Improving the Operating Conditions of Rice Irrigation Systems as Part of the Water Management Complex of the Lower Kuban

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Abstract. The rice irrigation system is designed to irrigate rice and related rotation crops. It consists of canals of the irrigation and drainage network, irrigation cards (divided into checks by rollers), structures (water intakes, pumping stations, settling tanks). Water in rice paddies comes from cart sprinklers, the last link in the irrigation network. After sowing in dry soil, the field is flooded with a layer of water 5–7 cm, part of which evaporates, a certain amount is absorbed into the soil, the rest of the water is discharged after a few days. The field is then flooded with a layer of water (20–25 cm) to control weeds. During the tillering phase, the water layer is reduced to 5 cm, and at the end it is again increased to 12–15 cm, maintaining this layer of water in the check until the rice milky ripeness phase. At the onset of the phase of wax ripeness, the water remaining in the check is dumped, and the soil is dried to ensure rice harvesting. At present, rice growing has embarked on the path of expanded diversification with a wide range of production, processing and marketing of agricultural products produced in the irrigated area. However, the rice irrigation system functionally does not correspond to this modern concept, and the strategy for its reconstruction still does not have a clear methodological basis. In the article, the authors develop the conditions that must be met by a modern rice irrigation system that meets the ecological nature of all crops cultivated in the crop rotation, providing equal rights for irrigation and agrotechnological operations at the required time in accordance with the biological phases of plant development.

Keywords: Rice system · Rice · Rice cultivation · Rice rotation crops · Rice maps

1 Introduction

Currently, rice is grown in three federal districts of the Russian Federation: Southern, North Caucasian and Far Eastern. More than 90% of domestic rice is grown in the Southern Federal District, which includes the following rice-growing regions: Astrakhan Region, Republic of Kalmykia, Rostov Region and Krasnodar Territory. In the North Caucasian Federal District, rice is grown in the Republic of Dagestan and the Chechen Republic. In the Far Eastern Federal District, rice is produced only in Primorsky Krai and the Jewish Autonomous Region [1, 2].

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The main volume of rice grown in the Krasnodar Territory, which share on average amounted 80% of the total volume of domestically produced rice. The area of rice irrigation systems in the Krasnodar Territory is 234,000 hectares. At the same time, taking into account the crop rotation on rice systems and the capacity of inter-farm canals, the optimal sown area is no more than 62 percent of the total. This year it amounted to 131 thousand hectares.

In the context of the regions of the Territory, the largest are the Krasnoarmeisky district – 47.8 thousands of hectares of rice crops, Slavyansky – 44.3 thousand hectares, Abinsky – 16 thousand hectares and Kalininsky – 13.7 thousand hectares [3, 4].

Rice is demanding on water, so the main rice systems are concentrated just below the Krasnodar reservoir – the main reservoir that accumulates irrigation water [5, 6].

The basis of the rice complex are inter-farm facilities, which include: large head water intakes for systems, main, distribution and collector-discharge channels, pumping stations with a total capacity of more than 800 cubic meters of water per second, a complex of retaining and regulating hydraulic structures [7, 8].

Let us list the designs of rice irrigation systems in the Kuban. The first engineering rice irrigation systems began to be built after 1932, even before the completion of the embankment of the Kuban River. When designing the on-farm network and laying out the fields, the issues of water supply, distribution and drainage of water were solved from the conditions of minimal manual labor costs, and therefore semi-engineering solutions were taken as the basis for the projects [9, 10].

The first systems were characterized by small maps without field roads and small checks of irregular shapes, without planning, located along a “chain” and without equipment for the supply and discharge of water [11, 12].

After 1950, rice irrigation systems were improved, and bilateral command irrigation systems began to be designed and built, increasing the distance between kart discharges to 400 m. This design of the rice kart was called “Krasnodarskaya”. Map of the “Krasnodarsky” type is widespread in many rice-growing zones of the country [13, 14].

Starting from 1963, along with this design, the design of a check card of a wide front of flooding and discharge was widely distributed in the Kuban. According to the authors of the system, the map-check of a wide front of flooding and discharge is flooded with water faster than the map of the “Krasnodarsky” type, water is also discharged from it faster [7, 10].

On check maps of a wide front of flooding and discharge, the labor productivity of irrigators increases, the land use coefficient increases by 4–5%.

The “Kubanskaya” system in the Krasnodar Territory has been introduced on an area of about 100 thousand hectares. However, the “Kubanskaya” system also has disadvantages. [15, 16]:

- secondary salinization of lands due to the outflow of colder and more mineralized groundwater in the areas adjacent to checks, as well as along between check ridges on low checks, which inhibits rice plants, especially in the corner areas of checks adjacent to cart irrigation.
- the inability to irrigate the accompanying crops of the rice rotation using commercially available sprinkler equipment;

- ameliorative moisturizing irrigation and combined regime of rice field irrigation are not provided.

The presented designs of rice irrigation systems are based on the provision of technological processes for tillage, a given irrigation regime and harvesting of the main crop – rice. Other crop rotation crops, including perennial grasses, the main phytomeliorant in irrigated agriculture, were not planned to be irrigated. This was the main mistake in the design of rice irrigation systems and the program for the development of the rice growing industry in the Krasnodar Territory and in other areas of rice cultivation. [17, 18].

2 Materials and Methods

The work is based on a generalization of our own research and published data on the design of rice irrigation systems. Also, stock materials of JSC Research Institute "Kubanvodproekt" and FSBU "Administration" of "Kubanmeliovodkhoz" were used.

The methodological basis for innovative solutions in this article is the transition of rice growing to a safe sustainable operation based on the principles of rational environmental management.

The purpose of the work is to substantiate the principles of expanding the functionality of the rice irrigation system for the cultivation of crop rotation crops with rice.

Objectives:

- to develop a combined rice irrigation regime;
- to develop crop rotations based on a landscape-adaptive approach, allowing to follow the principles of expanded reproduction of soil fertility;
- to increase the profitability of rice production;
- to increase rice yield.

3 Research Methods

Modern rice irrigation system should create conditions for high rates of spring sowing and autumn harvesting, maintain favorable water-air, thermal and salt regimes in the soil throughout the year to restore its fertility in the inter-irrigation period and obtain high yields of rice and related rice crops and crop rotation during the irrigation period.

These conditions are met by the design of a rice irrigation system of a universal type, the design version of which is shown in Fig. 1.

The proposed type of rice map provides a guaranteed and highly efficient combined irrigation of agricultural crops of rice crop rotation without deteriorating the reclamation state of the land. This is achieved by the fact that along one long side of the map, perpendicular to the district distributor, an open drainage channel is arranged, called the irrigation drain 6, made in a half-cut-semi-fill, having a shaft-road 7 3.0–4.5 m wide. In the end part of the drain-irrigator, a control waste facility is installed, and in the head part, a control facility is installed to supply water from the distributor to the drain-irrigator.

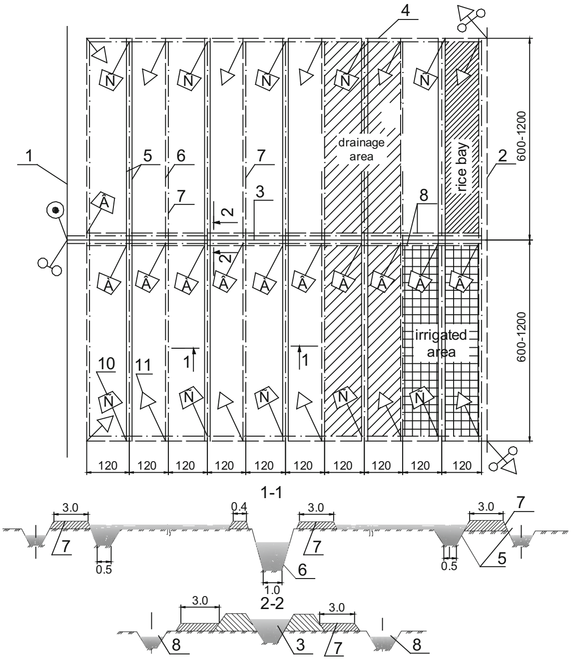

Fig. 1. Plot of rice system from "Universal Type" maps:1 – high order distributor; 2 – high-order collector; 3 – district distributor; 4 – local discharge; 5 – discharge sprinkler; 6 – drain-irrigator; 7 – road; 8 – cut-off open drain; 9 – 4 water outlet hydraulic structures from the district distributor to irrigation discharges; 10 – 2 water outlet hydraulic structures from discharges-irrigators to the local discharge; 11 – end discharge; 12 – 2 water outlet hydraulic structures from the district distributor to the drain-irrigator

Therefore, the channel is called the irrigation drain. Along the other long side of the map, at a distance of two radii of action of the sprinkling machine, a shaft-road 7 is arranged, on both sides of which there are sprinkler outlets 5, also having head and end structures that allow water to be supplied to the sprinkler outlet and to the check, as well as to dump it from a check.

Rice irrigation systems using wide-sprinkler front or circular sprinklers are typical modules that are a crop rotation field. Irrigation system is completed from such modules-blocks.

The on-farm irrigation and drainage-discharge network of rice systems is reinforced with prefabricated reinforced concrete hydraulic structures. The vast majority of hydraulic structures in rice systems are tubular regulators.

Typical check water outlets (tubular regulators) are shown in Figs. 2 and 3.

48 standard sizes of structures have been developed. The main indicators that determine the standard dimensions of the structure are as follows: the purpose of the structure, the diameter of the pipe of the drainage part, the hydraulic drop, the water depth in the channel at the inlet head, the presence or absence of a berm.

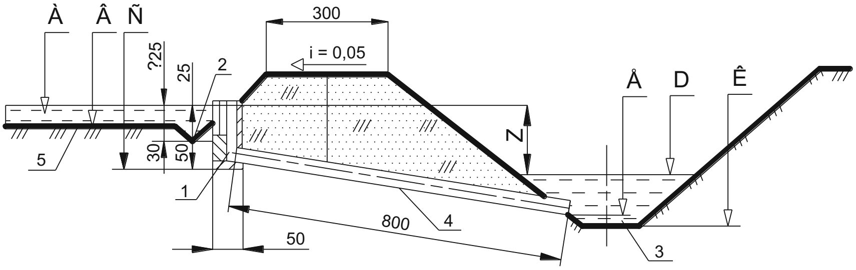

Fig. 2. Water outlet from check to dump:1 – input cap; 2 – check groove; 3 – discharge channel; 4 – non-pressure pipe; 5 – check; *A, B, C, D, K* – water level in the check, ground surface in the check, head bottom, downstream pipe, water level in the discharge channel, bottom of the discharge channel

All standard sizes of structures are designed with crossings according to a single concept scheme: inlet head, water-carrying part, outlet part.

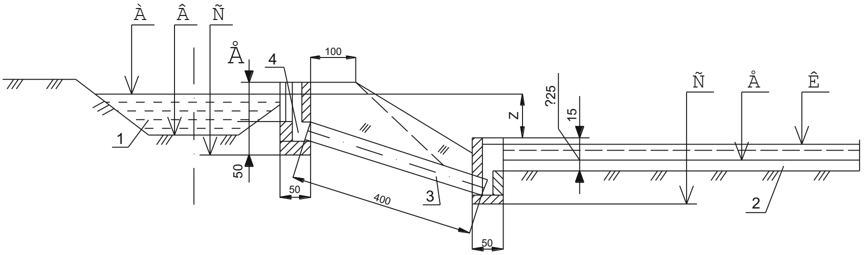

Fig. 3. Water outlet from the sprinkler in the check:1 – sprinkler; 2 – check; 3 – non-pressure pipe; 3 – input cap; marks: *A, B, C, E, K* – water level in the upstream, channel bottom, bottom of heads in the upstream and downstream pools, ground surface in the check, water level in the check [5]

Tubular regulators are designed to regulate the flow and water levels in the channels of rice systems. They can serve as head, partitioning structures, water outlets and outlets, and can also be the main parts of the structure nodes (Figs. 4, 5).

The entrance head is made of bulk blocks with diving walls. The slopes of the channel at the head are fixed with flat reinforced concrete slabs. The water-conducting part is made of asbestos-cement non-pressure pipes with a nominal diameter of 300 mm or from socket reinforced concrete non-pressure pipes with a nominal diameter of 0.6 and 1 m.

In structures of the “tubular regulator” type, the outlet part is made in the form of an open trapezoidal well, consisting of a drain and a transition section. In structures of the “tubular regulator for waste channels” type, the outlet part consists of a combination of a pipe-nozzle with a damper sleeve.

The drainage network in rice systems is designed as open or closed horizontal, vertical and combined drainage. (Martin-Anton, M., Negro, V., Del Campo, J.M., López-Gutiérrez, J.S. & Esteban, M. D. (2016)).

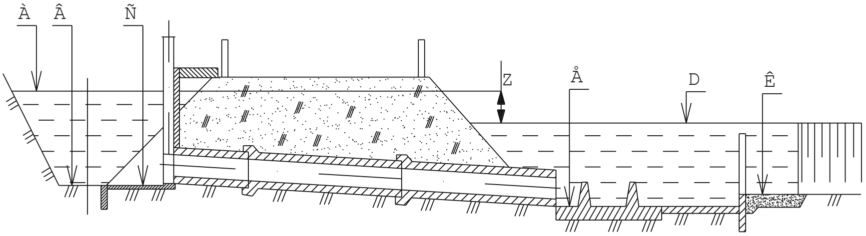

Fig. 4. Tubular regulator on irrigation canal: marks: *A, B, C, D, E, K* – upstream water level, distribution channel bottom, tip bottom, water well bottom, sprinkler water level, sprinkler bottom; z – upstream and downstream level difference

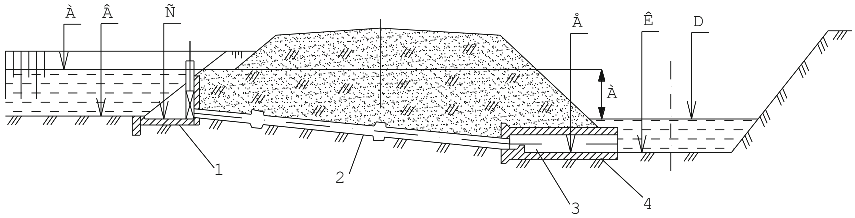

Fig. 5. Tubular regulator on the drainage and waste channel: marks: *A, B, C, E, D, K* – upstream water level, channel bottom, tip bottom, absorber bottom, water level in the discharge channel, discharge channel bottom; 1 – input cap; 2 – non-pressure pipe; 3 – tubular regulator; 4 – sand and gravel preparation

In difficult hydrogeological conditions, with an appropriate feasibility study, closed material drainage can be used.

Taking into account the specifics of the organization, territory and irrigation network, horizontal drainage in rice systems consists of cut-off (contour, inter-check and near-canal) systematic and operational drainages.

4 Results and Discussion

Consider rice irrigation regimes. Five types of water regime are noted in the practice of world rice cultivation: continuous and intermittent flooding; periodic humidification without creating a layer of water; shortened flooding and combined rice irrigation regime.

When cultivating rice without the use of herbicides, in contrast to conventional technology, it is necessary to maintain a differentiated regime of soil moisture for two periods: before and after sowing rice.

With a shortened irrigation regime, the initial flooding, depending on the quality of the layout, is carried out to a depth of 7–10 cm, and the highest parts of the check should be covered with a layer of water of 4–5 cm. This is necessary to prevent the germination of seeds of millet weeds.

After mass pecking of rice seeds with the formation of seedlings 5–8 mm long, and in some seeds even 10 mm long, unabsorbed water is discarded from the surface of the checks. Checks remain without water for three to four days. In millet, by this time no more than one, in rare cases, two leaves can form. If two or three leaves are formed, it is necessary to increase the flooding layer to 20–25 cm.

The water layer is reduced after the seedlings of millets under water die completely. By this time, rice, as a rule, has three leaves, and it goes to tillering. It is necessary to ensure that the leaves are freed from water as quickly as possible. This will protect them from pests, and photosynthesis will be more intense. If at this time such pests as barley miner, rice mosquito and others are found in a significant amount, then the water from the checks is completely removed and after three to four days the fields are gradually flooded again. With the formation of seven to eight leaves in early-ripening rice varieties, and eight to nine in medium-late-ripening ones, the plants pass to the period of differentiation of the growth cone, that is, to the laying of the future crop. If at this time high air temperatures occur (+ 32 °C), then in order to reduce it and thereby increase this period in rice plants, it is recommended to increase the water layer in the checks to 20–22 cm. If air temperatures do not exceed 28–32 °C, then there is no need for this approach. In the future, up to the onset of the period of wax ripeness in rice, the grains in the checks maintain a layer of water of 12–15 cm, and then its supply is stopped. On checks with a total flow of a layer of water of 1 cm per day, it is completely “worked out” without resetting in 10–12 days, and the checks must dry out for the same amount of time.

5 Conclusion

The water use regulation includes a reasonable water-saving regime for irrigating rice and programmatic distribution of water both for drawing up dispatching schedules for the operation of the reservoir and regulating hydroelectric facilities, and for intra-system water use plans:

- the combined rice irrigation regime on an area of 299.5 hectares was developed and tested at the “Kuban” educational farm of the Kuban State Agrarian University, which made it possible to increase the coefficient of irrigation water use by 14.7–17.5%, to reduce unproductive costs of irrigation water by 9–13%; save irrigation rate by 20%;
- an innovative project for sustainable ecological rice growing and diversification of production, based on an environmentally friendly resource- and energy-saving rice cultivation technology, as well as the principles of expanded reproduction of soil fertility, including the introduction of crop rotations based on a landscape-adaptive approach, was developed and tested in the farms of the Slavyansky district (on an area of 22,800 ha) and the Kalininsky district (on an area of 12,645 ha), which made it possible to increase the yield of rice by 20–30%, to reduce direct production costs for tillage by 40–50%, to increase the production of green mass of perennial grasses, hay, haylage and silage by 1.8–2.2 times;
- a stable long-term positive dynamics of increase up to 65.5–130% of the profitability of rice production was obtained.

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