Research of the rice productivity on saline lands of rice systems in Kazakhstan Republic

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Abstract. Rice irrigation systems in the lower reaches of the Syrdarya River are located on the river terraces and trees near the stream canal. Lands of river terraces are differed by drainage and water conductivity, soils – by content of humus and nutritive elements, mechanical composition and salinity that gave rise to the diversity of crops in 2-3 times. Efficient use of water and land resources on saline lands of rice systems is directly dependent on economy of the rice irrigation regime and the problem of improving rice productivity on saline paddy systems of Kazakhstan is a current task and it requires careful study. During the pilot phase determined were water-physical properties of soils, salt content and nutrients. Water balance of different parts in the research site was established. There are four studied modes of rice irrigation: shortened and constant flooding, with change of water between plant rice seedlings and without changing water in the rice fields and the data were compared data of manufacturing rice crops.

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Introduction

Rice systems, initially focused on "hard" environmental management and water resources management, and initially achieved a significant growth in agricultural production. Then the increase in production has stabilized at some level, after that there was a drop in biological productivity of soils and economic productivity of rice systems. In recent years, more than 20% engineering rice systems have left agriculture due to salinization and water [1].

Experience of the rice farming shows conclusively that on saline lands with appropriate cultivation technology and the drainage effect it is possible to have higher and more stable yields of rice. Rice ability to grow on saline lands is confirmed by the practice of rice cultivation both at home and abroad. High yields are produced in Guiana, where rice is grown in heavy alluvial clay soils containing large amounts of sodium and magnesium. Rice cultivation in adaptive-unfavorable lands is widely developed in India, Japan, Pakistan, China, France, Italy, Hungary and other countries [2-5].

Rice is cultivated in India on soils which contain more than 0.2% sodium bicarbonate, sodium chloride, sodium sulfate and 0.4-0.8%. There are Indian varieties, which are the most hard to salinization: Sadamonda #55-308, Hohla, #55-940 and Bahrah #54-15-5. They can be grown on soils with a total salt content of 0.5 to 4.5%. In France the cultivated rice culture made possible to master saline land in the Delta of the river Kamergi. Egyptian cotton is cultivated after periodic leaching of saline soils with rice culture [6-8].

In Pakistan, rice was grown in saline soils 3 years in a row. For 15 years, more than 100 thousand hectares have been introduced in agriculture. But the high standing of groundwater and absence of drainage resulted that approximately on the same square site the irrigation land situation was degraded [9]. At the same time, a result of leaching with the following rice cultivation under the deep horizontal drainage, heavily saline soils of Nile Delta were successfully mastered and transformed into blooming oases.

At the farm of the Indian agricultural Institute in New Delhi for four years there were conducted experiments on soil desalinization through continual coating the soil surface by plants (crop rotation: rice-wheat or barley-pea). Rice harvest in the alternation of crops made 1.57-1.78 t/ha. Permanent coating plants soil surface promoted reduction of accumulated salts in the soil in areas with high ground water level standing. In the State of Andhra Pradesh (India) before sowing rice on saline lands, we recommend that you wash the upper most layer of salted soil [10].

In Japan, before sowing rice there is preliminary inundation of soils. Sowing rice starts, if 0-10 cm layer of soil is enough desalted [11]. In Romania, for desalinization of the deeper soil horizons in the floodplain of Dunai River it is recommended to cultivate rice continuously for 5 years. In Hungary, the problem was solved by introducing the so-called land desalinization by the grass and pond circulation of land where fields are used as ponds for 3 years, 2 years under crops of Lucerne and 3 years under crops of rice. As there result, there is the achieved improvement of saline soils. From such sites on each hectare the rice yields make 3.5-4.0 t, Lucerne hay – 200 tons, pond fish – 0.7 t [12-14].

It should be noted that rice irrigation systems in the lower reaches of the Syrdarya River, Ile, Karatal are near the stream canal and river terraces. Lands of river terraces have different drainage and water conductivity; soils are differed by content of humus, nutrient elements, mechanical composition and salinity. All this has created diversity in crop yields in 2-3 times within the same irrigation system.

When there is land reclamation of flood-deltaic river basin landscapes disturbed is the balance of natural processes, historical soil balance, there is a change of many properties (volume weight, filtration characteristics), which, in most cases, has a degenerate character. If to consider that with rice irrigation there is the rising of ground waters with high mineral content 8-10 g/l, and the effectiveness of drainage is very low, inside the rice system, especially in low areas, there is the secondary soil salinization [15-17].

Materials and methods

Studies were made on rice systems of LLP "Kaptagaj&Co" in Chielinsky district of Kyzylorda region. LLP "Kaptagaj&Co" is located on the right bank of the Syrdarya River. The relief is flat, an average slope of irrigation – 0.0001-0.0002. The climate is sharply continental, the sum of temperatures during the growing season of May–September – 22.32^{0}C and atmospheric precipitation – 220 mm per year.

Soils of the test plot by the mechanical structure are middle and heavy loam, with volume weight – 1.44-1.53 g/cm^3, specific gravity of 2.7-2.8 g/cm^3, soil porosity – 47-58%, filtration coefficient – 0.014-0.02 m/day. The amount of water required to saturate the soil layer with water makes 0-2 m: on check with the rice predecessor – 6029.92 m^3/ha, with predecessor alfalfa third year – 5579.59 m^3/ha. Lands of the pilot plot are strongly saline, with the sulfate-chloride dense remnant of – 1.4-2.3 % (Figures 1, 2).

To Study an optimal regime for the rice irrigation in rice systems with salted oils in the experimental plot since 10 to 14 May there were 5 installed water drainages Chipoletti, to account water in the rice fields, 3 hydraulic metric gauges, 1 quarter irrigator and 2 quarter discharges, to account for the water flow through the channels (Figure 3).

There are two wells–gages to monitor the level of ground waters, a vessel with an evaporator of 3000 cm^2 and two vessels-physical models of the rice check, for observation during the growing period of evaporation, filtering and external evaporation (Figure 4).

In the experimental plot there are four rice irrigation regimes: shorten and constant flooding, with change of water between the plant rice seedlings and without changing water in the rice fields.

When the shortened flooding during rice germination up to 2-3 leaves there is periodic flooding, (soil moisture before fully saturated water), then on the rice field there is a formed permanent layer of water from 5 to 15 cm.

With constant flooding of the rice field there is a permanent layer of water from rice crops to the milky – wax ripeness of grain, the water layer varies from 5 to 15 cm, depending on phase of the plant growing.

Observations and measurements of water consumption on the pilot site on all devices and water accounting are conducted daily, according to SGI.

During the growing season there are phenol observations of the plants growing and development, account of the mould density.

During the field work on the experimental and pilot land the following questions are disclosed:

1 – determination of characteristics for formation of structural elements in the rice yield in saline lands;

2 – identification of regularities in salt and food regimes of saline soils under the rice culture;

3 – determination of the maximum allowable concentration of salts in the water of the rice checks and periods of water changing;

4 – there is the study of rice irrigation on saline lands, irrigation and irrigation norms;

5 – there is development of biologically based farming techniques that increase rice productivity on saline lands.

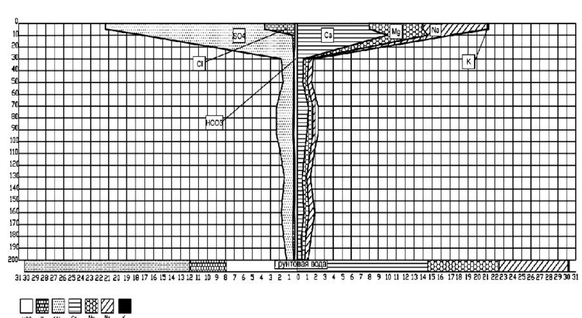

Fig. 1. Dynamics of soil salt regime under section 1

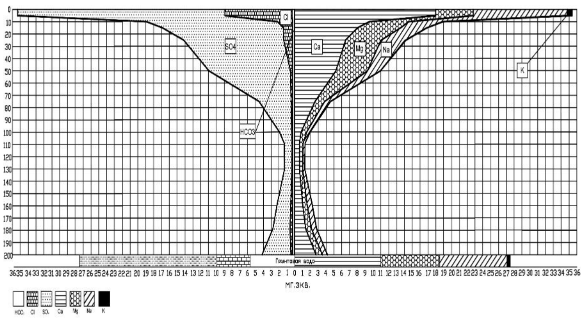

Fig. 1. Dynamics of soil salt regime under section 2

Fig. 3. Flooding of rice water flow check, check across the threshold of the spillway

Fig. 4. Vegetation vessels on the rice check

Research results

Comparative analysis of water supply for the industrial crops of the rice farm "Kaptagaj&Co" and the studied irrigation modes shows that water consumption per hectare of the rice seed during the growing season for industrial crops makes 29860 m^3/ha for the rice irrigation regimes with continuous water flooding without changing the water in the rice check – 25080 m^3/ha, with the change of water – 26060 m^3/ha; with the shorten flooding without the change of water - 25840 m^3/ha, with the change of water – 26870 m^3/ha (Table 3). Table 1 shows the possible reduction of water resources in the rice cultivation on saline lands of 20% or more, without the loss of yield.

Large volumes of water crops for rice in production conditions are caused by unjustified dumping water of water from rice checks that overflow drainage-waste pipes, reducing their melioration effect, which results in increase of ground waters and secondary salinization of land rice systems.

Water mineralization of in irrigation and drainage-waste waters varies depending on mode of the rice irrigation technology and irrigation (flooding). During the rice checks flooding, water mineralization in quarter irrigators makes – 1.037 g/l in drainage reservoirs – 3.260 g/l and in collectors – 3.001 g/l (Table 1).

For variants of permanent and short flooded with interchangeable water during the rice growing an average water salinity in rice checks during germination makes 1.501-1.679 g/l, and without changing the water – 2.368-2.071 g/l (Table 2), in remaining phases of vegetation, mineralization does not deteriorate the rice plants and external environment in formation of vegetative and generative organs. In rice checks, persistence and shorter irrigation regimes, without changing the water in the rice fields, water salinity during germination of rice plants on some days is increased up to 2.801-2.911 g/l (Table 2), in other phases of vegetation up to 3.743-3.822 g/l. Where there is flooding with the change of water, due to water supply, water mineralization in checks is reduced and at end of the irrigation period an average water salinity is constant with the continuous flooding – 2.071/l, reduced flooding – 3.208 g/l, and maximum values make 2.814 g/l and 3.001 g/l accordingly (Table 2).

Change of water in rice fields during the period of plants seedling reduces the concentration of salt in the rice paddy fields for 1.2-1.7 g/l, which has a positive effect on density of the plants standing. With constant flooding with change of water between the plant density, rice seedling after germination makes 103-127 plants/m^2 (Table 2), average-108 plants per m^2, before the rice harvesting – 101-114 plants/m^2, average – 104 plants per m^2. The change between variants, before the rice harvesting, makes 12%. In the rice irrigation regime as shortened flooding with the change of water between during the plants germination the plant density makes 125-147 plants per m^2, before the rice harvesting – 118-132 plants/m^2; without the water changing – 117-136 plants per m^2 and 104-123 plants/m^2. The average density of standing rice crops before harvesting makes accordingly 120 and 108 plants/m^2; the difference between all variants on average is 12 plants/m^2 (Table 2).

Table 1. Salinity of water in irrigation, drainage and discharge canals of rice checks and ground water of the pilot plot LLP «Kaptagaj»

##	Water sample	Selection date	Water analysis g/l / m.eq. on absolutely dry soil			
			Sum of salts, %	PH	Alkalinity	
					Total HCO_3^-	From normal carbonates with CO_3^-
1	2	3	4	5	6	7
1	Irrigator	09.05.08	1.037	8.0	0.195 / 3.20	no
		27.06.08	1.148	8.57	0.161 / 2.64	no
2	check №1 44 card	27.06.08	1.180	8.25	0.161 / 2.64	no
3	check №1 42 card	27.06.08	1.283	7.89	0.063 / 1.03	no
4	check №1 39 card	27.06.08	1.026	8.40	0.102 / 1.67	no
5	check № 1 38 card	27.06.08	1.042	8.09	0.166 / 2.72	no
6	Piezometer No. 2 (Lucerne)	09.05.08	1.864	8.12	0.346 / 5.67	0.005 / 0.17
		27.06.08	1.369	8.36	0.102 / 1.67	no
7	Drainage collector 1	09.05.08	3.260	8.15	0.224 / 3.67	no
		27.06.08	2.922	8.43	0.234 / 3.84	no
8	Drainage collector 2	27.06.08	3.123	8.50	0.366 / 6.00	no
9	Collector	09.05.08	3.001	7.9	0.356 / 5.83	0.005 / 0.17
		27.06.08	3.203	8.30	0.303 / 4.97	0.002 / 0.07

Table 1 (continued)

##	Water analysis g/l m.eq. on absolutely dry soil					
	Cl^-	SO_4^{-2}	Ca^{+2}	Mg^{+2}	Na^+	K^+
1	8	9	10	11	12	13
1	0.089 / 2.51	0.474 / 9.88	0.110 / 5.50	0.073 / 6.00	0.091 / 3.96	0.005 / 0.13
	0.100 / 2.82	0.566 / 11.79	0.12 / 6.00	0.067 / 5.51	0.129 / 5.61	0.005 / 0.13
2	0.095 / 2.68	0.603 / 12.56	0.110 / 5.50	0.085 / 6.99	0.121 / 5.26	0.005 / 0.13
3	0.113 / 3.19	0.744 / 15.49	0.120 / 6.00	0.085 / 6.99	0.150 / 6.52	0.008 / 0.20
4	0.092 / 2.59	0.542 / 11.30	0.100 / 5.00	0.061 / 5.02	0.125 / 5.44	0.004 / 0.10
5	0.089 / 2.51	0.500 / 10.42	0.100 / 5.00	0.067 / 5.51	0.116 / 5.04	0.004 / 0.10
6	0.151 / 4.26	0.842 / 17.55	0.220 / 11.00	0.091 / 7.48	0.197 / 8.57	0.017 / 0.43
	0.116 / 3.27	0.755 / 15.73	0.120 / 6.00	0.073 / 6.00	0.194 / 8.44	0.009 / 0.23
7	0.240 / 6.77	1.862 / 38.79	0.400 / 20.00	0.182 / 14.97	0.294 / 12.78	0.058 / 1.48
	0.265 / 7.47	1.587 / 33.07	0.240 / 12.00	0.207 / 17.02	0.419 / 18.22	0.007 / 0.18
8	0.286 / 8.07	1,599 / 33,32	0.240 / 12.00	0.161 / 2.64	0.419 / 18.22	0.006 / 0.15
9	0.259 / 7.30	1.555 / 32.40	0.320 / 16.0	0.194 / 15.95	0.306 / 13.30	0.011 / 0.28
	0.338 / 9.53	1.625 / 33.86	0.320 / 16.00	0.146 / 12.01	0.464 / 20.17	0.007 / 0.18

Change of water in the rice fields during the period of germination reduced concentration of salts in water of rice checks and increases the density of standing rice plants for 12%, and between variants of continuous and shorten flooding with change of water for 16 plants per m^2.

Table 2. Water mineralization in rice checks and density standing during germination and before harvesting on saline lands of the pilot plot

Rice irrigation mode	Content of salts in 0-100 cm of the soil layer before rice cultivation, %/ m/ha	Water mineralization in rice checks, g/l (limits/ average)		Number of rice plants (limits/ average)	
		During the rice growing	At end of irrigation period	During the rice growing, pcs/m^2	Before rice harvesting, Pcs/m^2
1	2	3	4	5	6
Permanent flooding, without changing the water	1.033 / 132.2	1.172–2.801 / 2.071	2.602–3.743 / 3.208	89–113 / 103	87–96 / 92
Permanent flooding, with the change of water	1.067 / 136.5	1.180–2.538 / 1.501	1.805–2.814 / 2.071	103–127 / 108	101–114 / 104
Shorten flooding, without changing the water	1.013 / 129.6	1.160–2.911 / 2.368	2.170–3.832 / 3.578	117–136 / 127	104–123 / 108
Shorten flooding, with changing the water	1.041 / 133.2	1.159–2.574 / 1.679	2.230–3.403 / 3/001	125–147 / 135	118–132 / 120
Control, production crops	0.982 / 125.7	1.162–2.405 / 2.097	2.360–3.380 / 2.922	115–133 / 125	72–104 / 98

Conclusion

On saline lands of LLP "Kaptagaj &Co" change of water in rice checks during germination of rice plants reduces water mineralization in checks, and doses of fertilizers, agricultural technique of rice cultivation used in LLP "Kaptagaj&Co" provides the rice yield no lower than on slightly saline lands. The rice yield in varieties of permanent flooding with change of water during the rice germination makes 59.3 kg/ha (Table 3), without changing the water is 48.7 t/ha. In variants of the shorten flooding the rice yield with the change of water is 50.2 kg/ha, without the change of water – 46.2 kg/ha. The lowest cost of water per the rice hundred weights 439 m^3/c is received in the variant of continuous flooding with the change of water during rice germination. In variants of continuous and shorten flooding with the change of water in rice checks water costs per one hundredweight makes 515 and 559 m3/c. Water costs per the rice hundredweight proves a possible reduction of water resources during the rice cultivation on saline lands on 15-20%, with loss of yield and efficiency of the rice cultivation.

The change of water in rice checks during germination improves the rice yield in18% with constant flooding and in 8% with the shorten flooding. The water is changed in rice checks once per year during germination of sprouts, with volume –900-1100 m^2/ha. (Table 3). In variants of constant and shorten flooding, without the change of water during the rice germination in some days there was increase of water salinity in checks for more than 2.5 g/l, in the remaining phase of vegetation there is an increase of water mineralization above 3.5 g/l, which affected decrease of the rice yield for 9.4 and 4.0

c/ha. In these variants there is a reduced rice standing before harvesting for 12% and the grain weight of panicle for 2-8%.

Table 3. Rice productivity on saline lands of rice systems in LLP "Kaptagaj&Co" Shielisky irrigation massive of Kyzylorda region

Rice irrigation modes	Number of plants, pcs/m²	Productive bushes	Average length of panicle, *cm*	Average weight of the panicle grain, *g*	Weight of 1000 grains, *g*	Rice crop, *c/h*	Irrigation norm, *m³/h*	Water consumption, *m³/h*
1	2	3	4	5	6	7	8	9
The permanent flooding of water in rice without changing checks	92	1.6	15.6	3.31	29.2	48.7	25080	515
Permanent flooding with the change of water in rice checks	104	1.7	15.8	3.36	30.1	59.3	26060	439
Shorten flooding without change of water on rice checks	108	1.3	14.9	3.29	29.4	46.2	25840	559
Shorten flooding with change of water on rice checks	120	1.3	15.1	3.30	29.8	50.2	26870	535
Production crops (control)	98	1.5	15.3	3.27	29.7	47.8	29860	625

Conclusions:

– Study experiences of the rice productivity on saline lands were conducted on saline lands (salt marshes), with salt content in the plough layer 1.390 ÷ 2.313% on solid residue, salinity type is sulfate-chloride-sodium. Soil heavy loam was with volume weight of more than 1.5 g/cm^3 and the density 2.76 to 2.80 g/cm^3. Filtration coefficient of soil is low, less than 0.2 m/day. Soils are unfavorable for the rice cultivation

– Water consumption per one hectare of the planted rice during irrigation period made on production plants – 29860 m^3/h, on studied variants of the rice irrigation with continuous flooding with the change of water in the rice check – 26060 m^3/h, without the change of water – 25080 m^3/h; with the shorten flooding and the change of water in the period of rice germination –26870 m^3/h, without the change of water – 25870 m^3/h. Such data demonstrates possible reduction of water resources during the rice cultivation on salty lands up to 20% without the crop losses.

Large volumes of supplied water on the rice plants in production conditions are resulted from unreasonable discharge of water from the rice checks, which overfill the drainage – collecting canals, reducing their melioration action which provides more ground waters and secondary salinity of lands in rice systems.

– With the planting rate of 750 pcs/m^2, there is a good growing of seeds; the rice standing in the phase of full germination makes 89÷147 pcs/m^2. On variants with continuous and shorten flooding with the changeable water in the rice check in the period of rice germination the plant density is 4-6% more as compared with variants of the rice irrigation without the change of water.

– Water mineralization of rice checks changes from 1.026 g/l up to 1,283 g/l and it depends on the mode of rice irrigation. In the variant of the rice irrigation with the water change during the plants germination water mineralization in rice checks makes 1.026÷1.042 g/l, in variants without the change of water, with continuous flooding – 1.18 g/l, with shorten– 1.283 g/l. Salinity type of the rice checks – sulphate – chloride sodium. Mineralization of irrigation water makes 1.037 g/l, drainage – collecting– 2.32-3.26 g/l.

– The least water losses per one hundred weight of rice – 439 m^3/h are received in the variant of continuous flooding with the change of water during the rice germination. Water losses per one rice hundred weight proves possible reduction of water resources during the rice cultivation on salty lands for 15-20%, without the crop losses and improved efficiency of the rice cultivation.

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