Development of modern technology of rice cultivation on rice engineering irrigation systems in the Krasnodar Territory

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Abstract. Rice irrigation systems are complex engineering structures, the main task of creating favorable conditions for growing rice. This situation poses a challenge for the workers of the rice-growing sector in Russia to create effective and modern engineering irrigation systems that will reduce the anthropogenic load and generally improve the ecological and reclamation situation in the ecosystem of the rice irrigation system. Consequently, our research on the development of new rice engineering systems is relevant, and their widespread implementation will strengthen the food security of Russia. The developed technology of rice cultivation has shown its effectiveness on the rice irrigation system at LLC "Chernoerkovskoye" of the Slavyansky District of the Krasnodar Territory. The effectiveness of the proposed technology was expressed in improving the reclamation state of soils, reducing the irrigation rate by more than five times, increasing the biometric indicators of rice plants and the quality of the resulting rice grain. The research carried out makes it possible to "level" the gap between scientific and technical achievements in the construction of irrigation systems and their practical implementation in production, facilitating the exchange of new experience and improving the professional level of workers in the agro-industrial complex. In turn, the accumulation of production experience will make it possible to update the regulatory and technological framework for rice production to make timely management decisions and obtain guaranteed high yields of high-quality rice grain.

1. Introduction

The northernmost rice in the world is grown in Russia [1]. In this connection, technology and rice breeding issues have always been relevant and supported at the regional and federal levels [2]. However, the technology change is associated with many problems that prevent new technologies from replacing resource-intensive traditional rice cultivation technologies by flooding. The reasons are the "ossification" of the entire system of rice production, the high cost of construction and/or reconstruction of existing rice engineering systems, as well as the risks of complete or partial loss of yield [3-5].

Our research "relied" on the best world experience in rice cultivation [6-10]. Analysis of existing modern technologies of rice cultivation showed that the most effective and modern technology is drip irrigation of rice, which has been successfully used for more than ten years in China [11-12]. In Russia, research on the introduction of technologies for growing rice on drip irrigation in the Krasnodar Territory, Volgograd, and Rostov Regions was carried out by scientists: I.P. Kruzhilin, N.N. Dubenkom M.A. Ganiev, K.A. Rodin, and others researchers [13-16] proved the effectiveness of the development of technologies for drip irrigation of rice in Russia. In this regard, the development of
new engineering systems for drip irrigation through the construction of new or reconstruction of existing amelioration systems is a promising and urgent direction.

Development of new or optimization of modern engineering irrigation systems already tested in Russia will allow accumulating sufficient production experience to develop automated information and reference systems implemented in the form of software, which will be based on multilevel simulation models [17]. Such a decision will ensure that Russia reaches a new level in agricultural production while guaranteeing food security in Russia and making it a leading exporter of high-quality agricultural products in the world market without reducing the agro-resource potential of agricultural lands [18].

2. Materials and methods

For the implementation of the project for the construction of an engineering irrigation system for drip irrigation of rice on the checks of the rice irrigation system, we have developed a technological scheme of one capture, taking into account the technical characteristics of soil cultivation and harvesting equipment at OOO Chernoerkovskoye, Slavyansky district of Krasnodar region (Figures 1-3)

![Figure 1](image.png)

Figure 1 – Technological one capture taking into account the technical characteristics of soil cultivation and harvesting equipment in LLC "Chernoerkovskoe" of the Slavyansky district of the Krasnodar Territory when cultivating rice and related crops of rice crop rotation on underground drip irrigation with laying an underground drip hose and/or tape to a depth of 0.18 m for mulching films, including biodegradable ones: 1 – underground drip hose and/or tape; 2 – technological passage; 3 – round perforation in the mulch film for planting crops; 4 – mulching film; 5 – technological passage; 6 – ridge

The technology of rice cultivation on underground drip irrigation under polyethylene and biodegradable mulch perforated film was carried out as follows.

In the autumn, in the first year of the implementation of the method of rice cultivation on the lands of the irrigated rice fund with underground drip irrigation under polyethylene and/or biodegradable mulching perforated film, preliminary, after harvesting the predecessor, one-time cutting and restoration of peripheral check grooves with a depth of 0.4-0.6 m, leveling the surface of checks, basic tillage to a depth of 0.25-0.30 m, cleaning of irrigation and waste canals, filling check rollers up to the design marks, deep loosening (chiseling) to a depth of 0.16-0.18 m, disking with the incorporation of organic fertilizers to a depth of 0.10-0.12 m with an application rate of 40-50 tons per hectare of manure or green fertilizer.

In the spring of the first year of implementing the method, harrowing is performed with tooth harrows in two tracks to a depth of 0.08 m. Then ridges are formed by making depressions in the form of inter-ridge technological passages and passages covered with non-woven geosynthetic material. At the same time, the dimensions and distance between the ridges depend on the technical characteristics of the technique used for the cultivation of rice and related crops of rice crop rotation.
Figure 2 – Fragment of the central part of the technological scheme of one capture, taking into account the technical characteristics of soil cultivation and harvesting equipment in LLC Chernoerkovskoye, Slavyansky District of Krasnodar Territory when cultivating rice and related crops of rice crop rotation on underground drip irrigation with laying an underground drip hose and / or tape to a depth 0.18 m for mulching film, including biodegradable one: 1 – underground drip hose and / or tape; 2 – technological passage; 3 – round perforation in the mulch film for planting crops; 4 – mulching film; 5 – technological passage; 6 – ridge
Figure 3 – Fragment of the left part of the technological scheme of one capture, taking into account the technical characteristics of soil cultivation and harvesting equipment at LLC "Chernoerkovskoye" of the Slavyansky district of the Krasnodar Territory when cultivating rice and related crops of rice crop rotation on underground drip irrigation with laying an underground drip hose and / or tape to a depth 0.18 m for mulching film, including biodegradable one: 1 – drip tube; 2 – technological passage; 3 – round perforation in the mulch film for planting crops; 4 – mulching film; 5 – technological passage; 6 – ridge

Then, the main line and underground hoses and / or drip irrigation tapes are laid to a depth calculated taking into account the height of beds 6 and the depth of the root system of rice crop rotation for up to eight years inclusive, while the location of underground hoses and / or drip irrigation belts should not be below the base of the ridge and not above the middle of the root system of rice crop rotation, and also not above the depth of soil cultivation, the step between the outlets of underground hoses and / or drip irrigation tapes is 20 cm, the diameter and thickness of the walls of the underground drip hose and / or tape is 16 mm and 0.9 mm, respectively, and the water outflow of the underground drip hose and / or tape in l / h per 1 m is taken from the condition of ensuring the required moisture content in a given soil layer for rice crop rotation, while the distance between
underground drip hoses and / or tapes is 48 cm, and the laying of the underground drip hose and / or tape is carried out in compliance with the condition of soil moistening in the root a broken layer with one underground drip hose and / or tape of two rows of perforations on a mulching film, the perforation diameter being 8 cm, the distance between which in a row and between adjacent rows is 28 cm and 24 cm, respectively.

Next, an annual spring-autumn technological cycle of work is performed, including:
- rolling the soil of the ridges;
- growing rice seedlings in an amount of 1 to 4 plants in one nutrient pot with a diameter of 8 cm, in the substrate, the components of which: highly fertile field soil, sod land, hummus, high peat, coarse sand are taken in such a ratio that the humus content in the substrate is not below 60%, substrate density – 0.8-1.0 g / cm³, porosity – 80-90%, air content – not less than 15-20% with the addition of microelements to the substrate before planting rice seeds in the amount of 75% of the full norm N\textsubscript{150}P\textsubscript{60}K\textsubscript{45} in kg a.i. / ha and one top dressing with nitrogen fertilizers in the phase of 2-3 leaves with a rate of N40 in kg a.u. / ha, maintaining the temperature regime during the growing period of seedlings: during the day 24-26°C, in cloudy weather – 20-22°C, at night – 18-20°C, optimum pre-irrigation substrate moisture content at 80% of the lowest moisture capacity, relative air humidity – 70-80% and illumination: the first three days, additional illumination time 24 hours, after the third day – at least 12-14 hours depending on the light nva and weather conditions;
- pre-planting watering before planting rice with a rate that provides soil moisture of 90% of the lowest moisture capacity in a layer of 0.6 m;
- soil surface treatment with soil herbicides; covering the ridges with a perforated mulch film;
- planting rice seedlings in perforation 3 mulching films 4 in the phase of 6-7 leaves with a green color, a well-developed root system and not infected with pests and diseases, while 1-2 days before planting rice seedlings in open ground, the seedlings are sprayed with biologically active substances;
- drip irrigation of rice through a system of underground drip irrigation during the growing season of rice with the frequency and rate of irrigation, depending on compliance with the condition of ensuring constant soil moisture of 80% of the lowest moisture capacity in a layer of 0.4 m;
- application of 25% of the full norm of mineral fertilizers with two equal norms of N\textsubscript{25}P\textsubscript{20}K\textsubscript{15} in kg a.i. / ha in the phase of 8-9 leaves after complete survival and the tillering phase by the fertigation method through the underground drip irrigation system, while the full rate can be adjusted from the recommended depending on the agricultural background and the adopted crop rotation;
- processing of rice plants: with pesticides in the tillering phase, biologically active substances at the end of the tillering phase before the start of stemming; twice with fungicides in the phase of emergence into the tube and again after 20–25 days, with insecticides during the growing season when pests exceed the economic threshold of harmfulness;
- rice harvesting;
- pre-planting irrigation before planting accompanying crops of rice crop rotation with the provision of moisture and depth of soil moisture necessary and sufficient for planting a culture through an underground drip irrigation system with the introduction of mineral fertilizers, the rates and timing of which are taken in accordance with the adopted technology for the production of this crop;
- growing seedlings and / or planting accompanying crops of rice crop rotation with the introduction of mineral fertilizers, treatment of crops with pesticides, fungicides and insecticides, the rates and timing of which are taken in accordance with the adopted technology for the production of this crop;
- drip irrigation of rice crop rotation through the system of underground drip irrigation during the growing season with the frequency and rate of irrigation, depending on the compliance with the conditions for providing in the required culture production technology a layer of soil necessary for the normal development of soil moisture culture;
- harvesting of crops of rice crop rotation, after which a mulching perforated film is collected from the ridges, and in the case of using a biodegradable mulching film, it is left on the ridges;
- peeling in two tracks to a depth of 0.06–0.08 m.
In the spring, in subsequent years of rice cultivation, the geometry of the ridges is restored with loosening to a depth of 0.06–0.08 m of the upper layer of the ridges. After this process, the annual spring-autumn technological cycle of work is repeated.

3 Results and its discussion

An engineering project for the construction of a drip irrigation system for rice under a mulching film on a rice irrigation system was tested at LLC "Chernoerkovskoye" of the Slavyansk region (2nd department) of the Krasnodar Territory on an area of 4.5 hectares (one rice check). The farm uses the scheme of an engineering rice plot of the Krasnodar type. The cultivated rice crop was the Rapan variety. The predecessor in the first year of the implementation of the method is rice.

On the experimental field from 2016 to 2019, the following crop rotation was applied: 2016: rice (seedlings) + melon (seedlings); 2017: rice (seedlings) + chickpeas (seed); 2018: rice (seedlings) + tomatoes (seedlings); 2019: rice (seedling) + vetch (seed).

The implementation of the project is based on the use of a simulation model developed by us for the economic substantiation of environmental protection measures on a rice irrigation system and a mathematical model of the optimal volume of measures planned for implementation [19-20]. The use of simulation and mathematical models made it possible to develop an optimal-adaptive technological map taking into account all the technical and technological, energy, material, labor resources available in the economy, as well as taking into account the climatic conditions and soil reclamation parameters. This approach allowed the farm to "smoothly" switch to resource-saving technology, the use of which ensured effective resource management, reduced negative load on the ecosystem of the rice irrigation system, improved the quality of the obtained grain, and improved the reclamation state of the soils of the reclamation system. As a result of the approbation of the method of rice cultivation on drip irrigation in LLC "Chernoerkovskoe" of the Slavyansky district, with an area of 4.5 hectares for 2016–2019, managed to prove the efficiency of rice cultivation (Figures 4-6), which is expressed by the improvement of the following indicators: rice yield reached 6.3 t / ha, total porosity increased by 15%, structural coefficient increased from 0.95 to 1.19, soil density decreased from 1.41 to 1.28, the acid-
The base properties of the soil changed from slightly acidic – 6.8 to neutral – 7.0, the content of the main macronutrients in the soil increased: hydrolyzable nitrogen by 13.2%, mobile phosphorus by 25.5%, mobile potassium by 33.3%, the content of trace elements in the soil increased: manganese Mn by 20.8%, copper (Cu) by 38.1%, zinc (Zn) by 50%, cobalt (Co) by 40%, molybdenum (Mo) by 31.8%.

![Figure 5. Dynamics of humus recovery when using drip irrigation of rice](image1)

![Figure 6. Dynamics of changes in the content of macroelements (NPK) in the arable horizon when using drip irrigation of rice](image2)

The effectiveness of the introduction of new technologies for rice cultivation was also expressed in the improvement of the biometric and quantitative characteristics of rice in comparison with the adopted technology (control). Thus, the number of spikelets in a panicle increased by 5%, the total number of grains per plant – 65%, the survival rate of rice culture was 100%.

The proposed technology allows obtaining programmed-high yields of high-quality rice grain.
without reducing the reclamation state of the soil, and reducing of the following:
- the irrigation rate by an average of 5 times relative to the traditional technology of rice
cultivation by flooding;
- labor intensity by 40%;
- the cost of rice production by an average of 30%;
- doses of macro and microelements introduced by an average of 25%, as well as to increase the
profitability of rice production by 26%.

4 Conclusion
The developed engineering irrigation system makes it possible to cultivate elite rice varieties, which
provides 100% of the farm’s own needs in seed and allows receiving super profit from its sale. Further
replacement of traditional technologies of rice cultivation by flooding with modern engineering
irrigation systems for drip irrigation of rice will free up a large number of resources, will allow the
development of fundamentally new rice crop rotations with the inclusion of melons and vegetables in
them, and will also enable workers of the agro-industrial complex to grow rice on previously non-
irrigated lands.

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