Improving the rice irrigation practice in Priamurie

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Abstract. This article discusses the prospects for rice cultivation based on the current food balance data in the Far Eastern Federal District in Russia. Our studies have proven the patterns of the production process and yield of adapted rice cultivars depending on irrigation practices. It has been found that the rice irrigation practice based on surface flooding provides stable grain yield of 4.5-5.0 t/ha and proves the rational use of water resources in the southern part of Amurskaya oblast.

With the growing popularity of rice in Russia, its acreage is increasing and now it is cultivated in Krasnodarskiy Krai, Stavropolskiy Krai, Astrakhanskaya oblast and Rostovskaya oblast, as well as in the Russian Far East.

One of the most important tasks in the development of agriculture in the Far Eastern Federal District is the increase in rice production – it is possible to achieve quite high yields, which is confirmed by the experience of rice cultivation in Primorye.

At present, according to the Ministry of Agriculture of the Russian Federation, the Russian Far East has at least 240 thousand hectares of land suitable for rice cultivation. Thus, not only the population of this region, but the entire Eastern Siberia can be provided with rice [1].

Rice grown under flood irrigation is fundamentally different from rice grown under sprinkler irrigation [2,3,4]. When a rice paddy is flooded, a layer of water, which covers the irrigated area, is absorbed by the soil. This method is used due to its high performance [5].

Research purpose: to develop optimal rice irrigation practices involving surface flooding which will ensure stable yield and rational use of water resources in the southern part of Amurskaya oblast.

Field studies were conducted on the experimental field of the Far Eastern State Agrarian University, in the village of Gribskoe in Blagoveshchensky district of Amurskaya oblast.

In terms of soil-geographic zoning Amurskaya oblast is located in one of the moderate and moderately cold soil climatic zones. The soil cover of the experimental site is represented by meadow-brown soils [6].

Studies to justify the under flood irrigation were conducted with the rice cultivars "Kaskad", "Rassvet" and "Lugovo" in two-factorial field experiment:

Factor A (irrigation practice) includes two options for surface flooding: option A1 – short flooding practice, option A2 – in intermittent flooding practice;

Factor B (cultivar) includes three options: B1 – “Kaskad”; B2 – “Rassvet”, B3 – "Lugovo".
Sowing in rows with a standard of 6.0 million pcs/ha was carried out in the third decade of May and the row spacing of 15 cm was used. A post-emergence herbicide of broad spectrum called “Segment” was used in order to manage weeds.

Water balance calculations for rice paddies were carried out according to the method of the All-Russia Research Institute of Rice.

The short flooding practice (the option A1) has been known for a long time, is widespread in our country and is the most prospective. This practice requires temporary absence of a water layer on the field at the beginning or at the end of the rice growing season. In order to regulate the water layer, it is necessary that a gauge be installed in each rice paddy, which is how the water level can be monitored [7]. The short flooding practice involves creating a water layer of 0.10-0.12 m after sowing, from germination phase to tillering phase – 0.10-0.12 m, reducing the water layer to 0.05 m up to the booting phase, increasing the water layer to 0.15 m up to the end of milky stage of ripening (control) (figure one).

![Figure 1. Diagram of the short flooding practice in general.](image1)

The premises for implementing the intermittent flooding practice were very diverse. In some areas, interruptions in flooding occurred for natural reasons – due to lack of water in the water source, to reduce irrigation rates, in other areas to dry the rice field so as to improve the oxygen concentration of the soil [8].

In our experiments, the initial layer is 0.10 m. A layer of water is created immediately after sowing and kept for 10 days, after germination it stays on 0.07 m for 2-3 days, with 2-3 leaves a layer is 0.12 m up to tillering stage, 0.05 m – for 10 days, 0.15 m – up to the end of milky stage of ripening (figure 2).

![Figure 2. Diagram of intermittent flooding practice (option A2) in general.](image2)
In different stages of the growing season, the need of rice plants for water varies. Depending on the choice of surface flooding practice, its root system changes along with its top part. When working on the water balance of rice plants, it is necessary to understand how effectively irrigation water is used. The components of the water balance depend on the irrigation system equipment, the type of irrigation system, as well as on the layout of the rice checks.

The water balance of the rice paddy is estimated by water inflow and water consumption [9]. The inflow is based on irrigation requirement rate which maintains the required level of water layer in the rice paddy, as well as the level of precipitation (table 1).

| Indicators | Kaskad | Rassvet | Lugovy |
|------------|--------|---------|--------|
| Irrigation practice | Short flooding | Intermittent flooding | Short flooding | Intermittent flooding | Short flooding | Intermittent flooding |
| Irrigation rate | 10382.8 | 11337.9 | 10801.3 | 11680.2 | 12683 | 12945.3 |
| Precipitation | 1905 | 2043 | 2027 | 1968 | 2475.7 | 2327.3 |
| Total water consumption | 12287.8 | 13380.9 | 12826.3 | 13648.2 | 15158.7 | 15272.6 |
| Change in moisture reserves in the aeration zone* | -219.6 | -191.4 | -219.6 | -264.6 | -197.1 | -281.4 |

| Water consumption, m³/ha | | | |
|---------------------------|-----------------|-----------------|-----------------|
| Maintaining a water layer | 2400 | 2900 | 2400 | 2900 | 2400 | 2900 |
| Filtration (F_v+F_h) | 1922 | 1954.3 | 2087.3 | 2077 | 2459.3 | 2397.3 |
| Transpiration + evaporation | 3521 | 3401.7 | 3895.7 | 3656.4 | 4478 | 3697.4 |
| Leakage loss | 521.5 | 545.9 | 578.9 | 579.3 | 669.2 | 691.6 |
| Flowrate | 477 | 496.5 | 526.2 | 526.7 | 608.5 | 599.8 |
| Process water discharge | 3400 | 3900 | 3400 | 3900 | 3400 | 3900 |
| Total | 12461.1 | 13389.8 | 13107.7 | 13904 | 14212.1 | 14467.5 |
| Residual, m³/ha | -173.3 | -8.9 | -879.4 | -255.8 | +946.6 | +805.1 |
| Residual, % | 1.4 | 1.9 | 2.2 | 1.9 | 6.2 | 5.3 |

Most of the irrigation water is used to create the necessary water layers in rice paddy. The highest irrigation rate in case of intermittent flooding of the “Lugovoy” cultivar is 12,945 m³/ha, and the smallest value with the “Kaskad” cultivar is 10,382.8 m³/ha.

In terms of water balance of the rice paddy map, evaporation and transpiration vary from 3401.7 m³/ha (intermittent flooding with the “Kaskad” cultivar) to 4478 m³/ha (short flooding with the “Lugovoy” cultivar).

Water losses due to leakage through water discharge outlets depend on their structure and technical condition. Due to leaks between 521.5 and 691.6 m³/ha were lost. The water flow through the rice paddies creates simultaneous supply of irrigation water to the paddy and its discharge through the back-end outlet. As a rule, the water flow is set up in order to reduce the salinity of the flooded layer on saline lands or to reduce the water temperature in the paddy. Since the soil on the experimental rice paddies is not saline, the water flow rate through on non-saline soils is assumed to be 10% of the total. Water consumption flow rate comprised between 477 and 608.5 m³/ha.
To ensure a specific irrigation mode, process water discharge is produced in case of a decrease and discharge of the flooding layer or in case of heavy precipitation. Amurskaya oblast is characterized by an uneven distribution of precipitation, when occasionally there are years with heavy rainfall and vice versa. In this regard, depending on the amount of precipitation, the need for process water discharge either manifested or not. On average, over the entire vegetation period, the volume of process water discharge ranged from 3,400 to 3,900 m³/ha over the years of research.

The maintenance of the water layer in rice paddies is equally important. With short flooding option, the water consumption was 2400 m³/ha. As for the intermittent flooding, water consumption increased to 2,900 m³/ha, which resulted from an increase in the flooding layer and the timing of paddies’ flooding.

Another item in the water balance data is the change in moisture reserves in the aeration zone. Despite the fact that the water consumption here is not significant (191.4-281.4 m³/ha), this number is of great importance. Over the years of research, the change in soil moisture reserves takes on a negative value.

The difference between the inflow and consumption parts of the water balance is the residual, which must be below 10% [10]. According to our calculations, the residual ranged from 1.4 to 6.2%, which indicates the reliability of the calculations.

With surface flooding the transpiration ratio becomes a very important indicator as it enables us to evaluate the effectiveness of a particular irrigation practice. As a rule, the higher the yield is, the more efficiently irrigation water is consumed. This is evidenced by the correlation analysis of the transpiration ratio and rice yield (figure 3).

![Figure 3. The dependence of the transpiration ratio of rice on yield.](image)

The correlation ratio is 0.92. There is a strong link between yield and water consumption. Our research has shown that the short flooding option is considered to be the most effective with “Kaskad” and “Rassvet” cultivars (the transpiration ratio was 704-866 m³/t), and with “Lugovoy” cultivar the most effective was intermittent flooding, where the transpiration ratio was 999 m³/t.

Research results indicate that the average rice yield using short flooding was 4.3 t/ha, with the maximum being 5.0 t / ha (“Kaskad”), and the minimum 3.5 t / ha (“Lugovoy”) (table 2).

| Irrigation practice | "Kaskad" | "Rassvet" | "Lugovoy" |
|--------------------|----------|-----------|-----------|
| Option 1 - Short flooding (sowing 0.12 m once, shoots 0.12 cm up to tillering, 0.05 m 12 days, 0.15 m up to the milky) | 5.0 | 4.5 | 3.5 |

Table 2. Influence of irrigation practices on the rice yield, t/ha, average over 2014-2016.
stage of ripening)

| Option 2 - Intermittent flooding (after sowing 0.10 m for 10 days, after germination of 0.07 m for 2-3 days, when 2-3 leaves appear 0.12 m layer up to tillering, 0.05 m for 10 days, 0.15m to the end of milky stage of ripening) | 4,6 | 4,2 | 3,7 |

LSD_{0.05} = 0.26; LSD_{0.05A} = 0.155; LSD_{0.05B} = 0.190

To sum up, the suggested rice irrigation practices using surface flooding provide stable grain yield of 4.5-5.0 t/ha and prove the rational use of water resources in the southern part of Amurskaya oblast.

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