Impact of impulse irrigation in different phases of the growing season on rice yield in the Krasnodar Territory

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Abstract. The article presents a study of water consumption of rice crops during periodic watering in various interphase periods of the growing season. The experiments were carried out on a plot of 21.2 hectares in the rice-growing enterprise RBF "Krasnoarmeysky", geographically located on the Kuban rice irrigation system. The object of the study was an intensive variety of Rapan rice of Russian selection. The subject of the study was the water regime during the growing season of rice. It was found that the transition to intermittent irrigation during the growing season of rice "germination-tillering", "tying-flowering" and "ripening" allowed to reduce the irrigation rate by 2122.83, 949.66 and 279.32 m3/ha, or by 11.4, 5.1, 1.5%, respectively, compared to traditional methods of rice irrigation. The results of harvesting rice grains showed that the average yield according to the experiment was 75.7 c/ha, which is more than in the control by 1.2 c/ha. Additional profit from the increase in yield on the experimental variants ranged from 1,440 rubles/ha to 2,880 rubles/ha, net profit - from 480 rubles / ha to 960 rubles/ha.

1 Introduction

Sustainable management of agricultural land and water resources is fundamental to food security, both globally and regionally, especially in the face of climate change and increasingly unstable weather events. This helps boost agricultural production and food security while conserving natural resources.

The Krasnodar Territory, despite the favorable natural conditions for the cultivation of agricultural crops, is a zone of unstable moisture; therefore, land reclamation for the region is relevant. Nevertheless, limited water resources dictate the need to introduce technologies

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on agricultural lands aimed at rational water use without reducing the productivity of crops [1].

The most water-demanding crop in the region is rice, which is cultivated on reclamation systems in the lower river flow of Kuban. Rice is planted annually on about 125 thousand hectares, which is about 53% of the crop rotation, for which about 2.5 billion m^3 of water is used, including 502.8 million m^3 of recycled water from the collector-drainage network (Figure 1).

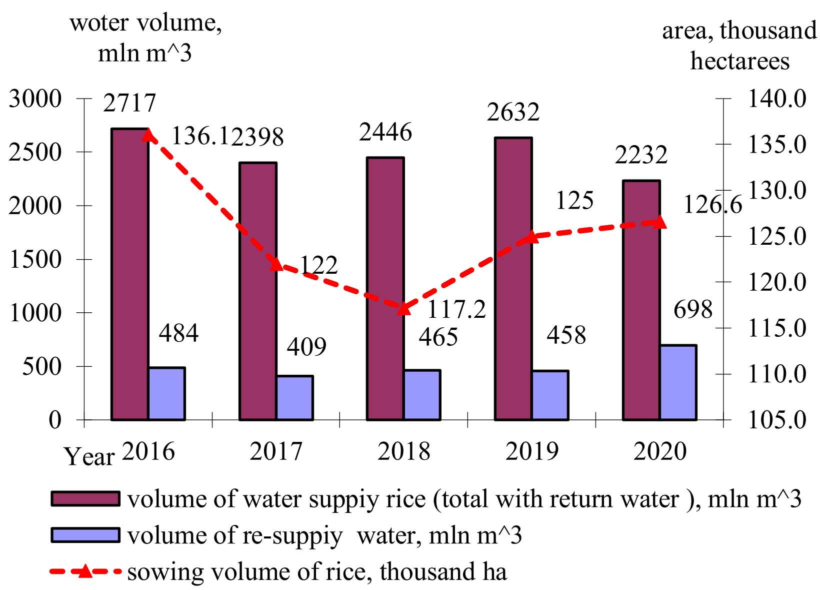

Fig. 1. The volume of water supply for rice crops in the Krasnodar Territory, 2016-2020.

The analysis shows that the irrigation rate for rice is quite high and on average for the reclamation systems of the Krasnodar Territory is 19.9 thousand m^3/ha with the maximum value over the past 5 years of 21.1 thousand m^3/ha (Figure 2).

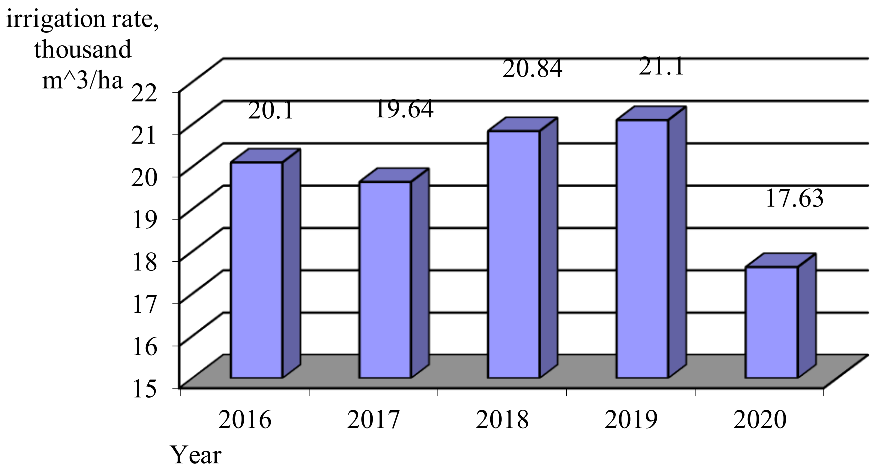

Fig. 2. Irrigation rate for rice in the Krasnodar Territory, 2016-2020.

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2 Material and research methods

The object of research was the intensive rice variety Rapan of the Russian selection, which occupies 65% of the cultivated area in the region. The subject of research is the water regime of the rice field during the growing season.

The studies were carried out in a dry year of 2020 at the RBF Krasnoarmeisky Rice Plant, located in the Kuban rice irrigation system. The total area of the experimental plots was 21.2 hectares. Direct sowing of rice into dry soil was used with further water supply and provision of the water regime for the rice field according to the options of the experiment. Care work during the growing season was carried out in accordance with varietal agricultural techniques recommended by the originator of the variety.

The irrigation regime in the control option corresponded to the technology of shortened flooding, that is widespread in the rice-growing enterprises of the Krasnodar Territory. In the experimental options, the impulse "watering-draining" was carried out in the following phases of the growing season of rice plants: "germination-tillering", "booting-flowering", "grain pouring - ripening". To ensure measurements of the flow rates of the supplied water, topographic survey was carried out on the elements of the irrigation system with the

CST/bergner BOSCH SAL 24X optical leveling device in order to determine the marks of checks and heads of water outlets. To determine the flow rates and volumes of supplied water in all checks, water gauge rods were installed on the check water outlets and structures in the cart sprinkler. In the experiment, the check flooding time was determined, as well as the time of the flooding layer activation.

The harvesting of grain was carried out with small-sized equipment; the crop accounting was carried out according to the methodology of the profile scientific and technical center of rice (Krasnodar). The flow rate characteristic of the water outlets from the sprinkler to the check was determined by calculation according to the methodology of the Kuban State Agrarian University by means of in-situ measurements of water flow rates at various hydraulic pressures on the structure.

3 Results and discussion

During the experiment, the volumes of water supply were established for constant and intermittent flooding. The impulse parameters were determined, including the check flooding time, the drying time and the duration of the inter-impulse period.

During the growing season, according to the scheme of the experiment, 1-2 impulses were carried out. The average value of the check flooding duration was 2-3 days, the check drying time was 10-12 days, and the inter-impulse period was 5-10 days.

It is known that rice is sensitive to unsaturated soil conditions (Bouman and Tuong, 2001), which requires maintaining the maximum moisture capacity of the soil on the check with periodic irrigation of at least 85% [4, 5]. This is consistent with our experimental results. The moisture content of the surface-exposed soil between impulses varied from 100 to 85% of the maximum moisture capacity (MMC). When the maximum soil moisture content of 85% was reached, the water outlet on the structures was opened from the sprinkler to the check for the next impulse of water supply. This prevented rice crops from excessive drying out and excessive loss of water in the soil, as well as its shrinkage during irrigation [6].

According to the data of measurements and calculations carried out during the growing season of rice in the experiment, the irrigation rate in the control option of the experiment was 18621.03 m^3/ha, while maintaining the intermittent irrigation regime during the period of "germination-tillering" it was 16498.20 m3/ha, during the period of "booting - flowering" it was 17671.37 m^3/ha, and during the period of "ripening" it was 18341.71 m^3/ha (Table 1).

Table 1. Water supply and irrigation rate for rice, m^3/ha.

Experiment option	Check area, ha	Water supply volume, m^3	Irrigation rate, m^3/ha	+/- to control, m^3/ha
Control option	6.0	111726.15	18621.03	-
"Germination-tillering" impulse	5.2	85790.64	16498.20	2122.83
"Booting-flowering" impulse	4.2	74219.74	17671.37	949.66
"Ripening" impulse	5.8	106381.89	18341.71	279.32

Thus, the transition to intermittent irrigation during the growing season of rice "germination-tillering", "booting-flowering" and "ripening" made it possible to reduce the irrigation rate by 2122.83, 949.66 and 279.32 m3/ha, or by 11 , 4, 5.1, 1.5%, respectively.

The result of work in crop production is a gross grain harvest, which depends on the yield of the crop per unit area. It has been proven that the yield of any crop, including rice, is an integral indicator and depends on many factors, both agronomic and soil-climatic [7, 8]. Nevertheless, in rice growing, the irrigation regime of the rice field, as an element of rice cultivation technology, plays an essential role, providing the physiological need of plants for water, due to the genetic characteristics of the crop.

In our experiment, the results of harvesting rice grain showed that the average yield in the experiment was 75.7 c/ha, which is more than in the control option by 1.2 c/ha (Table 2).

Table 2. Rice grain yield of Rapan variety under different irrigation regimes.

Experiment option	Index		
	Area, ha	Gross harvest, c	Yield, c/ha
Control option	6.0	447.0	74.5
"Germination-tillering" impulse	5.2	395.7	76.1
"Booting-flowering" impulse	4.2	317.5	75.6
"Ripening" impulse	5.8	436.7	75.3
Least significant difference LSD_{05}			5.23

Analysis of the data in Table 2 shows that the minimum yield value was observed in the control option with the shortened irrigation regime - 74.5 c/ha. In experimental options with intermittent irrigation during the growing season "germination - tillering", "booting - flowering", "ripening" the value of the yield indicator practically did not differ, amounting to 76.1 c/ha, 75.6 c/ha and 75.3 c/ha, respectively. Interruption differences in comparison with the control ranged from 0.8 c/ha to 1.6 c/ha (1.0% - 2.1%). Nevertheless, the experimental data on the yield of 75.3 c/ha obtained in our experiment, which is more than in the control by 0.8 c/ha, with the impulse during the ripening of rice grain, is consistent with the results of studies by Yang and Zhang (2006, 2008) and Lee et al. (2016), who indicate that drying the soil during the grain loading phase can increase yields by promoting faster carbon mobilization and larger roots for maximum nutrient uptake.

In addition, statistical data on rice yield in the Krasnodar Territory in 2020 can also serve as a confirmation of the effectiveness of impulse irrigation, especially during the period of grain ripening (Figure 3).

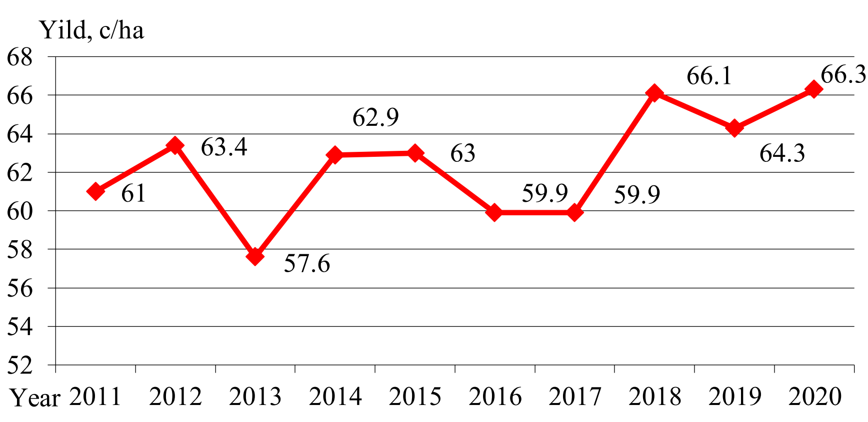

Fig. 3. Rice yield in the Krasnodar Territory, 2011-2021.

Despite the lack of water and minimal volumes of water intake for the needs of agricultural water supply, the introduction of intersystem water rotations from the beginning of the vegetation season, which ensured the regime of irrigation of rice throughout the vegetation season according to the system of alternate wetting (irrigation) and drying (Alternate Wetting and Drying (AWD) [7-10], and the complete cessation of water supply in the second decade of August during the period of grain loading and ripening, the region obtained record yield in the entire history of rice growing in the Kuban region of 66.3 c/ha, which is by 2.0 c/ha more than in 2019, when the irrigation regime for rice was not violated, and water supply was carried out stably throughout the growing season, according to water use plans.

Any agricultural technique used in rice production technology must be economically justified. The efficiency of agricultural activities requires economic feasibility. Economic efficiency is determined by comparing the obtained effect (result) with the used resources or costs with the results from the sale of the obtained products [7, 11-15].

In this regard, there was calculated the economic efficiency of the applied irrigation regimes with impulse water supply in different phases of rice plant development, which consisted of increase in yield according to the experimental options and irrigation water saving (Table 3).

Table 3. Economic efficiency from the increase in yield according to the options of the experiment.

Experiment options	Increase in yield to control option t/ha	Additional profit RUB/ha	Costs for the production of additional yield, RUB/ha	Net profit RUB/ha
"Germination-tillering" impulse	0.16	2880	1920	960
"Booting-flowering" impulse	0.11	1980	1320	660
"Ripening" impulse	0.08	1440	960	480

So, at the prime cost of 1 ton of rice in the "Krasnoarmeisky" rice-growing enterprise, on the basis of which the research was carried out, of 12.0 thousand RUB/t, the net profit compared with the control option was 960 RUB/ha at the “germination-tillering” impulse, at the “booting - flowering " impulse it was 660 RUB/ha and at the "ripening" impulse it was 480 RUB/ha.

Irrigation water saving is also economically beneficial for rice-growing farms, since at present in Russia, enterprises engaged in the production of rice pay for services for supplying water to engineering rice irrigation systems of the operating organization, including for electricity when supplying water to fields mechanically using pumping and power equipment. The estimated value of the cost of 1 m3 of water on average for reclamation systems is 0.25 RUB.

Based on the indicators of the irrigation rate in the experimental options comparing with the control option, the financial savings for rice production were calculated and range from 69.83 RUB/ha with the impulse during grain ripening up to 530.71 RUB/ha with the impulse during the "germination-tillering" phase development of plants (Table 4).

Table 4. Financial costs saving for paying for water supply services.

Experiment option	Irrigation rate, m^3/ha	+/- to control, m^3/haa	Cost savings on payment for water supply, RUB/ha
Control option	18621.03	-	-
"Germination-tillering" impulse	16498.20	2122.83	530.71
"Booting-flowering" impulse	17671.37	949.66	237.42
"Ripening" impulse	18341.71	279.32	69.83

Thus, the calculations reveals that the total economic effect from the introduction of the irrigation regime into production in different interphase periods of rice growing will be from 549.83 RUB/ha to 1490.71 RUB/ha (Table 5).

Table 5. Economic efficiency of using impulse irrigation in different phases of growth and development of rice plants.

Experiment options	Net profit from an increase in yield, RUB/ha	Cost savings on payment of services for water supply, RUB/ha	Total, RUB/ha
Control option	-	-	-
"Germination-tillering" impulse	960	530.71	1490.71
"Booting-flowering" impulse	660	237.42	897.42
"Ripening" impulse	480	69.83	549.83

The results of experiments and calculations show that it is most advisable to use impulse irrigation of rice in the phase of "germination-tillering" development of rice plants, while receiving not only increase in yield and saving water resources, but also an economic effect, reducing the cost of crop production and receiving additional profit.

4 Conclusion

Studies have shown that the use of intermittent irrigation in different interphase periods of rice growing with soil moisture at the end of each impulse of at least 85% MMC does not adversely affect the growth, development of plants and the yield of rice grain. In the control option with shortened flooding, the average yield was 7.45 t/ha, on impulse irrigation during the "germination - tillering" period it was 7.61 t/ha, during the "booting - flowering" period it was 7.56 t/ha, during the "ripening" period it was 7.53 t/ha.

With the impulse irrigation regime, the saving of irrigation water was revealed, which does not reduce the productivity of plants and the yield of rice. The irrigation rate in the control option was 18621.03 m^3/ha, in the experiment with the impulse in different phases of growth and development of rice plants: "germination-tillering", "booting-flowering" and "ripening" it was 16498.20 m^3/ha, 17671.37 m^3/ha and 18341.71 m^3/ha, respectively. Saving of irrigation water, depending on the applied combined irrigation regime, varied from 949.66 m^3/ha to 2122.83 m^3/ha.

It was revealed that the additional profit from the increase in yield on the options of the experiment ranged from 1440 RUB/ha to 2880 RUB/ha, net profit ranged from 480 RUB/ha to 960 RUB/ha. In addition, savings in financial resources for payment for services for water supply will amount to 69.83 RUB/ha to 530.71 RUB/ha. The total economic effect from the introduction into production of the impulse irrigation regime for rice in various interphase periods ranges from 549.83 RUB/ha to 1490.71 RUB/ha.

Nevertheless, when summing up the results of the experiments, it must be said that despite the positive result for all options of the experiment, in which the yield was not lower than in the control option, it is necessary to conduct additional studies in various soil and under ameliorative conditions on various irrigation systems, which are characterized by the variety of agricultural landscapes. It is quite possible that the conclusions on the application of the indicated impulses of drying and irrigation of rice can be adjusted depending on the properties of soils, hydrological conditions, the level of salinity of groundwater, cultivated varieties of rice and other factors.

These results demonstrate that irrigation of rice using impulse water supply at different periods of plant growth and development is the promising practice in water management. However, it should be borne in mind that saving water resources is not an end in itself, and it should affect the overall increase in rice production in the region through the introduction

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of additional irrigated land due to the saved water. Otherwise, the strategy of saving water in rice production at the level of individual fields of rice cultivation enterprises and farms could potentially reduce rice production in general.

References

1. N. Malysheva, A. Khadzhidi, E. Kuznetsov, N. Sharaby, A. Koltsov, E3S Web of Conferences **175**, 01006 (2020) https://doi.org/10.1051/e3sconf/202017501006.
2. M. A. Bandurin, A. A. Solodunov, Journal of Physics: Conference Series **1661(1)**, 012027 (2020)
3. A. A. Solodunov, M. A. Bandurin, IOP Conference Series: Earth and Environmental Science **720(1)**, 012081 (2021)
4. B. A. M. Bouman, T. P. Tuong, Agricultural Water Management **1615**, 1-20 (2000)
5. N. Malysheva et al., E3S Web of Conferences **210**, 04006 (2020) https://doi.org/10.1051/e3sconf/202021004006.
6. Geethalakshmi, T. Ramesh, A. Palamuthirsolai, Lakshmanan, Arch. Agron. Soil Sci. **57**, 159-166 (2011)
7. L. L. Nalley, B. Linquist, K. F. Kovacs, M. M. Anders, Agron. J. **107**, 579-587 (2015)
8. B. A. M. Bouman, R. M. Lampayan, T. P. Tuong, Water Management in Irrigated Rice: Coping with Water Scarcity (International Rice Research Institute, Los Baños, Philippines, 2007)
9. P. L. C. Paul, M. A. Rashid, Bangladesh Rice J. **17**, 37-41 (2013)
10. F. Yao, J. Huang, K. Cui, L. Nie, J. Xiang, X. Liu, W. Wu, Field Crops Res. **126**, 16-22 (2012)
11. H. Purwono, и A. Aprianto, Geoplanning: Journal of Geomatics and Planning **5**, 237-250 (2018) https://doi.org/10.14710/geoplanning.5.2.237-250
12. R. G. Joergensen and C. Emmerling, J. Plant Nutr. Soil Sci. **169**, 295–309 (2006) doi: 10.1002/jpln.200521941
13. S. Pandey, T. Sulser, M. W. Rosegrant, H. Bhandari, Asian Journal of Agriculture and Development 7(21) (2008)
14. V. N. Parashchenko et al., V.N., Recommendations for the use of fertilizers, ameliorants and other agrochemicals in rice cultivation (FASO RUSSIA, FSBSI "All-Russian Research Institute of Rice", Krasnodar, 2016)
15. A. K. Sheudzhen et al., Soil productivity of rice agricultural landscapes depending on their ameliorative state. Polythematic Network Electronic Scientific Journal of the Kuban State Agrarian University (2017)