Caspian Journal of Environmental Sciences
Online ISSN: 1735-3866
Print ISSN: 1735-3033

Contamination of crops and productivity of rice in various ways of its aerobic cultivation and irrigation

Aizada Sembayeva[1,2] Zhumagali Ospanbayev[1,2], Ainur Doszhanova[1]*, Muhit Bekbauov[1], Alma Saikenova[2], Karima Myrzabek[1], Makpal Kanatkyzy[2], Dzhulduz Abildayeva[2]

1. Kazakh National Agrarian Research University, Almaty, Kazakhstan
2. Kazakh Research Institute of Agriculture and Plant Growing, Almalybak, Kazakhstan

* *Corresponding author's Email: ainurdoszhanova@mail.ru*

ABSTRACT
The article presents the results of research conducted in the conditions of the foothill irrigation zone of the South-east Kazakhstan. The features of grain harvest formation and the degree of contamination of rice crops have been studied, depending on irrigation methods, timing and methods of sowing, and methods of weed control. The research results have shown that in conditions of irrigation in the South-east Kazakhstan, sufficiently high yields of rice can be obtained by aerobic cultivation using fine sprinkling or drip irrigation. At the same time, effective ways of weed control have been identified, forming a favorable phytosanitary condition of rice crops without traditional irrigation with flooding. The results of studies on the contamination of rice crops with various methods of weed control, irrigation, timing and methods of sowing are presented.

Key words: Agricultural rice, Contamination, Sowing, Irrigated agriculture, Drip Irrigation, Fine Irrigation, Yield, Soil Fertility.
Article type: Research Article.

INTRODUCTION
Rice, *Oryza sativa* is the staple food of more than 60% of the world's population. Rice irrigated by flooding uses two or three times more water than other crops such as wheat and corn. In Asia, rice cultivation, irrigated by flooding, consumes more than 45% of the total volume of fresh water used. The growing water crisis threatens the sustainability of irrigated rice production. By 2025, 15 of the 75 million hectares of rice crops irrigated by flooding in Asia are projected to experience water shortages. The growing water crisis threatens the sustainability of irrigated rice production. By 2025, 15 of the 75 million hectares of rice crops irrigated by flooding in Asia are projected to experience water shortages. However, it is necessary to produce more rice using less and less water to feed an ever-growing population that needs sound water management practices and suitable water-saving technologies for rice cultivation (Tuong *et al.* 2005*;* Belder *et al.* 2005). The International Rice Research Institute (IRRI) has developed an "aerobic rice technology" to address the water crisis in tropical agriculture. In the past, grain yields of 5 to 6 tons ha^{-1} have often been reported when growing high-yielding rice varieties in aerobic rice systems (George *et al.* 2002*;* Bouman *et al.* 2006*;* Peng *et al.* 2006). In Brazil, mountain varieties with high grain yields (from 5 to tons ha^{-1}) have been developed (Castaneda *et al.* 2002), whereas Wang *et al.* (2002) found that rice grain yields of 8 tons ha^{-1} and even higher can be achieved using high-yielding mountain varieties with suitable management methods in northern China. The highest grain yield record with an aerobic rice system (11.4 tons ha^{-1}) was observed in Japan in 2007 (Kato *et al.* 2006). A review of studies conducted in Australia, the USA, China, the Philippines, and Japan indicates that crop losses from aerobic rice in temperate climates are usually lower than in the tropics (Kato *et al.* 2006). In the tropics, yield losses in wet seasons are lower than in dry seasons (Bouman *et al.* 2005). In Northern China, in a temperate climate region, where the yield potential of aerobic rice

Publisher: University of Guilan,

has been intensively analyzed (Bouman *et al.* 2005; Yang *et al.* 2005; Xue *et al.* 2008; Xue *et al.* 2008), the patterns of soil moisture at a depth of 20 cm were similar to those in the present study, but the yield decrease averaged 13% even for local aerobic rice varieties. Thus, the difference in yield between aerobic and flooded rice seems to depend on the climate and physical properties of the soil, increasing in hotter and drier conditions. Increased labor costs and limited irrigation water supplies have forced farmers to switch from manual seedling to direct sowing in many Asian countries (Pandey & Velasco 2005). However, there is a risk of greater crop losses due to weeds in direct-seeded rice than in seedling rice, due to the simultaneous appearance of crops and weeds and the lack of standing water in the early stages of sowing to suppress weed growth (Tuong *et al.* 2005; Chauhan & Johnson 2010c). In a recent study, shoot competition for light was the main mechanism determining competitive outcomes between direct-seeded dry rice and *Echinochloa colona* (Chauhan & Johnson 2010b). Despite farmers' weed control methods, weed losses are typically 10-20% for lowland rice in Asia, and they can be significantly higher where weeds are not controlled. Studies show that there are significant opportunities to increase yields due to improved weed control in direct rice sowing (Haefele *et al.* 2000; Chauhan & Johnson 2010b; Doszhanova *et al.* 2025). Aerobic rice is a direct seeding system in which dry rice seeds are sown in dry or moist soil, and then irrigation is applied to keep the soil moist but not saturated. This is an emerging agronomic production system designed to save irrigation water compared to flooded rice (Tuong *et al.* 2005). Manual weeding is still important in many Asian countries; however, the shortage of labor in rural areas is a deterrent. Thus, herbicides are expected to become the main means of weed control on aerobic rice. In addition to the intervals chosen for weed selectivity, the timing of herbicide application should be based on critical periods of weed control; these are the periods during which weeds have the greatest impact on crop growth and yield. Crop losses may increase further if the periods of weed infestation are prolonged, and in these cases, late application of herbicides may lead to poor results. To compensate for this, increased doses of herbicides may be required to effectively control weeds, which increases costs and can lead to phytotoxicity of crops (Johnson *et al.* 2004). For irrigated rice in the lowlands of the Sahel (West Africa), critical periods for weed control to obtain 95% of the crop of weed-free areas are estimated at 29-32 days after sowing in the rainy season and 4-83 in the dry season (Johnson *et al.* 2004). Similar studies have been conducted for corn and soybeans (Hall *et al.* 1992). The information obtained from such studies can be used as a guide for optimizing weed control in order to avoid maximum competition between crops and weeds. There has been increased interest in the application of cultural approaches in integrated weed control systems (Gibson *et al.* 2002; Chauhan & Johnson 2010c; Chauhan *et al.* 2010). One approach is to reduce the row spacing to increase the competitiveness of crops against weeds (Christensen *et al.* 2008; Mashingaidze *et al.* 2009; Chauhan & Johnson 2010a). It is noted that *E. colona* and *Echinochloa cruscalli* seedlings appearing during the first month of the growing season had a higher amount and biomass in aerobic rice sown in 30-cm rows than in 20-cm ones (Chauhan & Johnson 2010a). Akobundu & Ahissu (1985) reported that the distance between rows (15-45 cm) with direct sowing of rice had little effect on the crop yield in the absence of weeds, but in conditions of competition with weeds, the widest distance led to a significant decrease in yield. It is assumed that narrow aisles can shorten the interval of critical periods of weed competition. The aerobic rice system is a new production system in which rice is grown in unfilled, undamaged, and unsaturated soil conditions. The expected yields in ARS are slightly lower than those obtained in lowland flooding conditions, however, two or three times higher than in upland conditions. Nevertheless, ARS has been successful in cool temperate regions. For regions with warm, moist rice, a partial aerobic rice system may be a more likely alternative. Rice is cultivated in Kazakhstan on an area of about 100 thousand hectares. More than 3 billion rubles are spent on growing this crop in Kazakhstan, or 40% of irrigation water reserves. In Kazakhstan, as in the countries of Central Asia, a method of rice cultivation based on prolonged flooding of its crops with a layer of fresh water in artificially formed checks has been adopted. In production conditions, the irrigation rate of rice with constant flooding and flow varies from 25 to 35 thousand m^3 ha^{-1}. Using this irrigation technology, the consumption of irrigation water for rice cultivation far exceeds the biological need of plants for water, much of which is lost to evaporation, filtration and recharge of groundwater. In addition, rice irrigation by flooding is one of the methods of reclamation of heavily saline lands and a way to control weeds. Rice cultivation with the consumption of such a huge amount of irrigation water for more than 60 years has led to an environmental problem in the Aral Sea and in recent years Lake Balkhash. Long-term rice cultivation with flooding has led to a sharp decrease in the efficiency of irrigated land use with a significant reduction in the area and productivity of other irrigated crops. In recent years, we have conducted research on the effectiveness of drip irrigation of major field crops on irrigated lands in the south and southeast parts of

Kazakhstan, for rice, sugar beet, corn and soybeans (Yeraliyeva *et al.* 2016; Ospanbayev 2017; Sembayeva *et al.* 2025; Doszhanova *et al.* 2025). The research results have shown a fairly high efficiency of drip irrigation in the cultivation of the most water-intensive field crops, such as rice and sugar beet. Our previous research has proved the economic, especially environmental effectiveness of drip irrigation of rice in the conditions of the Akdala irrigation massif in Southeastern Kazakhstan. The optimal irrigation regime, timing, methods and doses of mineral fertilizers, and methods of drip irrigation of rice with and without mulching films have been established (Abdukadirova *et al.* 2016; Kenenbayev *et al.* 2017; Yelnazarkyzy *et al.* 2020). In these studies, the issues of the phytosanitary condition of rice crops during its aerobic cultivation have not been sufficiently studied. This article is based on the results of research conducted in 2023-2024 within the framework of grant funding from the Ministry of Education and Science of the Republic of Kazakhstan, IRN AP19676592.

MATERIALS AND METHODS

The tasks were solved by laying and conducting multifactorial field experience in the fields of «Agrofirma Birlik» LLP, Balkhash district, Almaty region (coordinates N 44.38.260 E 76.43.966). The soils of the experimental site are takyrovidny, typical for the rice-growing zone of the Akdalinsky irrigation massif.

Scheme of multifactorial microfield experience.

Irrigation methods	Methods of sowing	Sowing dates	Ways to control weeds
Traditional irrigation	ordinary sowing 15 cm	April 10th	Mechanical
Drip irrigation	ribbon seeding 30 × 60 cm	May 01	Chemical
fine-dispersed		May 20th	Combined

Irrigation methods were carried out as follows:

To lay the options with traditional irrigation, after the main tillage in spring, a check with an area of 108 m^2 (length 18 m, width 6 m) was formed for irrigation of rice by flooding, where options with sowing dates and methods of controlling rice weeds were laid three times. Pre-sowing tillage and rice sowing were carried out manually using a hand marker with a row spacing of 15 cm to a depth of 4-5 cm. At the beginning of rice tillering, the checks were filled with irrigation water, the level of which was maintained at a height of 18-20 cm during the growing season. In the drip and fine-dispersed irrigation variants, after the main treatment, pre-sowing tillage was carried out with a Veles and Agromaster disc harrow to a depth of 9-11 cm three days before rice sowing. Sowing was carried out with a Vence-Tudo 12000 seed drill to a depth of 4-5 cm. In the variant with two-row rice sowing, two row-by-row tillage with a YCM-5 cultivator to a depth of 5-7 cm was carried out during the growing season to destroy the weeds that appeared. Watering was carried out from the beginning of the tillering phase. In the drip irrigation variants, Vence Tudo-7300 drip tapes were placed along rice rows at a distance of 90 cm. At the same time, in variants with two-line rice sowing, drip tapes were placed between the lines in the tape. In the variants with fine-dispersed irrigation, spray strips were laid across the rows of rice crops at a distance of 6 m.

Ways to control weeds

The mechanical method consisted of pre-sowing tillage before sowing rice and double tillage between the belts in variants with belt sowing in the phases of the beginning of tillering and tubing of plants. The chemical method consisted of spraying crops at the beginning of the tillering phase with the herbicide Ballerin at the rate of 0.5 L ha^{-1} and in the full tillering phase with the herbicide Gulliver at the rate of 0.030 kg ha^{-1} +surfactant "Trend" 0.2 L ha^{-1}. The combined method consisted of pre-sowing tillage before sowing rice and double tillage between the belts in the belt-seeding variants during the phases of the beginning of tillering and tubing of plants. Spraying of crops at the beginning of the tillering phase with Balerin herbicide at the rate of 0.5 L ha^{-1} against dicotyledonous annual and perennial weeds, during the full tillering phase with Gulliver herbicide at the rate of 0.030 kg ha^{-1} + Trend surfactant 0.2 L ha^{-1} against annual and perennial weeds. The records and observations in the experiments were carried out according to generally accepted methods used in biological and agronomic research (Dospekhov 1985):

Taking into account the density of standing plants by counting the number of plants per 1 m^2 at the beginning and end of the growing season of the studied crops in threefold repetition. Accounting for the dynamics of plant biomass accumulation in the main phases of their development by sampling 0.30 m^2 from each variant in a triple repeat with measurement of wet and dry weight. The accounting of crop contamination was carried out according to the generally accepted method of counting the number of weeds from an accounting area of 0.30 m^2 in a threefold repetition. Crop accounting was carried out individually with a small-sized HEGE-160 combine harvester. Statistical data processing was performed using the Dospekhov method (Dospekhov 1985). Irrigation water was recorded according to the data of the Bulk caliber-DN-50-300 water meter.

RESULTS AND DISCUSSION

This study examines the effects of irrigation methods, sowing timing, and weed control strategies on rice yield and contamination in the foothill irrigation zone of Southeastern Kazakhstan. The results highlight significant differences in productivity and phytosanitary conditions between traditional flooding and aerobic cultivation methods, including fine-dispersed and drip irrigation systems. Table 1 represents the key results of the study, as it quantifies the impact of various agricultural practices on rice yield, a primary indicator of agricultural success. The data, collected over two growing seasons (2023 and 2024), allows for a robust analysis of how irrigation methods, sowing times, and weed control strategies interact to influence rice productivity in the specific environmental conditions of Southeastern Kazakhstan. The most prominent observation is the superior performance of traditional irrigation in maximizing rice yield. Across both years, yields under flooded conditions consistently equaled or surpassed those achieved with fine-dispersed and drip irrigation. This finding aligns with the understanding that rice is a semi-aquatic plant that has evolved to thrive in flooded environments. Flooding provides several advantages, including optimal water availability, weed suppression, and nutrient management. However, the study also clearly demonstrates that aerobic rice cultivation is indeed feasible under fine-dispersed and drip irrigation. While yields may be lower, these methods present a pathway to significantly reduce water consumption, a crucial consideration in water-scarce regions. Sowing date is another critical factor highlighted in the findings presented in Table 1. The results indicate a general trend towards increased yields with later sowing dates (May 1st and May 20th) compared to the earliest sowing date (April 10th). This suggests that delaying planting until early to mid-May might better synchronize the rice plants' growth cycle with optimal temperature and solar radiation conditions in this region. It could also be related to managing cold stress at the early growth stages of rice. Weed control is another major factor in this study. The data unequivocally demonstrates the necessity of effective weed management for achieving high rice yields. The chemical and combined weed control methods consistently outperformed the mechanical method. This underscores the challenges posed by weeds in aerobic rice systems, where the absence of standing water makes weed proliferation easier. Herbicides, when used judiciously, play a vital role in minimizing weed competition and allowing rice plants to thrive. The combined approach, integrating both chemical and mechanical methods, often yields the best of both worlds, reducing herbicide reliance while maximizing weed control. Finally, the year-to-year variation in yield, with 2024 showing higher productivity overall, emphasizes the influence of environmental factors on agricultural outcomes. These interannual differences highlight the importance of conducting multi-year studies to obtain a comprehensive understanding of the long-term effects of different cultivation practices. Table 2 provides a quantitative assessment of weed infestation in rice crops, offering valuable insights into the effectiveness of different weed control strategies under varying cultivation conditions. Weed contamination is a critical factor in rice production, as weeds compete with rice plants for resources such as light, water, and nutrients, leading to yield reduction. The data in Table 2 reinforces the findings from Table 1 regarding the importance of effective weed control. The chemical and combined weed control methods consistently demonstrate their superiority in reducing weed density compared to the mechanical method. This is evident in the lower weed counts observed at both the tillering and ripeness stages of rice development when herbicides are used. Mechanical weed control, relying solely on tillage, proves inadequate in providing season-long weed suppression, highlighting the aggressive nature of weeds in aerobic rice systems. While the impact of irrigation methods and sowing dates on weed contamination is less consistent, some trends can be observed. In 2023, there's a tendency for later sowing dates to correlate with reduced weed counts at ripeness. This could be attributed to several factors, including enhanced early crop vigor due to warmer soil temperatures, which increases the rice plants' competitive ability against weeds. Furthermore, the effectiveness of specific weed control methods may be influenced by the irrigation method, suggesting complex interactions between these factors. The comparison of weed counts between the tillering and ripeness stages reveals the dynamics of weed growth and the impact of weed control interventions. As expected, weed densities are generally higher at the tillering stage, when weeds establish themselves, and decrease towards ripeness due to weed control measures and competition from the developing rice canopy. However, the extent of this reduction varies significantly depending on the weed control method employed.

Table 1. Rice yield depending on the timing of sowing, irrigation methods and weed control (ton ha^{-1})

Irrigation methods	Methods of sowing	Sowing dates	Ways to control weeds		
			Mechanical	Chemical	Combined
		2023			
		10.04	3.96	4.55	4.32
Traditional	Ordinary sowing	01.05	4.50	4.58	4.73
		20.05	4.01	4.76	5.23
		10.04	0.92	3.92	3.66
	Ordinary sowing	01.05	1.96	4.44	4.74
Fine-dispersed		20.05	2.35	4.38	4.68
	Ribbon seeding	10.04	1.22	3.01	3.00
		01.05	2.31	3.47	3.53
		20.05	2.17	3.18	3.30
		10.04	1.01	4.01	3.85
	Ordinary sowing	01.05	1.82	4.12	4.38
Drip irrigation		20.05	2.02	4.65	4.95
	Ribbon seeding	10.04	1.23	3.52	3.12
		01.05	1.96	3.85	3.80
		20.05	1.74	3.55	3.21
$HCP_{0.5}$			0.17		
		2024			
		10.04	4.52	5.41	5.22
Traditional	Ordinary sowing	01.05	5.74	6.62	6.91
		20.05	6.02	6.66	7.04
		10.04	2.01	4.32	4.59
	Ordinary sowing	01.05	2.02	4.77	5.01
Fine-dispersed		20.05	2.63	5.44	6.03
	Ribbon seeding	10.04	2.23	3.44	3.52
		01.05	1.93	3.77	3.54
		20.05	2.45	4.06	5.22
		10.04	1.35	4.73	4.56
	Ordinary sowing	01.05	2.02	6.23	6.44
Drip irrigation		20.05	2.76	6.25	6.61
	Ribbon seeding	10.04	2.28	3.69	3.54
		01.05	2.54	4.33	4.40

		20.05	2.88	4.72	5.02
$HCP_{0.5}$			0.24		
		The average for 2023-2024			
		10.04	4.24	4.98	4.77
Traditional	Ordinary sowing	01.05	5.12	5.60	5.82
		20.05	5.02	5.71	6.14
		10.04	1.47	4.12	4.13
	Ordinary sowing	01.05	1.99	4.61	4.88
Fine-dispersed		20.05	2.49	4.91	5.35
		10.04	1.73	3.23	3.26
	Ribbon seeding	01.05	2.12	3.62	3.54
		20.05	2.31	3.62	4.26
		10.04	1.18	4.37	4.21
	Ordinary sowing	01.05	1.92	5.18	5.41
Drip irrigation		20.05	2.39	5.45	5.78
	Ribbon seeding	10.04	1.76	3.61	3.33
		01.05	2.25	4.09	4.10
		20.05	2.31	4.14	4.12
$HCP_{0.5}$			0.17-0.24		

The contamination percentages confirm the effectiveness of irrigation methods in suppressing weeds. Fine-dispersed irrigation exhibited the highest contamination rate (87.3%) in April 10 sowing, demonstrating that aerobic irrigation methods require enhanced weed control measures. Traditional flooding provided superior weed suppression, with contamination levels as low as 10.4%, reinforcing its phytosanitary benefits. Drip irrigation demonstrated moderate contamination levels, indicating that precision irrigation can mitigate weed interference but requires further optimization. Fig. 2 demonstrates contamination percentages at harvest, showing the effectiveness of weed control strategies. The final contamination percentages at harvest highlight the effectiveness of weed control strategies.

Table 2. Contamination of rice crops depending on irrigation, sowing and weed control methods (pcs. m^{-2}).

Irrigation methods	**Methods of sowing**	**Sowing dates**	**Ways to control weeds in the development phases**					
			Mechanical		**Chemical**		**Combined**	
			Tillering	**Ripeness**	**Tillering**	**Ripeness**	**Tillering**	**Ripeness**
			2023					
		10.04	276	27	303	21	321	23
Traditional	Ordinary sowing	01.05	212	24	243	21	229	20
		20.05	177	27	128	20	182	18
		10.04	304	221	282	24	343	29
	Ordinary sowing	01.05	236	155	156	22	266	21
Fine-dispersed		20.05	178	146	83	22	202	19
		10.04	321	157	331	18	336	33

	Ribbon seeding	01.05	245	126	286	16	253	28
		20.05	202	109	178	17	182	30
		10.04	306	206	295	23	320	28
	Ordinary sowing	01.05	228	159	236	23	264	24
Drip irrigation		20.05	232	153	158	20	206	21
		10.04	288	157	307	15	347	27
	Ribbon seeding	01.05	233	106	260	14	283	26
		20.05	190	88	178	15	225	32
			2024					
		10.04	328	34	346	6	333	6
Traditional	Ordinary sowing	01.05	246	28	258	6	254	3
		20.05	152	28	173	5	163	5
		10.04	353	308	349	17	346	21
	Ordinary sowing	01.05	282	230	235	13	252	14
Fine-dispersed		20.05	204	276	188	16	176	24
		10.04	340	221	370	26	359	19
	Ribbon seeding	01.05	266	203	252	21	225	13
		20.05	169	176	167	24	159	16
		10.04	336	304	347	12	330	8
Drip irrigation	Ordinary sowing	01.05	225	201	222	7	232	7
		20.05	164	141	150	8	152	8
		10.04	361	126	356	37	332	30
	Ribbon seeding	01.05	280	92	272	25	256	23
		20.05	205	63	188	32	190	27

Table 3. The effectiveness of cultivation and irrigation methods on the dynamics of contamination of rice crops (%).

Irrigation methods	**Methods of sowing**	**Sowing dates**	**Ways to control weeds**		
			Mechanical	**Chemical**	**Combined**
		2023			
		10.04	9.8	6.9	7.2
Traditional	Ordinary sowing	01.05	11.3	8.6	8.7
		20.05	15.3	15.6	9.9
		10.04	72.7	8.5	8.5
	Ordinary sowing	01.05	65.7	14.1	7.9
Fine-dispersed		20.05	82.0	26.5	9.4
		10.04	48.9	5.4	9.8
	Ribbon seeding	01.05	51.4	5.6	11.1
		20.05	54.0	9.6	16.5

		10.04	67.3	7.8	8.8
	Ordinary sowing	01.05	69.7	9.7	9.1
Drip irrigation		20.05	65.9	12.7	10.2
		10.04	54.5	4.9	7.8
	Ribbon seeding	01.05	45.5	5.4	9.2
		20.05	46.3	8.4	14.2
		2024			
		10.04	10.4	1.7	4.5
Traditional	Ordinary sowing	01.05	11.4	2.3	1.2
		20.05	18.4	2.9	3.1
		10.04	87.3	4.9	6.1
	Ordinary sowing	01.05	81.6	5.5	5.6
Fine-dispersed		20.05	86.3	8.5	13.6
		10.04	65.0	7.0	5.3
	Ribbon seeding	01.05	76.3	8.3	5.8
		20.05	68.6	14.4	10.1
		10.04	90.5	3.5	2.4
	Ordinary sowing	01.05	89.3	3.2	3.0
Drip irrigation		20.05	86.0	5.33	5.3
		10.04	34.9	10.4	9.0
	Ribbon seeding	01.05	32.9	9.2	9.0
		20.05	30.7	17.0	14.2

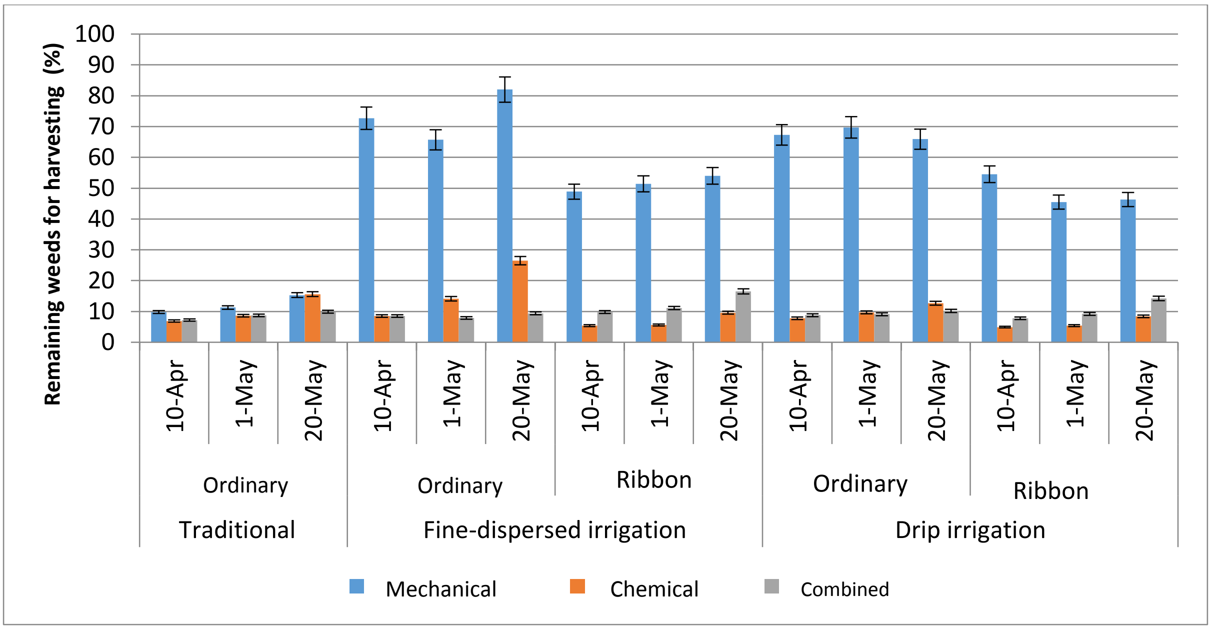

Fig. 1. The degree of contamination of rice crops, depending on the methods of cultivation and irrigation (%) in 2023.

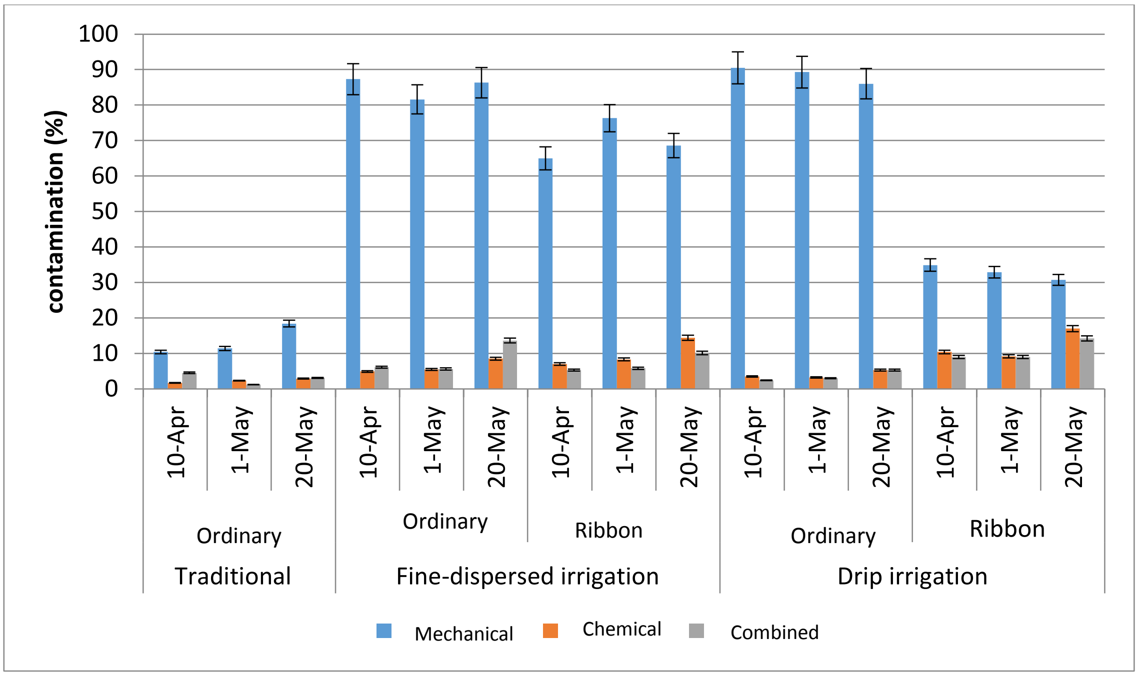

Fig. 2. The degree of contamination of rice crops for harvesting, depending on the methods of cultivation and irrigation (%) in 2024.

The lowest contamination percentage (1.7%) was recorded under traditional irrigation (April 10 sowing, combined weed control), emphasizing the role of integrated weed management in sustaining crop health. Fine-dispersed and drip irrigation still exhibited higher weed presence, although improvements were noted with chemical and combined control methods. This underscores the importance of multi-phase weed management strategies in aerobic rice cultivation to minimize weed-induced yield losses. These results suggest that transitioning from traditional flooding to aerobic rice systems can be successful if irrigation timing, sowing methods, and weed control strategies are optimized. While fine-dispersed and drip irrigation offer promising alternatives for water conservation, they require strong weed suppression measures to maintain competitive yields. Future research should explore advanced weed control methods tailored to aerobic rice conditions to enhance environmental and economic sustainability.

CONCLUSION

The study highlights the potential of aerobic rice cultivation methods, particularly fine-dispersed and drip irrigation, as viable alternatives to traditional flooding techniques in Southeastern Kazakhstan. While flooding ensures higher yields due to effective weed suppression, aerobic cultivation offers significant water conservation benefits and, when properly managed with combined weed control strategies, can achieve competitive yield levels. Weed contamination remains a major challenge in non-flooded irrigation systems, with early sowing dates leading to increased weed competition. The findings emphasize the importance of integrated weed management, where chemical and mechanical control methods complement each other to maintain optimal crop health. Future research should focus on refining irrigation scheduling and weed control measures to improve the sustainability and productivity of aerobic rice in Kazakhstan's irrigation zones.

ACKNOWLEDGEMENT

The work was carried out under the project: "Agrobiological research on the study of aerobic rice for introduction into the culture of irrigated agriculture in Kazakhstan", IRN AP19676592.

REFERENCES

Abdukadirova, ZhA, Kurmanbayeva MS & Ospanbayev, ZhO 2016, Effect of mulch on soybean (*Glycine max* L. Merr.) at Cultivation under Drip Irrigation in the South-east of Kazakhstan. *Biosciences Biotechnology Research Asia*, 13: 751-759, http://dx.doi.org/10.13005/bbra/2094.

Belder, P, Bouman, BAM, Spiertz, JHJ, Peng, S, Castaneda, AR & Visperas, RM 2005, Crop performance, nitrogen and water use in flooded and aerobic rice. *Plant Soil*, 273, 167-182.

Bhagirath, SC & Johnson, DE 2011, Row spacing and weed control timing affect yield of aerobic rice. Field Crops Research, 121: 226-231, https://doi.org/10.1016/ j.fcr.2010.12.008.

Bouman, BAM, Yang, X, Wang, H, Wang, Z, Zhao, J & Chen, B 2006, Performance of aerobic rice cultivars under irrigated conditions in North China. *Field Crops Research*, 97: 53-65.

Bouman, BAM, Peng, S, Castañeda, AR & Visperas, RM 2005,Yield and water use of tropical aerobic rice systems in the Philippines. *Agricultural Water Management*, 72: 87-105.

Bouman, BAM, Yang, X, Wang, H, Wang, Z, Zhao, J & Chen, B 2006, Performance of aerobic rice varieties under irrigated conditions in North China. Field Crops Research, 97: 53-65

Castaneda, AR, Bouman, BAM, Peng, S, Visperas, RM 2002, The potential of aerobic rice to reduce water use in water-scarce irrigated lowlands in the tropics: Opportunities and challenges. In: Proceedings of the International Workshop on Water-Wise Rice Production, Los Baños, Philippines, pp. 8-11.

Doszhanova, A Ospanbayev, Zh, Sembayeva, A, Bekbauov, M, Kazkeyev, D, Myrzabek, K, Duisenbekova, O 2025, Effectiveness of biochar on degraded irrigated soils in Southeast Kazakhstan. *Caspian Journal of Environmental Sciences*, 23: 1-11, http://doi.org/10.22124/CJES.2025.8478.

Dospekhov, BA 1985, Methodology of field experience (with the basics of statistical processing of research results). 5th ed., supplement and revision Moscow, Agropromizdat, 351 p.

Gibson, C L, Zhao, J, Lovrich, N P, & Gaffney, M J 2002, Social integration, individual perceptions of collective efficacy, and fear of crime in three cities. *Justice Quarterly*, 19: 537–564. https://doi.org/10.1080/ 07418820200095341.

George, T, Magbanua, R, Garrity, DP, Tubana, BS & Quiton, J 2002, Rapid yield loss of rice cropped successively in aerobic soil. *Agronomy Journal*, 94: 981.

Haefele, SM, Wopereis, MCS, Ndiaye, MK & Kropff. MJ 2003, A framework to improve fertilizer recommendations for irrigated rice in West Africa. *Agricultural Systems*, 76: 313-335. https://doi.org/10.1016/S0308-521X(02)00080X.

Johnson, RB & Onwuegbuzie, AJ 2004, Mixed methods research: A research paradigm whose time has come. Educational Researcher, 33:14-26, http://dx.doi.org/10.3102/0013189X033007014.

Kato, Y, Okami, M, Katsura, K 2009, Yield potential and water use efficiency of aerobic rice (*Oryza sativa* L.) in Japan. *Field Crop Research*, 113: 328-334.

Kato, Y, Kamoshita, A, Yamagishi, J 2006, Growth of three rice (*Oryza sativa* L.) cultivars under upland conditions with different levels of water supply. 2. Grain yield. *Plant Production Science*, 9: 435-445.

Kenenbayev, SB, Zhumagali, O, Ospanbayev, AK, Kydyrov, N, Musagodzhaev T & Aristangulov, SS 2016, Effectiveness of Sugar Beet Cultivation under Drop Irrigation in South-East Kazakhstan. *Biosciences Biotechnology Research Asia,* 13(2): 917-924. http://dx.doi.org/10.13005/bbra/2115.

Pandey, S & Velasco, L 2005, Trends in crop establishment methods in Asia and Research Issues, In: K, Toriyama, KL, Heong & B, Hardy, Eds., Rice is life: Scientific perspectives for the 21st Century, International Rice Research Institute, Los Banos, pp. 178-181.

Ospanbayev, ZhO, Kurmanbayeva MS, Abdukadirova ZHA, Doszhanova, AS, Nazarbekova ST, Inelova ZA, Ablaikhanova, NT, Kenenbayev, SB, Musina, A S 2017, Water use efficiency of rice and soybean under drip irrigation with mulch in the south-east of Kazakhstan. *Applied Ecology And Environmental Research* 15: 1581-1603, http://www.aloki.hu ISSN 1589 1623 (Print) ISSN 1785 0037 (Online) DOI: http://dx.doi.org/10.15666/aeer/1504_15811603, 2017, ALÖKI Kft., Budapest, Hungary.

Peng, S, Bouman, B, Visperas, RM, Castañeda, A, Nie, L, Park, H-K 2006, Comparison between aerobic and flooded rice in the tropics: Agronomic performance in an eight-season experiment. *Field Crops Research,* 96: 252-259.

Sembayeva, AS, Ospanbayev, Zh, Zhapayev, RK, Kenenbayev, SB, Pejic, B, Kunypiyaeva, GT, Doszhanova, AS & Bekbauov, M 2025, Corn hybrids assessment for grain yield under the soil tillage regimes and drip irrigation in Southeast Kazakhstan. *SABRAO Journal of Breeding and Genetics*, 57(1), http://doi.org/10.54910/sabrao2025.57.1.

Tuong, TP, Bam, B & Mortimer, M 2005, More rice, less water-integrated approaches for increasing water productivity in irrigated rice-based systems in Asia. *Plant Production Science*, 8: 231-241.

Wang, H, Bouman, BAM, Zhao, D, Wang, C, Moya, PF 2002, Aerobic rice in northern China: Opportunities and challenges. In: Proceedings of the International Workshop on Water-Wise Rice Production, Los Baños, Philippines, pp. 8–11.

Xue, C, Yang, XG, Bouman, BAM, Deng, W, Zhang, QP, Yan, WX, Zhang, TY, Rouzi, A & Wang, HQ 2008, Optimizing yield, water requirements, and water productivity of aerobic rice for the North China Plain. *Irrigation Science*, 26: 459-474.

Xue, CY, Yang, XG, Bouman, BAM, Deng, W, Zhang, QP, Yan, WX, Zhang, TY, Rouzi, A 2008, Effects of irrigation and nitrogen on the performance of aerobic rice in northern China. *International Journal of Plant Biology*, 50: 1589-1600.

Yang, XG, Bouman, BAM, Wang, HQ, Wang, ZM, Zhao, JF, & Chen, B 2005, Performance of temperate aerobic rice under different water regimes in North China. *Agricultural Water Management*, 74: 107-122.

Yelnazarkyzy, R, Kenenbayev, SB, Ospanbayev, ZO, Kalashnikov, PA 2020, Soybean yield and vegetative water consumption in various irrigation methods. *Journal of Ecological Engineering,* 21: 87-93. https://doi.org/10.12911/22998993/118294.

Yeraliyeva, ZhM, Kunelbayev, M, Ospanbayev, ZhO, Kurmanbayeva, MS, Kolev, TP, Kenesbayev, SM & Newsome, AS 2016, The study of agricultural techniques of cultivation of new varieties of winter wheat under drip irrigation. *Asian Journal of Microbiology, Biotechnology & Environmental Sciences*, 18: 779-785, © Global Science Publications, ISSN-0972-3005.

Bibliographic information of this paper for citing:

Sembayeva, A, Ospanbayev, Z, Doszhanova, A, Bekbauov, M, Saikenova, A, Myrzabek, K, Kanatkyzy, M, Abildayeva, D 2025, Contamination of crops and productivity of rice in various ways of its aerobic cultivation and irrigation, Caspian Journal of Environmental Sciences, 23: 397-407.