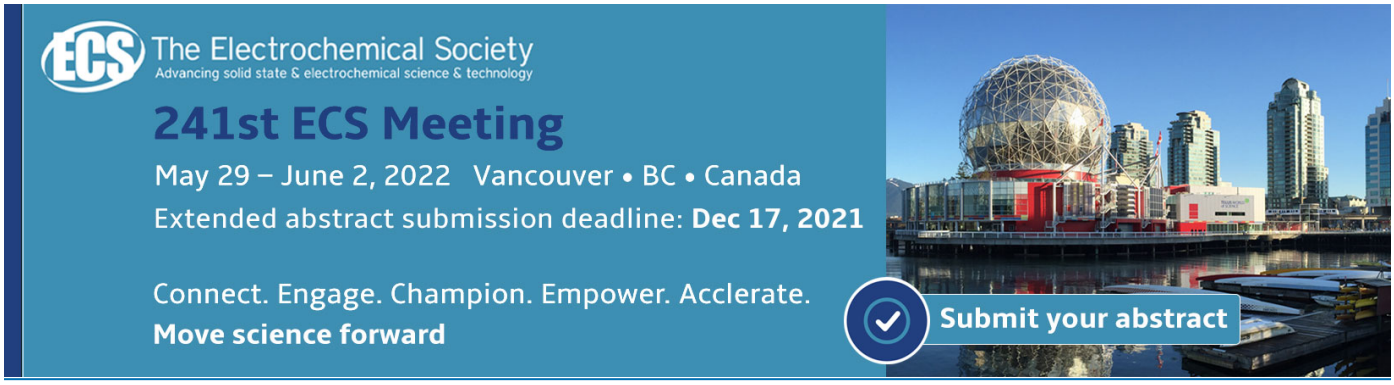
# Study on the influence of rice paddies' water layer temperature on rice yield





# Study on the influence of rice paddies' water layer temperature on rice yield

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**Abstract.** Studies on Akdala rice system found that rice plants sensitive to meteorological conditions. Climate change leads to changes in crop structure. The temperature of the rice field air and water has a special influence on the structure of the rice crop. It is established that the temperature of the water layer in rice paddies in the irrigation period does not exceeds $29^0$ C, which is below the threshold of $35^0$ C, when the flow and discharge of water from the paddies are recommended. The temperature of water in rice paddies, the surface layer was determined by an express thermometer, at the depth of the water layer 5, 10, 15 and 20 cm by Savin Thermometers, soil – thermometers TM-5.

## 1. Introduction

Rice sowing in Kazakhstan takes place on irrigated lands in the basins of the Syrdarya, Ile, Karatal Rivers, which is a traditional specialization of more than 220 thousand hectares area. The available surface water resources are insufficient to meet the increasing needs of rice growing [1, 2]. For this reason, on tens of thousands of hectares of the rice irrigation systems crops experience a lack of moisture in the soil, which leads to a significant decline of agricultural productivity? In 1990, the rice sowing area in Kazakhstan was 110 thousand hectares, the gross harvest of grain was 450 thousand tons, in 2015 the area of rice was sown on 76 thousand hectares, the gross harvest of grain constituted 300 thousand tons, which affects domestic prices, which increased 2.5 times compared to 1990 [3].

The rice production decline in the country has increased rice imports from China, Uzbekistan, Egypt, Pakistan and other countries. The quality of imported rice is relatively low and it is inferior in protein and carbohydrate content to rice varieties like Marzhan, Bakanaskiy, Leader, Aisaule, Syr-suluy, which are cultivated by using crop rotation schemes and are organically untainted, in comparison with imported rice varieties grown as a monoculture using mineral fertilizers, herbicides and pesticides against diseases and pests.

The growing rice technique assumes maintenance of a water layer on the rice field, which performs a multifactorial role, for instance, environmental factor that determines the conditions for the formation and productivity of rice plants. The water layer on the rice field influences the temperature and salt regime of water and soils in rice growing systems.

Rice cultivation on irrigation systems of Kazakhstan follows recommendations of the Ministry of Agriculture of the Kazakh SSR [4, 5], which recommend establishing a periodic water flow within 10% of its input to prevent overheating of the water layer on the field.

The disadvantage of this irrigation regime is excessive consumption of irrigation water. Unjustified (spontaneous) discharges and the creation of water flow on rice paddies lead to overflow of drainage and discharge canals, a decrease in their drainage effect, mix with groundwater and cause pressure on groundwater, as a result of which secondary salinization and waterlogging of rice field soils occurs, and irrigation water overrun reaches 20-30%. The mineral fertilizers are carried out by wastewater runoff, which leads to a decrease in rice productivity [6, 7]. As a result of this rice growing method application, yield is reduced to 40 c/ha on most of the area, and the irrigation rate increases to 36 thousand $m^3$/ha. Rice cultivation on saline lands became unprofitable, saline lands were abandoned and excluded from agricultural use. There are more than 60 thousand hectares of such lands in the Kyzylorda rice irrigation system out of 220 thousand hectares, in Akdala - 8 thousand hectares out of 29 thousand hectares.

The study aims to improve the water resources use efficiency on rice irrigation systems by reducing unjustified discharges and water flow, developing critical threshold indicators for the water temperature on rice paddies at which water needs to be discharged.

The hypothesis is that water temperature affects the decomposition of organic matter in the soil. At a water temperature of $35^0$C and above, the oxygen content decreases, and the soil recovery processes are markedly enhanced, accompanied by the formation and accumulation of large amounts of toxic substances ($H_2S$, etc.) that have a detrimental effect on rice roots [2, 8, 9]. As a result, the absorption of nutrients is inhibited, which entails the development of disease as plants are covered by brown spots. In contrast, when water temperature is low, a less intensive decomposition of organic matter in the soil occurs, the plants' development is slowed down and the emergence of plants is delayed, diseases (panicle blast) may appear and the number of ripe grains decreases, which leads to a declining rice yield.

## 2. Materials and Methods

**Table 1.** Average monthly air temperatures according to the weather station in Bakanas village

| Title | Month | | | | | Sum of the temperatures during rice growing season |
|---|---|---|---|---|---|---|
| | May | June | July | August | September | |
| Average daily air temperature, $^0$C | 16.8 | 22.0 | 24.1 | 22.0 | 15.8 | |
| The sum of air temperatures for a month, $^0$C | 520.8 | 660.0 | 747.1 | 682.0 | 474 | 3083.9 |
| Average daily air temperature, $^0$C in 2018 | 16.0 | 21.6 | 23.8 | 21.7 | 15.8 | |
| The sum of air temperature for the month, $^0$C in 2018 | 496.0 | 648 | 737.8 | 672.7 | 474 | 3028.5 |
| Deviation of average monthly temperatures, $^0$C 2018 from long-term | -0.8 | -0.4 | -0.3 | -0.3 | 0 | |
| Deviation of the sum of average monthly temperatures, $^0$C 2018 from long-term | -24.8 | -12.0 | -9.3 | -9.3 | 0 | -55.4 |

The research was carried out on the Akdala rice system of the Ile river basin in Balkhash district of Almaty region. According to the weather station in Bakanas village the average daily long-term air temperatures sum in the period from May to September varies from 520.8 to 747.1$^0$C, totaling 3,083.9$^0$ C during the rice growing season (table). Such heat supply during the rice growing season, only enable

cultivation of early ripening rice varieties (Leader, Bakanskiy), developed for the northern rice growing zone of Kazakhstan. The Bakanas village is located in the middle of the Akdala irrigated landmass.
In 2018, the average daily sum of temperature during the rice growing season was 55.4$^0$C lower than the long-term avaerage (Table 1).
Weather conditions in 2018 affected the length of the rice growing season, which lasted for 8 days longer. Rice harvesting began in the first decade of September, while usually it starts at the end of August.
The water temperature in the rice paddies was measured every day at 15:00 by express and Savinovsky thermometers. The express thermometer measured water temperature of the surface layer, while Savinsky thermometers measured water temperature at a depth of 5 cm, 10 cm and at the surface of the soil; as well as at a depth of 5 cm, 10 cm, 15 cm of the soil.
The use of water resources on rice irrigation systems in circumstances of limited access to water requires fundamentally new approaches to the management and use of water resources on rice irrigation systems, which currently have hundreds of cooperatives and peasant farms that are water consumers and according to the Water Code of the Republic of Kazakhstan they have equal rights to irrigation water. However, a lot of problems arise in connection with water resources scarcity exacerbated by the use of outdated rice cultivation techniques and technologies, which regulating irrigation water use in rice irrigation systems. The study establishes the water layer temperature threshold indicators of rice paddies, at which the water should be discharged, thus improving the existing techniques for rice irrigation.

## 3. Results and Discussions

The water temperature in rice paddies during the irrigation period closely follows the daily variation of air temperature. In the month of June, when the stalk of rice plant does not shade the water surface of the rice paddies, the average ten-day water temperature in the paddies is higher than the average ten-day air temperature by 2-4$^0$C. The maximum water temperature in the rice paddies in June, during the period of tillering of the rice plant on surface water layer 37$^0$C, at a depth of 5 cm it is 29$^0$C, at a depth of 10 cm it is 27$^0$C. During rice grain milk and wax ripeness the water temperature in the paddies drops to 21$^0$C (Figure 1).

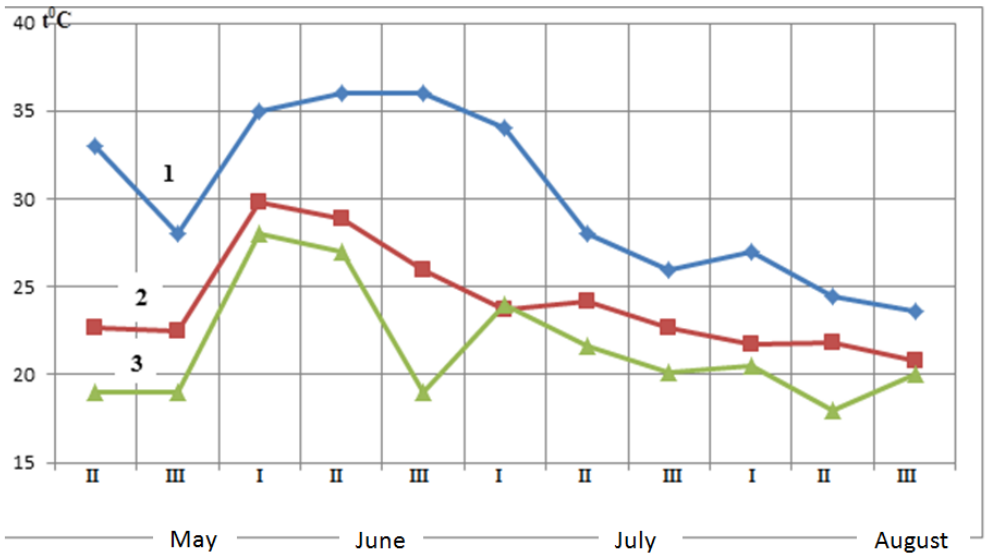


**Figure 1.** Water temperature on the rice paddy: 1 - surface layer, 2 - at a depth of 5 cm, 3 - at a depth of 10 cm

From the water and soil thermoisopleth layer of rice paddies shown in Figure 2, it can be seen that the maximum temperature of the water and soil layer was 28-29$^0$C in the rice tillering phase, when the depth of flooding of rice paddies was 5-6 cm, in the remaining phases of growth and development of rice plants the temperatures were its not higher than 26$^0$C, and during the period of waxy and full ripeness of rice grains temperatures were 19-21$^0$C.

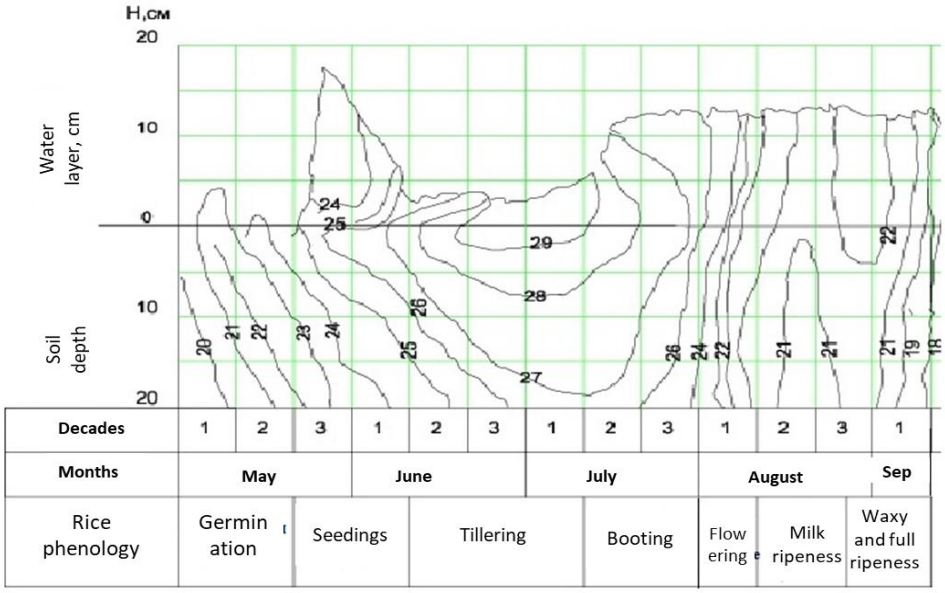


**Figure 2.** Water and soil layer thermoisopleths on rice paddies

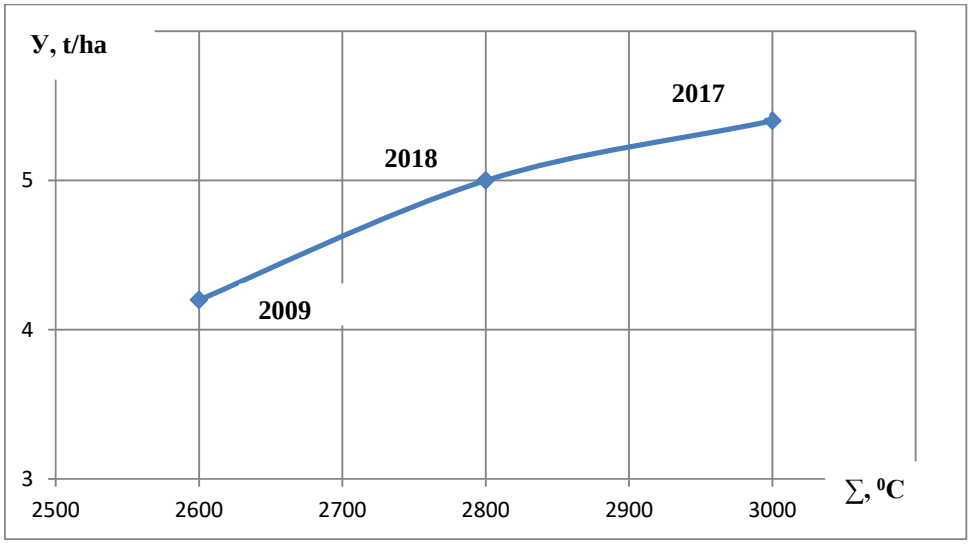


**Figure 3.** Correlation of the rice yield and the sum of air temperatures during the growing season, according to the weather station of Bakanas village and rice sowing cooperative Agrofirm "Birlik"

To forecast the temperature of water in rice paddies, its dependence on air temperature was established according to the meteorological station in Bakanas village, with a correlation coefficient 0.77±0.06

$$t_г = 6.2 – 0.17\ t_в + 0.04$$

where $t_г$ – average daily water temperature in rice bays and $t_в$ – average monthly air temperature of Bakanas meteorological station.

In the irrigation period of 2018, the water layer temperature in rice paddies did not exceed $29^0$C, and no water was discharged from rice paddies.

Taking into account the Bakanas weather station and Agrofirm "Birlik" rice yield data we plotted the dependence of rice yields on the sum of air temperature for the growing season (Figure 3). Comparison of the metrological conditions with the rice yield figures demonstrate that the higher the sum of the average monthly temperatures for the growing season, the better the rice plants develop, the empty grain cases decrease significantly, tillering increases, as well as absolute weight of grain and yield of rice.

## 4. Conclusions

The water layer on rice paddies in hot months (June-July) goes up to 27-$29^0$C, in May and August the temperature of the water layer does not rise above $26^0$C. During the rice growing season, rice plants did not show signs of suppression or infringement in the phases of plants development and growth caused by water layer temperature. Water flow and discharges from rice paddies due to overheating of the water layer during the irrigation period were not carried out. The temperature of the water layer in rice paddies was below the critical thresholds of $35^0$C.

## References

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