Natural features and rational use of water resources in rice irrigation systems of Kazakhstan

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Abstract. Akdala rice irrigation system is located on a high above-floodplain terrace of the Ili river basin, the geological structure of the top layer of soil is represented by 50 varieties that affect the rate of water consumption and rice yield. The soils are alluvial-meadow and takyr, the lithological composition of the aeration zone soils is characterized by a wide variety, differing in mechanical composition, water-physical properties and the degree of salinity. Water filtration on sandy loam, light loam, loam with layers of sandy loam rice paddies during rice irrigation constitutes 12-17 mm/day, which provides water renewal in rice paddies and removal of salts from the root layer of the soil. Rice is grown without flow and discharge of water from rice paddies, the rice yield is 6,8 t/ha and higher. Water filtration on heavy loam, loam with layers of clay soils rice paddies during rice irrigation constitutes 5-3 mm/day. On these soils, due to the convective diffusion of salts from the soil and from ground water, the salinity of water on rice paddies increases and reaches the critical threshold of toxicity of 2,5 g/l. To reduce the salinity of water in the paddies, water is discharged, with subsequent flooding from the irrigation channel, the rice yield is 4,8 t/ha.

The rice paddies water balance of the incoming and outgoing is stable. In the aeration zone during the irrigation period desalination occurs in salt balance; in autumn-winter period salts from the lower horizons are redistributed to the upper ones. Rice cultivation, taking into account the geological structure and lithological composition of soils in the aeration zone, provides a profit per hectare of 86,988 tg/ha, the profitability ratio is 25,5%.

1. Introduction

Akdala rice-growing area, located in the Ili river basin, is one of the most promising rice-growing areas of Kazakhstan. Currently, 31 thousand hectares have been used for rice growing there, and up to 43 thousand hectares can be used for rice crop rotations in the future.

The geological structure and lithological composition peculiarity of the upper soil level of the Akdala rice irrigation system is that it consists of large variety of soils, associated with their features of their formation, lithological structure, affecting the filtration water outflow, the soils reclamation regime, the water consumption rate and rice yield [1, 2, 3]. The most active zone of the soil-ground in agricultural constitutes 20-25 m. thickness of alluvial upper quaternary and modern sands, sandy loams, loams and clays, the filtration coefficient of which is 6 m/day and water capacity is 1,400 m²/day. The high water-transmitting capability of the active soil layer during rice irrigation creates an outflow of ground water from the high sections of the rice irrigation system to the lower ones, which are subject to secondary salinization and water logging and are considered as problematic in the Akdala rice system [4, 5, 6, 7].
The field study was conducted on the rice paddies of the Vladimir farm of Balkhash district, Almaty region. The chemical composition of soil salts in the aeration zone during the rice irrigation period, as well as filtration and mineralization of the water layer of rice paddies, water consumption and drainage rates and rice yield were determined in the spring before rice sowing and in the autumn after harvesting.

2. Results
In 2019, the summer was hot, with temperatures reaching 43 °C on some days in July. The sum of the average monthly air temperatures for the growing period, according to the weather station in Bakanas village was 3,340 °C, which is higher than the average long - term value by 274 °C. As the sum of temperatures increases, transpiration from rice plants and its yield also improves (figure 1). [8, 9]

![Figure 1. Dependence of Akdala rice system crop on the sum of air temperatures during the growing season.](image)

![Figure 2. Water filtration from rice paddies in irrigation period: 1 – loam soils with layers of sandy loam; 2 – loam soils with layers of clay.](image)

Depending on the geological structure and lithological composition of soils in the aeration zone, the filtration of water on rice paddies during the irrigation period varies significantly (figure 2). On sandy loam, light loam and loam with layers of sandy loam soils, there is a free outflow of filtration water, which during the flooding of rice paddies comprises 12.4 mm/day, at the end of the irrigation period it becomes 7.8 mm/day, the salinity of water in rice paddies during the irrigation period is 726 mg/l, water discharges from rice paddies during the irrigation period were not made. On loamy soils with clay layers, filtration during the initial flooding is 6.8 mm/day, at the end of the irrigation period – 3.3 mm/day, water salinity in rice paddies increases during the irrigation period and at the end of May is 1,310 mg/l. In June, during the period of rice plants tillering, when the water layer in the paddy is reduced to 5 cm, the water salinity reaches the critical threshold of toxicity of 2,530 mg/l, the water from the paddy is discharged, followed by flooding with water from the irrigation channel. In subsequent periods of vegetation of rice plants, the salinity of water in paddies remains 705-1,302 mg/l, which is below the critical threshold of toxicity of 2.5 g/l (figure 3).

The Akdala rice irrigation system contains soil characterized by light loams, loams with sandy loam and sandy loam layers, which constitute 90% of the irrigated area [2,3]. On these lands, ground water during the irrigation period does not merge with irrigation water and water exchange in the paddies happens due to filtration water, which removes salt and harmful toxic elements from the soil. Land with heavy loams, loam with layers of clay soils are located in microdepressions, on which during the irrigation period the groundwater merges with the water of a rice paddy and the water mineralization in paddies increases by the convective diffusion of salts from the soil and groundwater. When a critical threshold of toxicity 2.5 g/l is reached, water from the paddy has to be discharged, followed by flooding to the same level of irrigation water from channel [8, 9].
Figure 3. Mineralization of water in irrigation canal and rice paddies: 1 – irrigation canal, 2 – loamy rice paddies with sandy loam layers, 3 – loam rice paddies with clay interlayers.

Water mineralization in rice paddies affects the growth and development of rice plants [10, 11, 12, 13]. The negative influence of salts is that the salts increase the osmotic pressure of soil solutions, reduce transpiration, inhibit the ionization of mineral fertilizers, some of which remain in an undissociated state and therefore are inaccessible to plants, cells receive less water and dissolved elements of mineral nutrition, which results in reduction of rice yield (table 1).

Table 1. Productivity of rice plants and its yield rate on the experimental production field of the Vladimir farm.

| Soil structure                             | Number of plants, unit/m² | Number of stem, unit/m² | Tilling capacity | Thousand grain weight, gr. | Panicle grain weight, gr. | Crop yield, centners per hectare |
|--------------------------------------------|---------------------------|-------------------------|------------------|---------------------------|--------------------------|---------------------------------|
| Sandy loam soils, with layers of sandy loam | 183.4                     | 204.4                   | 1.118            | 27.17                     | 3.321                    | 67.8                            |
| Loam soils with layers of clay             | 153                       | 173                     | 1.13             | 26.7                      | 2.77                     | 48.2                            |

Regarding water balance of rice paddies, water supply constitutes 25,300-26,800 m³/ha, total water consumption is 10,108 m³/ha, water filtration on from rice paddies is 3,910-11,290 m³/ha, drainage runoff and outflow of ground water is 6,300 – 9,400 m³/ha, discharge runoff is 1,800 m³/ha, balance discrepancy is 1.3% (table 2).

Table 2. Water balance of rice paddies on the experimental fields of the Vladimir farm.

| №  | Item                           | Rice without discharge | paddies water | Rice with discharge | paddies water |
|----|--------------------------------|------------------------|---------------|---------------------|---------------|
| 1  | Water supply                   | 26,800                 | 25,300        |                     |               |
| 2  | Precipitation and groundwater inflow | 980                   | 1,900         |                     |               |
In the salt balance of the aeration zone, salt removal prevails over the intake; loam soil with layers of sandy loam is slightly saline, in the spring before rice sowing the salt content in the aeration zone of 1.8 m is 33.62 t/ha, in the autumn after rice harvesting - 31.38 t/ha, the balance discrepancy is 2.1%. Loam soils with clay layers are saline and the salt content in the aeration zone in spring is 57.15 t/ha, in the autumn after rice harvesting constitutes 33.59 t/ha, while the balance discrepancy is 1.0% (table 3).

| Elements of salt balance                                      | Loam soils with layers of sandy loam | Loam soils with clay layers |
|--------------------------------------------------------------|-------------------------------------|----------------------------|
| $S_1$ – salt reserve of the aeration zone before rice sowing | 33.62                               | 57.15                      |
| $S_2$ – arrival of salts with irrigation water               | 10.72                               | 9.72                       |
| $S_3$ – salt intake from ground water                        | -                                   | 7.0                        |
| TOTAL                                                        | 44.34                               | 73.87                      |
| $S_4$ – stock of salts in the aeration zone after the rice harvest season | 31.38                               | 33.59                      |
| $S_5$ – salt removal by filtration runoff                    | 4.50                                | 3.52                       |
| $S_6$ – salt removal by waste water                          | -                                   | 1.44                       |
| $S_6$ – salt removal by drainage runoff and groundwater outflow | 7.52                                | 34.58                      |
| TOTAL                                                        | 43.4                                | 73.13                      |
| Balance sheet                                                | 0.94                                | 0.74                       |
| Discrepancy, %                                               | 2.1                                 | 1.0                        |

Rice irrigation by taking into account the geological and lithological structure of the upper soil layer, provides a profit of 93,564-62,612 tg/ha and profitability rate of 26.9-25.0%. When rice irrigation at the Vladimir farm is carried out without taking into account the geological and lithological structure of the upper soil layer and with water discharges during the irrigation period, the profitability of all rice paddies is lower by 38,678 tg/ha and 10.2 %, respectively (table 4).

| Indicators            | Rice paddies without water discharge | Rice paddies with water discharge | Weighted average values | Control, rice paddies at the farm | Discrepancy |
|-----------------------|--------------------------------------|----------------------------------|-------------------------|-----------------------------------|-------------|
| Area, ha              | 25.2                                 | 2.8                              | 28.0                    | 100                               |             |
| Rice yield, t/ha      | 6.8                                  | 4.8                              | 6.6                     | 4.9                               | +1.7        |
| Irrigation norm, m³/ha| 26,800                               | 25,300                           | 26,650                  | 31,300                            | -4,650      |
overflows the drainage channels and reduces their draining effect. [14]

3. Conclusion

Rice cultivation on the Akdala rice irrigation system, taking into account the features of the geological structure and lithological composition of the soil in the aeration zone, saves 46,500 m$^3$ of irrigation water and additional rice yield of 17.1 thousand tons per year. The ecological effect of this method is visible in reduction of the wastewater discharge volumes from rice paddies by 18.6 million m$^3$ per year, which overflows the drainage channels and reduces their draining effect. [14]

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