88	-2.4	80,h = 0.6 м	$N_{109}P_{62}K_{75}$	4933	6184	1011
	5.29	+5.8	80,h = 0.4 and 0.6 м		5357	6672	1013
	5.13	+2.6	80 и 70,h = 0.4 and 0.6 м		4920	6529	959
6.00	5.70	-3.0	80,h = 0.6 м	$N_{131}P_{74}K_{90}$	4933	6184	854
	6.23	+3.8	80, h = 0.4 and 0.6 м		5357	6672	860
	6.11	+1.83	80 and 70, h = 0.4 и 0.6 м		4920	6529	805
7.00	6.64	-5.1	80, h = 0.6 м	$N_{157}P_{90}K_{108}$	4933	6184	743
	6.95	-0.71	80,h = 0.4 и 0.6 м		5357	6672	771
	6.87	-1.86	80 and 70,h = 0.4 and 0.6 м		4920	6529	716

Therefore, to obtain the planned yields of rice it was provided by the introduction of the corresponding yield to these level doses of fertilizers on the background of each of the variants of soil water regime. At the same time exploring options for maintaining water regimes is related to the need for different numbers, the rules and terms of irrigation, and hence the cost of irrigation water (Table-3).

Hence the experimental results showed the possibility of obtaining under drip irrigation on crops aerobic rice of variety "Volgogradsky" 5, 6 and 7 t/ha of grain in all variants of soil water regime, combined with fertilizer doses, calculated for a planned productivity. Close to 5.0 t/ha yield was formed against the background of fertilizer application dose equal to the difference of the removal of mineral nutrients and the presence of planned productivity of the soil in forms available to plants. In our experiments on light-brown soils to produce 5.0 t/ha of grain of rice, it was $N_{109}P_{62}K_{75}$.

This yield was formed in all three variants of the experiment. However, in the second variant, where the soil moisture is maintained at least 80% of the FMC to the end in the phase of tillering layer of 0.4 m, followed by increasing it to 0.6 m, the cost of water irrigation rate and the formation of units formed the highest yield. Most low-cost there was in the third option with the water regime of the irrigation water, where to start phase wax-howling ripeness soil moisture is maintained in the second variant, and grain mellow phase is reduced to 70% FMC.

Provided was such water regime of the soil in different weather conditions during holding 13 or 16 of watering, including 2 to 5 were the norm of 250 m^3/ha, 8...10 irrigation norm of 370 m^3/ha and 1 watering rate of 550 m^3/ha. Irrigation rate average was 4920 m^3/ha, and irrigation water consumption per 1 ton of grain of 950 m^3 over 3 years. This is the first indicator to 437 m^3/ha less than the second option and approximately equal size to the first. According to a second indicator in the third variant, the cost of water irrigation water mode on 1 ton of grain 50 m^3 formed below the first and second, which saves irrigation water not less than 250 m^3/ha.

Table-3. Rice irrigation regime options due to the water regimes of the soil.

Possiblewatersoilregime	Years of investigations	Irrigation norm, m^3/ha	Number of irrigations / Irrigation norm, m^3/ha	Timingofirrigation	
				first	last
80% FMC, h = 0.6 м	2013	4440	$\frac{12}{370}$	14.05	11.08
	2014	5550	$\frac{15}{370}$	25.05	10.08
	2015	4810	$\frac{13}{370}$	17.06	24.08
80% FMC, h = 0.4 and 0.6 м	2013	4700	$\frac{4}{250}\&\frac{10}{370}$	09.05	12.08
	2014	6060	$\frac{5}{250}\&\frac{13}{370}$	20.05	15.08
	2015	5310	$\frac{2}{250}\&\frac{13}{370}$	16.06	29.08
80 and 70% FMC, h = 0.4 and 0.6 м	2013	4510	$\frac{4}{250}\&\frac{8}{370}\&\frac{1}{550}$	09.05	09.08
	2014	5500	$\frac{5}{250}\&\frac{10}{370}\&\frac{1}{550}$	20.05	06.08
	2015	4750	$\frac{2}{250}\&\frac{10}{370}\&\frac{1}{550}$	16.06	19.08

Yields 6 and 7 t/ha rice grains formed in the same variants of water regime, but at a higher background of fertilizer application, $N_{131}P_{74}K_{90}$ and $N_{157}P_{90}K_{108}$, respectively/ Improved mineral plant nutrition background due to fertilizer application method increased productivity and was accompanied by an increase in the efficiency of irrigation water use. Thus, if the yield is close to 5 t/ha of grain irrigation water consumption per 1 ton of about 1 thousand m^3, with an average yield of 6 t/ha, they were reduced to 805...860 m^3 and 7 t/ha - 716...771 m^3.

The efficiency of drip irrigation of rice is characterized by a decrease in costs of irrigation water compared with the traditional in the Russian Federation flooding checks the water layer 3...5 or more times, irrigation by 15...20%, the profitability of cultivation of this crop, depending on the level of yields ranged from 45...90%.

CONCLUSIONS

The results obtained in the course of studies have shown the possibility of cultivating rice-drip irrigation system with a significant reduction of irrigation rates and high profitability. The main conditions for the successful development of the recommended innovative rice irrigation technology is the presence of aerobic or tolerant varieties to unsaturated water the soil, placing crops on cleared of weed fields, use, if necessary, crop protection from weeds and the combination of optimal water regime of the soil with doses of fertilizer application, calculated to produce the planned productivity.

The most rational water regime has proven itself a variant where the humidity of the soil, is not maintained below 80% FMC from sowing until the end of tillering phase in a layer of 0.4 m with a subsequent increase it up to 0.6 m. In the beginning phase of wax ripeness in connection with decrease in the average daily water consumption of plants pre-irrigation soil moisture threshold should be reduced from 80 to 70% FMC.

To maintain the water regime of the soil under the scheme on drip irrigation systems differ in the amount and distribution of years of precipitation in the conditions of the Lower Volga region requires from 13 to 16 irrigations, including 2...5 irrigation norm of 250 m^3/ha, 8...10 - the norm 370 m^3/ha and 1 - norm of 550 m^3/ha. The combination of the water regime with a dose of fertilizer application $N_{109}P_{62}K_{75}$ provides rice yield at 5.0 t/ha in excess of an average of 2.6% over three years, on the background of $N_{131}P_{74}K_{90}$- 6.0 t/ha with the increase at 1.8% and a dose of $N_{157}P_{90}K_{108}$ - 7 t/ha with shortfalls prior to the planned level of 1.9%.

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