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RICE CULTIVATION IN AMUR REGION

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Abstract. Rice plays an important role in the modern diet of Russian people. It occupies a leading position in area, yield, and gross grain harvest among all cereal crops. The aim of the research is development of optimal irrigation regimes that ensure rational use of water resources in southern agricultural zone of Amur Region. Setting and conducting field and laboratory experiments, system approaches and modern research methods were used. The article presents the results of studies on rice cultivation under different irrigation regimes. In the southern zone of Amur Region, along with water regimes of 70, 80, 90% of FMC, differentiated rice irrigation regimes were studied, combining differentiation of presumed humidity thresholds and wetting depth of active soil layer 75...85% of FMC (0.4 and 0.6 m); 80% of FMC (0.4 and 0.6 m). In addition, various flooding regimes of rice field (short and intermittent flooding), seeding rates, timing of sowing, rice cultivars were studied. Obtaining a rice grain yield of more than 4 tons per hectare is ensured by application of mineral fertilizers in the dose of $N_{120}P_{30}K_{30}$ and seeding rate of 5 million seeds. Optimum seeding time was set from 20 to 25 May. Based on the results of the research, irrigation water was saved, as well as yield increased by optimizing irrigation rice regimes using sprinkling by differentiating presumed moisture thresholds and wetting depth. When rice was cultivated under flooding system of irrigation, it was established that regime of shortened flooding turned to be optimal. When sprinkling in conditions of southern agricultural zone of Amur Region, differential irrigation regime of 75...85% of FMC in active soil layer was 0.4 and 0.6 m.

Keywords: rice, water regimes, sprinkling, flooding, fertilizer doses, seeding rates, varieties

INTRODUCTION

Rice is one of the most important crops in diet of Russian people. It occupies a leading position in area, yield, and gross grain harvest among all cereal crops. The demand for rice is increasing every year. Growth and stabilization of grain production in Amur region can help in solving problem of providing the population with own grain by increasing crop diversity. Amount of heat and light in the southern zone of Amur Region is sufficient to cultivate rice. Rice cultivation can contribute to increasing grain production in the area. According to the Ministry of Agriculture of the Russian Federation, area suitable for cultivating rice in the Far East is at least 240 thousand hectares. Thus, not only the population of this region, but also all of Eastern Siberia, can be provided with rice grains [1—3]. Currently in the Far Eastern Federal District rice is cultivated only in Primorsky region, but production is not enough to meet the growing food needs of the Far East [4]. Therefore, the relevance of our research is determined by the need to develop effective water regimes for rice cultivation in compliance with principles of water conservation and environmental safety requirements of production.

The aim of the research is the development of optimal irrigation regimes that ensure rational use of water resources in the southern agricultural zone of Amur Region.

MATERIALS AND METHODS

Field research has been conducted since 2005 on experimental field of Far East State Agrarian University, p. Gribskoye of Blagoveshchensk district of Amur region, located in the zone of Gribskoye irrigation system. Observations and records have been documented, while observing the requirements of techniques of the experimental case [5—7]. We studied water regime of soils: pre-irrigation soil moisture content of 70, 80, 90%, 75—85% of field moisture capacity (FMC) (0.4 and 0.6 m); 80% of FMC (0.4 and 0.6 m); 80% of FMC (0.6 m) (control) — sprinkling, shortened flooding: creating a water layer of 0.10...0.12 m after sowing, after 0.10...0.12 m seedlings till tillering phase, decreasing water layer to 0.05m before tubing phase, increasing water layer to 0.15 m until the end of milk ripeness (control); intermittent flooding: after sowing 0.10 m (10 days), then water removing, after emergence 0.07 m (2...3 days), water removing, then 0.10...0.12 m and maintained till tillering phase, water layer decreasing up to 0.05 m (10 days), increasing water layer to 0.15 m and maintaining until the end of grain ripeness; intermittent flooding: creating a layer of water 0.12 m after sowing, no water in rice field during 7 days, on the 8th day the whole cycle repeats. Then 0.10...0.12 m to tillering phase, followed by a water decreasing to 0.05 m (10 days), further increasing water layer to 0.15 m and maintaining till the end of grain milky ripeness. Fertilizer doses were control without fertilizers; $N_{60}P_{30}$; $N_{90}P_{30}K_{15}$; $N_{120}P_{30}K_{30}$. Seeding rates were 4 million (control); 5 and 6 million of seeds. Rice cultivars: dry-bottomed (early cultivar ‘Volgogradskiy’ of Research Institute of Irrigated Agriculture, high-yielding, resistant to sharply continental climate), and rice cultivars regionalized in Primorsky Krai, which are related to early ripening groups: round-grained — ‘Dariy 23’, ‘Priozerny 61’; long-grained — ‘Khankaisky 429’, ‘Khankaisky 52’, ‘Lugovoy’, ‘Rassvet’ and ‘Kaskad’ with high technological and culinary quality. Sowing terms: 10.05—15.05; 20.05—25.05; 30.05—04.06.

The soil cover of the site is represented by meadow-brown soils. The density of soil in calculated layers (0.6 m) is 1.33 t/m^3, the lowest moisture capacity of the soil is 22.50%, porosity is 49.18%. Humus content is low 2.13%, easily hydrolyzable nitrogen is 2.7 mg/100 g, mobile phosphorus content is 37.8 mg/kg, exchange potassium content is 122.5 mg/kg.

The years of research differed significantly in the magnitude and distribution of atmospheric precipitation, which made it possible to assess effectiveness of the irrigation regimes studied.

Rice cultivation in field experiments was carried out on the basis of existing zonal recommendations supplemented by variants of studied methods. To control weed vegetation a broad spectrum post-emergence herbicide Segment was used.

Phenological observations of rice growth stages, plant density, determination of crop structure by the method of Gossortoseti (1995), photosynthetic indicators of crops according to the method of A.A. Nichiporovich (1979, 1985) were carried out in the field experiments. Humus content was determined by the method of I.V. Tyurin and B.A. Nikitin in the modification of CINAO in accordance with GOST 26213-84, aqueous and salt pH — according to potentiometric method in accordance with GOST 26483-90, total nitrogen — according to Kornfeld, easily hydrolyzed nitrogen — by the method of M.M. Konova and I.V. Tyurin, mobile phosphorus and potassium — according to B.P. Machigin — GOST 26205-91. In determining water-physical properties of the soil granulometric composition was studied according to the method of N.A. Kachinsky, density of solid phase — pyknometric method, soil density — method of cutting ring, and field moisture capacity (FMC) — by flooded areas.

Analyzes for determination of water-physical and agrochemical properties of soils were carried out in agrochemical laboratory of Department of Ecology and Soil Science of Far East State Agrarian University and in laboratory of Soybean Research Institute.

Weed infestation of seedlings and before harvesting was carried out by applying a marking — 0.25 m^2 in 10 replicates. Water balance calculations for rice checks were carried out according to the method of Rice Research Institute (1979). Total water consumption — by A.N. Kostyakov (1975).

RESULTS AND DISCUSSION

We found that irrigation frequency varied during experimental years, depending on irrigation regime and cultivar [6, 7].

To maintain soil moisture at the level of 70% of FMC depending on meteorological conditions in 2005—2007 it was required to conduct 5...8 waterings with a rate of 670 m^3/ha. Increase in pre-irrigation humidity threshold to 80% of FMC was accompanied by increase in number of waterings to 8...12 with irrigation rate of 450 m^3/ha. Maintenance of 90% of FMC in calculated soil layer was achieved by 11...15 waterings with a rate of 220 m^3/ha. In 2008, all irrigation water for entire growth season was used during 8 waterings, in 2009 — during 6 waterings and in 2010 — during 10 waterings (Table 1).

Total water consumption of irrigated rice under different weather conditions varied from 6,179...9,199 m^3/ha. The greatest average for research years was noted in the variant with maintaining soil moisture of at least 90% of FMC and amounted to 8630 m^3/ha.

As field studies showed, the most favorable for rice cultivation in terms of water availability was 2013, when precipitation during the growing season was 166 mm higher. In the variant of differentiated moistening in 2013, it was necessary to conduct 2 vegetative waterings with irrigation rate 560 m^3/ha for cultivar 'Khankaisky 429' and 530 m^3/ha for cultivar 'Rassvet'. In 2011, in the same variant, it was necessary to conduct 8 watering operations with the rate of 2,060 m^3/ha for cultivar 'Khankaiskiy 429', 6 waterings with the rate of 1560 m^3/ha for cultivar 'Rassvet'; in 2012, irrigation rate was 1,810 m^3/ha and 1,560 m^3/ha for 'Khankaiskiy' and 'Rassvet', respectively (Table 2).

Table 1

The structure of rice total water consumption, 2005—2010

Pre-irrigation moisture, % of FMC	Research years	Total water consumption (E), m^3/ha	Irrigation Rate		Precipitation moisture		Soil moisture reserves	
			m^3/ha	% of E	m^3/ha	% from E	m^3/ha	% from E
70	2005	7 585	5 460	72.0	2 050	27.0	75	1.0
	2006	8 680	3 450	39.7	5 110	58.9	120	1.4
	2007	8 635	5 460	63.2	3 070	35.6	105	1.2
	average	8 300	4 790	58.3	3 410	40.5	100	1.2
80	2005	7 640	5 510	72.1	2 050	26.8	80	1.1
	2006	8 945	3 710	41.5	5 110	57.1	125	1.4
	2007	8 900	5 720	64.3	3 070	34.5	110	1.2
	2008	6 885	4 270	62.0	2 415	35.1	200	2.9
	2009	6 179	2 700	43.7	3 325	53.8	154	2.5
	2010	8 587	4 450	51.8	4 962	57.7	125	1.4
	average	7 856	4 393	55.9	3 488	44.1	132	1.8
90	2005	7 931	5 810	73.3	2 050	25.8	71	0.9
	2006	9 199	3 970	43.2	5 110	55.5	119	1.3
	2007	8 760	5 590	63.8	3 070	35.0	100	1.2
	average	8 630	5 123	60.1	3 410	38.8	96.7	1.1

Table 2

The structure of total water consumption of rice varieties under different sprinkler irrigation regimes

Pre-irrigation moisture, % of FMC	Research years	Total water consumption (E), m^3/ha	Irrigation Rate		Precipitation moisture		Soil moisture reserves	
			m^3/ha	% of E	m^3/ha	% of E	m^3/ha	% of E
Variant 1: 75% ... 85% of FMC, 0.4 and 0.6 m	‘Khankayskiy 429’							
	2011	3 750	2 060	54.9	2 410	64.3	–720	–19.2
	2012	4 830	1 810	37.5	3 520	72.9	–500	–10.4
	2013	5 598	560	10.0	5 460	97.5	–422	–7.5
	average	4 726	1 476	31.3	3 797	80.3	–547	–11.6
	‘Rassvet’							
	2011	3 010	1 560	51.8	2 170	72.1	–720	–23.9
	2012	4 180	1 560	37.3	3 120	74.6	–500	–11.9
	2013	5 198	530	10.2	5 090	97.9	–422	–8.1
	average	4 129	1 216	29.4	3 460	83.8	–547	–13.2
Variant 2: 80% of FMC, 0.4 and 0.6 m	‘Khankayskiy 429’							
	2011	3 780	2 160	57.1	2 410	63.8	–790	–20.9
	2012	5 040	2 160	42.8	3 520	69.8	–640	–12.6
	2013	5 646	690	12.2	5 460	96.7	–504	–8.9
	average	4 822	1 670	34.6	3 797	78.7	–645	–13.3
	‘Rassvet’							
	2011	3 200	1 820	56.9	2 170	67.8	–790	–24.7
	2012	4 300	1 820	42.3	3 120	72.5	–640	–14.8
	2013	5 306	800	15.1	5 010	94.4	–504	–9.5
	average	4 269	1 480	34.7	3 434	80.4	–645	–15.1
Variant 3: 80% of FMC, 0.6 m (control)	‘Khankayskiy 429’							
	2011	4 420	2 380	53.8	2 410	54.5	–370	–8.3
	2012	5 780	2 380	41.1	3 630	62.8	–230	–3.9
	2013	6 190	680	11.0	5 460	88.2	50	0.8
	average	5 463	1 813	33.2	3 833	70.1	–183	–3.3
	‘Rassvet’							
	2011	4 010	2 040	50.9	2 340	58.3	–370	–9.2
	2012	4 930	2 040	41.4	3 120	63.2	–230	–4.6
	2013	5 820	680	11.7	5 090	87.5	50	0.8
	average	4 920	1 587	32.3	3 516	71.4	–183	–3.7

In structure of the total water consumption of rice varieties under different irrigation regimes, share of atmospheric moisture over whole growing season in 2011 was 54.5...72.1%, in 2012 — 62.8...74.6%, in 2013 — 87.5...97.9%. The results of field studies showed that soil moisture is used only in the initial period of rice development, and it accounts for about 1% of total water consumption. The share of irrigation water in the structure of rice total water consumption varied 10.0—15.1% (in 2013) to 50.9...57.1%.

The results of the research showed that the optimal parameters of rice irrigation regime during sprinkling are formed under differentiated moistening: maintaining the pre-irrigation humidity at level more than 75% of FMC in 0.4 m layer during the sowing — tillering period, in 0.6 m layer — at level more than 85% of FMC during tillering — wax ripeness of grain, which contributes to reduction of irrigation water costs for obtaining projected grain yield.

The water balance of rice card-check is represented by income and expense items. In the incoming part there is an irrigation norm, which is supplied to maintain necessary water layer in checks, and precipitation. The expenditure part includes balance items used to maintain water layer in checks, water consumption, filtration, leakage, flow, and technological water removing.

In structure of water balance of irrigation card-check, the largest water consumption was 4,224 m^3/ha of expenditure part in the first variant of shortened flooding in cultivar ‘Khankayskiy 429’.

The lowest water consumption was noted in the second variant of intermittent flooding in ‘Rassvet’ cultivar and amounted to 2,859 m^3/ha of expenditure part.

The main indicators of water balance of card-check in experiment variants did not change significantly. The filtration was 1,726...2,480 m^3/ha of expenditure part. The flow rate for water was 417...631 m^3/ha in the first variant with shortened flooding. The volume of technological water removing varied from 3,200 to 4,367 m^3/ha on average over the research years (Table 3).

The highest irrigation rates 12,534 m^3/ha and 11,249 m^3/ha were established in the third variant with intermittent flooding for ‘Khankayskiy 429’ and ‘Rassvet’, respectively. The lowest irrigation rates were established at shortened flooding regime (9,811 m^3/ha and 8,758 m^3/ha for ‘Khankayskiy’ and ‘Rassvet’ cultivars, respectively), which is connected primarily with check flooding scheme and water layer.

The study of influence of seed rates on rice yield showed that the maximum yield was obtained at a rate of 5 million seeds. Increase in seed rate resulted in high plant density which consequently led to yield decrease.

Cultivating ‘Volgogradskiy’ rice cultivar under sprinkling irrigation with 80% of FMC, applying mineral fertilizers $N_{120}P_{30}K_{30}$ and at seeding rate of 5 million seeds, yield was 4.6 t/ha.

Depending on soil and climatic factors and factors studied, Primorsky rice cultivars formed the following grain yields: ‘Dariy 23’ (3.52 t/ha), ‘Priozerny 61’ (3.85 t/ha), ‘Rassvet’ (sprinkling — 4.19 t/ha, shortened flooding — 5,4 t/ha), ‘Lugovoy’ (4,2 t/ha), ‘Kaskad’ (sprinkling — 4.8 t/ha, flooding — 5.5 t/ha), ‘Khankayskiy 429’ (sprinkling — 4.38 t/ha, intermittent flooding of the IV type — 5.6 t/ha) [8—10]. The optimum time for rice sowing — 20 to 25 May — was established in the southern zone of Amur Region.

Table 3

Water balance of card-check under different regimes of rice flooding, average for 2011—2013

Indicators	Cultivar					
	'Khankayskiy 429'			'Rassvet'		
	irrigation regime					
	Variant 1: shortened flooding (sowing 0.12 m once, 0.12 cm shoots to tillering, 0.05 m 12 days, 0.15 m t o the end of milky ripeness)	Variant 2: intermittent flooding (after sowing 0.10 m — 10 days, after emergence of 0.07 m 2—3 days, 0.12 m at the appearance of 2—3 leaves till tillering, 0.05 m 10 days, 0.15 m to the end of milky ripeness)	Variant 3: intermittent flooding (after sowing 0.12 m once, after 7 days 0.12 m, after 7 days 0.10 m till tillering, 0.05 m 10 days, 0.15 m till the end of milky ripeness)	Variant 1: shortened flooding (sowing 0.12 m once, 0.12 cm shoots to tillering, 0.05 m 12 days, 0.15 m to the end of milky ripeness)	Variant 2: intermittent flooding (after sowing 0.10 m — 10 days, after emergence of 0.07 m 2—3 days, 0.12 m at the appearance of 2—3 leaves till tillering, 0.05 m 10 days, 0.15 m to the end of milky ripeness)	Variant 3: intermittent flooding (after sowing 0.12 m once, after 7 days 0.12 m, after 7 days 0.10 m till tillering, 0.05 m 10 days, 0.15 m till the end of milky ripeness)
Water input, m^3/ha						
Irrigation Rate	9 811	11 786	12 534	8 758	9 543	11 249
Precipitation	4 250	4 243	4 237	3 697	3 720	3 907
Total	14 061	16 029	16 788	12 455	13 263	15 156
Expenditure water, m^3/ha						
Maintaining water level	2 200	4 600	4 300	2 200	3 900	4 333
Change in moisture reserves in aeration zone	–254	–146	–136	–254	–146	–136
Filtration	2 470	2 201	2 480	2 015	1 726	1 846
Water consumption	4 224	3 705	3 870	3 470	2 859	3 201
Leakage loss	651	614	693	567	459	574
Flowing	591	543	631	515	417	523
Technological water removing	3 333	3 967	4 367	3 200	3 400	4 367
Total	13 723	15 776	16 477	12 221	12 907	14 980
Discrepancy, m^3/ha	338	254	311	234	356	176
Discrepancy, %	2.4	1.6	1.8	1.8	2.7	1.2

CONCLUSIONS

The possibility of rice cultivation is proved on the basis of effective use of irrigation water by optimizing water regime of soil. When sprinkling under conditions of the southern zone of Amur Region, optimal regimes were: differential irrigation regime with 75...85% of FMC in 0.4 and 0.6 m active soil layer, intermittent flooding of the

IV type of cultivar ‘Khankayskiy 429’ and shortened flooding of ‘Rassvet’ cultivar. Grain rice yield of more than 4 tons/ha is achieved by application of mineral fertilizers in the rate $N_{120}P_{30}K_{30}$ and seeding rate of 5 million seeds. The optimal sowing time was also identified — May 20—25.

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ОСОБЕННОСТИ ВОЗДЕЛЫВАНИЯ РИСА В УСЛОВИЯХ АМУРСКОЙ ОБЛАСТИ

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В статье представлены результаты исследований возделывания риса при разных режимах орошения (70, 80, 90% НВ). В условиях южной зоны Амурской области также были изучены режимы орошения риса, сочетающие в себе дифференцирование предполивных порогов влажности и глубины промачивания активного слоя почвы 75—85% НВ (0,4 и 0,6 м); 80% НВ (0,4 и 0,6 м). Кроме того, были изучены разные режимы затопления рисового поля слоем воды (укороченное и прерывистое затопление), нормы высева семян, сроки сева, сорта риса. Получение урожайности зерна риса более 4 т/га обеспечивается внесением минеральных удобрений в дозе $N_{120}P_{30}K_{30}$ и нормой высева 5 млн всхожих семян. Оптимальные сроки сева были установлены с 20 по 25 мая. По результатам исследований, за счет проведения оптимизации режимов орошения риса в условиях дождевания, посредством дифференцирования предполивных порогов влажности и глубин промачивания наблюдалась экономия оросительной воды и увеличение урожайности. При возделывании риса в условиях затопления было установлено, что оптимальными считаются режим укороченного затопления.

Ключевые слова: рис, водные режимы, дождевание, затопление, дозы удобрений, нормы высева, сорта

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