Development of best environmentally avallable rise irrigation technology

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Abstract. Research is aimed at developing the best environmentally available rice irrigation technology that provides normal physiological indicators of the growth and development of rice plants while maintaining favorable salt and thermal regimes of soil and water. The research study was based on certified methodological guidelines and standards. The agricultural rice production practices in the experimental plots corresponded to the recommendations of the LLP Kazakh Research Rice Institute.According to preliminary calculations, by more than 15-20% of the required amount of water is used for irrigation which leads to a deterioration of ecological and reclamation conditions and a diminished performance of the irrigated hectare.Saving of irrigation water on the recommended option for intensive rice varieties averaged 3,550 m^3/ha; it allowed to reduce irrigation water intake by 273 million m^3 of water per year in the course of the current rice land under cultivation - 77,000 ha.

1 Introduction

In his annual message to the people of Kazakhstan, Head-of-the-State Nursultan Nazarbayev called for the introduction of innovative technologies to achieve world standards in agriculture in Kazakhstan. Nazarbayev also gave evidence of the need to use environmentally friendly technologies in agriculture. “According to the adopted Concept for the transition to "green" economy by 2030, 15 percent of the lands under cultivation will be transferred to water-saving technologies [1]. Water is a necessary source of normal functioning of all ecosystems of the Earth.

Topicality of the research is determined by the utmost significance of water saving and improving the ecological and reclamation state of the lands. The Kyzylorda region is the main area of rice growing, since it accounts both for over 80-85% of the total rice lands under cultivation of this crop and accounts for about 90% of the total rice crop in Kazakhstan [2,3].

In this regard, one of the most important challenges of reclamation science is the development and implementation of water-saving technologies aimed at increasing the efficiency gains for irrigation water use in the practice of irrigated agriculture [4-12].

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By its biological characteristics a rice plant requires a constant layer of water during a significant part of the growing season, but its need for depth in development phases is not the same, especially in varietal section. Maintaining a different layer of water in checks is associated with the full supply factor of irrigation water. The solution to this problem should be carried out taking into account the biological capabilities of cultivated rice varieties [13].

The practical significance lies in the fact that the development of the environmentally available rice irrigation technology by maintaining the optimum water layer depth in checks for the phases of rice plant development which provide the most favorable conditions for the growth and formation of a high yield for intensive cultivars will allow to get significant irrigation water savings, to improve reclamation condition of rice fields and to create the ecological and reclamation situation of irrigated lands.

The scientific significance of the research is to identify the optimal water depths according to the phases of development and their influence on the irrigation rate, water and salt regimes of soils, yield of varieties of intensive type rice; development of optimal parameters for irrigation technology of paddy rice varieties.

2 Research Methodology

Field studies were carried out on rice crop rotation plots of the experimental farm of the LLP Kazakh Research Institute of Rice Production (figure 1).

The research study was based on certified methodological guidelines and standards. The agricultural rice production practices in the experimental plots corresponded to the recommendations of the LLP Kazakh Research Rice Institute [13].

The comprehensive observations of the water-physical properties and water-salt regime of soils, the level of groundwater constituents of the irrigation norm of rice, changes in soil moisture, phenology and rice yield were made at the selected experimental fields. Chemical analyzes of water were in progress in the soil-amelioration laboratory of the LLP Kazakh Research Institute of Rice Production. Wells and allopelagic piezometers were installed on the experimental fields to establish the regime of groundwater and their mineralization according to the methodology of V.B. Zaitsev [14]. The yield data were processed by the method of variance analysis according to the method of B.A. Dospekhov [15]. Meteorological observations of temperature and relative humidity, wind speed and direction, precipitation were carried out at the time established for meteorological stations and posts.

To measure elements of the water balance, trapezoidal weirs were installed on each check at the point of water supply from the field sprinkler to the check and at the point of discharge of water from the check into the field drain channel. To establish filtration losses, evaporation from the water surface and total water consumption of rice, V.B. Zaitsev's evaporation vessels were installed on the checks. In order to study the regime and chemical properties of groundwater, drip point piezometers were installed at depths of 100cm. They were observed every 3 days; water samples were taken once a decade. The dynamics of the salt regime of the soil was noted for each point, simultaneously soil samples were taken to a depth of 100 cm every 20 cm. 9 points were allocated in each check. The triple observations were carried out at 27 sites. Phenological observations were made at these 27 areas - periods of the onset and passage of the stages for full germination, tillering, stem extension, flowering, petty, yellowing and fully ripe of rice were noted. During the ripening period of the rice, the crop yielding is carried out by measuring. The depth of water in the check, water salinity level and its temperature are measured at each point. Measurements of water temperature are in progress at 9, 15, 19. The economic efficiency of rice cultivation was calculated according to the methods of D.T. Zuzik [16] and V.N. Polozhiy [17].

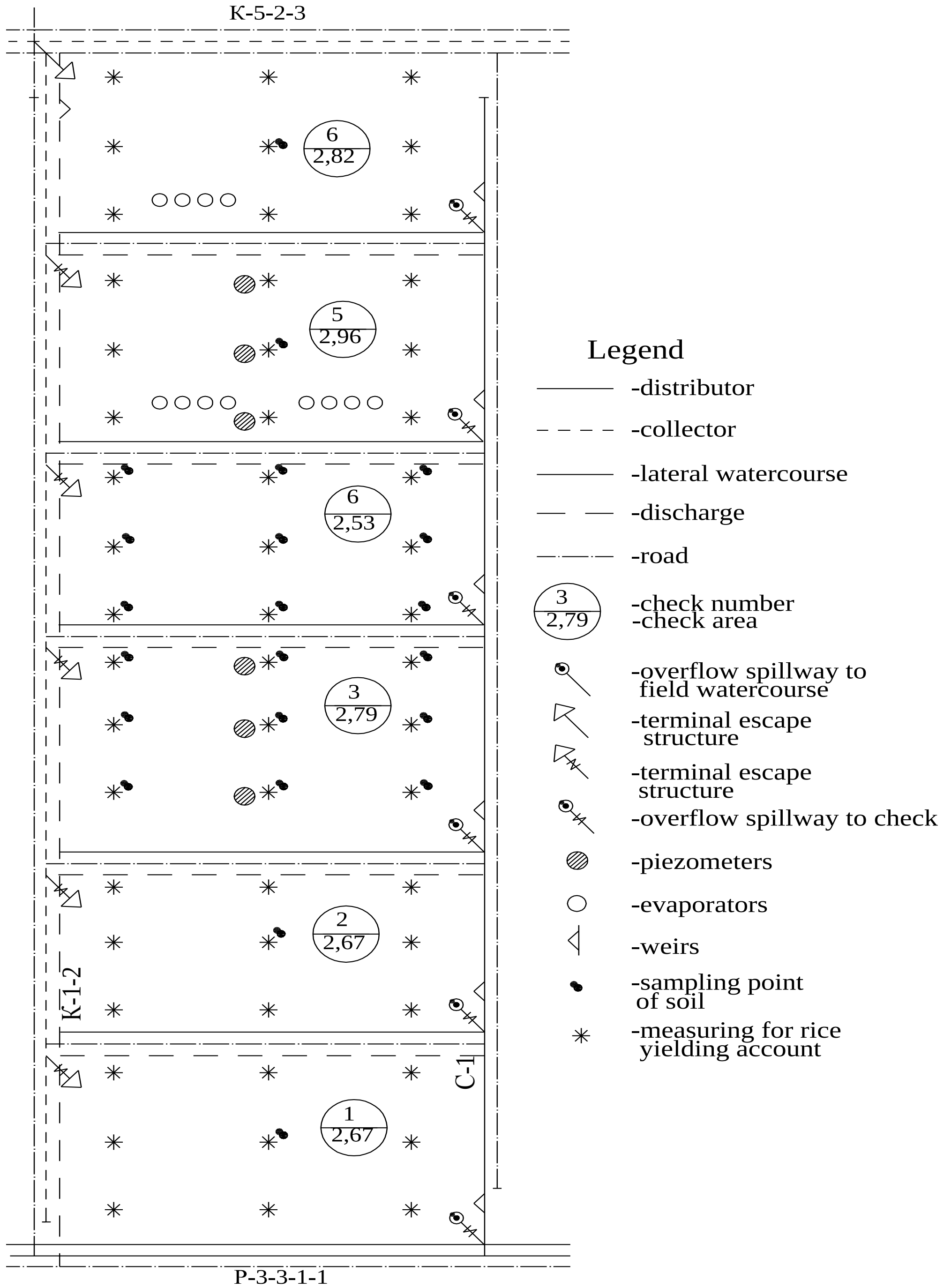

Fig.1. Plan of the trial field.

Trial 1. The growth and development of rice plant at different depth of water. The depths of water (cm) were maintained along the stages of the development of rice plants: during period of seedling, from seedling to tillering, in the course of tillering - 5 - 10 - 15 - 20; from mass tillering to full stem extension and from stem-elongation to yellowing ripeness of the grain 10 - 15 - 20 - 25. The experiment is a vegetative and a quadruplicated one.

Trial 2. Rice productivity depending on the technology of irrigation rice.

In the course of the first version (check experiment), the water depth was maintained according to the stages of rice development: from sowing to seedlings - 10 - 12; in the period of seedlings and tillering - 5 - 7 (three discharges); from mass tillering to yellowing ripeness of grain - 10 - 12 cm.

In the variant under study, the depth of water was maintained along the stages of rice development from sowing to sprouting - 15–20, from the onset of seedlings to mass tillering — 5–7, from mass tillering to full tubing — 20–25, from stem-elongation to yellowing ripeness of the grain - 10 - 15 cm.

3 Soil-reclamation characteristics of the experimental site

The soils of the experimental field of the Karaultyubinsk Experimental Production Farm (EPF) are represented by loams with interlayers of sand and sandy loam. 22 - 25 cm layer of sand lies under a small thickness of loamy deposits. The water and physical properties of the cover sediments were characterized by the following data: weight by volume - 1.48 - 1.60 g/cm^3, specific gravity - 2.66 - 2.70 g/cm^3, total soil space - 43 - 47%, minimum moisture holding capacity - 24.3 - 31.5% of the volume. The average value of the filtration coefficient of the suspended water is 0.40 m/ day. Groundwater lay at a depth of 2.0 - 2.5 m, its salinity was 4.0 - 7.0 g/l. The salt content in a 0–40 cm layer of soil varied from 0.429% to 0.853%.

The Kyzylorda region is characterized by a sharply continental climate, low precipitation, high evaporation capacity, low air humidity.

The climatic conditions of the area are generally favorable for the cultivation of early ripe, mid-seasoning ripening, late ripe rice varieties.

4 Results and discussion

The record results of the number of rice underground seedling and sprouting, as well as measurements of soil temperature on its surface showed that soil temperature decreases while water depth is under increasing. The number of sprouting rice seeds significantly decreases with an increase of the water layer in the check. Simultaneously, the difference in the number of seedlings between the shallow (5 cm) and deep (20 cm) water layers made up 14 pieces in Marzhan variety and 17 ones - in Avangard variety. The percentage of field emergence of rice seeds also under sharply decrease while depth of the water layer increases. At the 5 cm water layer it amounted to 32.9% according to the variety Avangard, at the 20 cm layer it makes up only 9.0%; 34.5% and 20.4% respectively.

The field emergence of rice seeds of the Avangard variety under a layer depth of 15 cm is only 14.8% and is more than 20% of the Marzhan variety even under a layer depth of 20 cm. With increase of the water layer depth, both the field emergence decreases and the duration of the seedling stage undergoing increases.

Summarizing the above data, it should be noted that under regular flooding, rice seeds favourably emerge with a small layer of water. In resistance to a deep layer of water during seedlings, the variety Marzhan surpasses the variety Avangard.

The second significant period in the formation of high yield of rice is “tillering-sterm extension”. The tillering stage begins from the formation of 3-4 leaves and continues until the formation of 8-9 leaves. It is the longest one and makes up 25-30 or more days. In the course of this period, stem shoots are formed in rice plants and they make up the main plant stand and at the same time ensure a high yielding crop.

Our studies showed that the appearance of stem shoots in rice plants is in direct dependence on the depth of water layer, i.e. under deeper layers during the period of rice tillering, this process begins a little later, and the number of stem shoots decreases affecting the formation of productive rice stems. The difference in the coefficient of productive bushiness in the shallow and deep water

The differential factor in the coefficient of productive tilling capacity under the conditions of shallow and deep water layer amounted 0.5 for the Marzhan variety and 0.4 for the Avangard one. As can be seen from the study findings, the average daily temperature on the soil surface or in the tillering node slightly decreases under an increase of water depth and it has a certain impact on the intensity of the tillering stage in plants of both varieties.

The observations of the undergoing of the stage of the stem extension of rice depending on the different depths of the water were carried out. The results showed that more increase of the water depth causes the increase of the leaf surface area of rice plants. Herein, the largest leaf area in both rice varieties occurs when maintaining a water layer with a depth of 20 cm. It should be noted that rice plants of the Marzhan variety have a larger leaf surface area compared to the Avangard variety. Maintenance of a deep layer (20 - 25 cm) of water increases the head length, the amount of grain of one head and its mass. The blind-seed disease decreases at such a layer of water. Its value decreased from 1.5% to 2% compared with the option of maintaining a shallow layer of water. All these elements that determine the productivity of rice plants have a significant role in the formation of the crop yielding.

Heading of the rice panicles ends with the emergence of spikelets from the vagina of the last leaf. With the beginning of heading, the spikelets come out first flowering, and then, as they come out, the subsequent spikelets are under the same action. By the method of flowering, rice refers to self-pollinated plants. In the heading-flowering stage, rice needs a layer of water. Its lack leads to the sterility of spikelets and the shriveling of the crop.

After the fertilization of flowers, there is a stage of the caryopsis ripening. There are three degrees of maturation: milk, yellowing and full ripeness. In practice, rice farmers usually maintain a layer of water in the checks until the yellowing ripeness. We studied the duration of these stages and determined the quality of the grain depending on the different depths of the water layer. The findings of the observations during the periods of heading and ripening showed that for both varieties an increase in the depth of the water layer of more than 15 cm lengthens the duration of these stages for 3-4 days. At the same time, under a deep layer of flooding (20 - 25 cm) during the period of heading and fertilization of flowers, the not sufficient ripening of rice is observed and it becomes weak. For the normal undergoing of this stage, it is necessary to maintain a water layer in the check at a depth of not more than 15 cm.

Summarizing the above research results, we can conclude that the most environmentally available layers in increasing the productivity of rice plants by development periods are as follows: from seed emergence to mass tillering - 5 cm; from mass tillering to full stem extension - 20 cm; from full stem extension to yellowing ripeness - 10 cm (for the Marzhan variety) and 15 cm (for the Avangard variety).

Maintaining the available water layer in the checks during the vegetation stages in the second variant contributed to an increase in the number of productive stems, full-grown spikelets on one panicle and a decrease in blind-seed disease that in total ensured an increase of the total rice yield.

Rice yields in all the years of research were also significantly higher: on average for three years for the Marzhan variety by 8.9 kg/ha (20.6%), for the Avangard variety by 6.5 kg/ha (15.3%).

The dynamics of the translocation and accumulation of salts in soils and the causes of secondary salinization of the lands on irrigated areas were studied by A.I. Golovanov, S.I. Koshkarov and others [19-24]. They found out that the drainage network, irrigation regime, cultivation technology, etc., affect the reclamation state of rice system soils.

The results of the study showed that when rice is cultivated, the salt regime of soils develops according to the type of desalination. In the first variant, the salt content in the solid residue at the end of the irrigation period in the 0 - 10 cm soil layer decreased from 0.853% to 0.212%, in the 10-20 horizon - from 0.720% to 0.361%, in the second variant - from 0.837% to 0.193 % and from 0.840% to 0.363% respectively. The chlorine content in these horizons decreased by 5-7 times. Soils moved from moderately saline category into the slightly saline ones.

Along with soil salinity, the mineralization of irrigation water has a great influence on the development of rice and the formation of its crop. The studied methods of rice irrigation had a positive effect both on the dynamics of salts in the soil and on the mineralization of irrigation water in checks during the growing season. The common pattern of increasing the salinity of irrigation water from the beginning to the end of the irrigation period is revealed.

The results of measurements for irrigation water expenditures for the entire irrigation period showed that the water supply from the Avangard variety on the control variant of the experiment averaged 24380 m^3/ha, on the studied one - 20760 m^3/ha, i.e. 3620 m/ha less. These indicators are respectively equal to 21520 for the crops of Marzhan variety; 18050 and 3470 m^3/ha.

5 Conclusion

1. Compliance of ecologically available depths of the water layer in the checks with the stages of rice plant development allows avoiding the water discharges in the checks, reducing the irrigation rate to 20% and increasing rice productivity by - 20.6% in comparison with the irrigation regime used in production.
2. Under the conditions of the Kyzylorda region, where rice is grown under constant flooding, the highest field emergnce of seeds of the Marzhan and Avangard varieties is provided while maintaining a 5 cm layer of water.
3. The emergence of the rice seeds of Marzhan variety is reduced by 40% when the depth of the water layer is 20 cm, of Avangard variety - by 70% compared with the 5 cm layer flooding. Our studies have confirmed the position that the optimal water depth during the tillering period of rice plants is 5 cm, herein, the tillering coefficient and the degree of accumulation of the aboveground mass increases. Maintaining a deep water layer (about 20 cm) during the spikelet laying period significantly increases the panicle percentage and leads to an increase in rice yielding.
4. Irrigation water saving on the recommended option for the two Marzhan and Avangard varieties averaged 3550 m^3/ha, under the current rice production area - 77000 ha it allowed to reduce the water intake for rice irrigation by 273 million m^3 of water per year.

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