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Rice (*Oryza sativa* L.) Yields Depending on Cultivars and Quality of Irrigation Water.

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ABSTRACT

The goal of our study was to determine whether they are appropriate for utilization by the reuse for irrigation of rice. Field experiments were conducted during the period from 2012 to 2015 at the rice checks of the Institute of Rice of the NAAS of Ukraine. We studied the effect of the mixed water containing 25% of the effluent and drainage water diluted with the pure water of the Dnipro river on the grain yields of different rice cultivars, viz. Prestyzh, Serpnevyi, Ontario and Vikont. The results of the study proved the possibility of reuse of the mixed effluent and drainage water for irrigation of rice. There was no significant decrease in the crop productivity: yield losses averaged just to 4.45-5.43% depending on the cultivar. Besides, we established that the best yielding capacity in the experiments was provided by the middle-ripening rice cultivar Vikont with grain yields of 9.73-10.26 t/ha depending on the water quality used for its irrigation. We recommend reuse of the effluent and drainage water for irrigation of rice in the check systems to improve the environmental conditions of the Black Sea coastal areas.
Keywords: irrigation water quality, effluent and drainage water, rice yields, rice cultivars.

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INTRODUCTION

Rice (*Oryza sativa* L.) is one of the most important cereal crops in the world. It is the number one grain crop in Asia. Rice occupies the third place after grain corn and sugarcane in the gross production volumes that reached 741.5 million tonnes in 2014 [4]. The crop is widely cultivated throughout the world, not only in Asian countries where rice is the main food product which appears in most dishes of national cuisines of China, Japan, Vietnam, etc. Rice was well-known in some European countries even before the first century AD, for example, in ancient Greece and Rome [13]. Nowadays it is used for human nutrition almost in all European countries. Besides, rice is cultivated in some of them.

In Ukraine the crop of rice is cultivated in Southern region at the coastal areas of the Black Sea in the special artificial agricultural constructions called rice irrigation systems. Rice irrigation systems of Kherson region were built at the saline lands that have never been used in agricultural purposes. Some parts of the systems were created at the pastures [6]. Intensive development of rice cultivation in Kherson region of Ukraine led to significant deterioration of the environmental conditions of the recreation coastal areas due to the high amounts of effluents with unfavorable chemical composition and high pesticides content that flew into the Black Sea basin from the rice irrigation systems. Rice systems effluents containing many different harmful substances have negative effect on the biosystems of the Black Sea coastal area. It was established that effluents from the rice systems increased ammonium nitrogen and phosphorus content in the Sea that led to the eutrophication processes [6].

The main way of increasing the efficiency of rice cultivation in Kherson region is using resource and ecology-safe technologies that will guarantee environmental preservation. One of the most important tasks is decrease of the amounts of drainage and effluent water outlets into the Black Sea. Solving of the issue will help to improve ecological state of the coastal areas [5, 14, 15]. In this case the question of reutilization of the drainage and effluent water of the rice irrigation systems is on the table now. Reuse of the drainage and effluent water provides facilities not only to decrease ecological pressure on the environment but gives an opportunity to irrigation water saving.

Effluent and drainage water of the rice irrigation systems are unfavorable for irrigation without previous amelioration [6, 17]. However, they might be used for crop irrigation after mixing them with pure water from the Dnipro river. Reuse of the effluents is expected to have a great economic effect on increasing rice production profitability.

The question of reuse of the effluent and drainage water from the rice systems needs to be scientifically substantiated and solved. The main goal of our study was to determine rice productivity under conditions of irrigation with water of different quality obtained by mixing rice systems effluents with pure water of the Dnipro river, and conclude whether the effluents are suitable for the crop irrigation after previous amelioration or not.

MATERIALS AND METHODS

We used a number of methods of scientific investigation in our study, namely: field and laboratory experiments, statistical methods and analysis of variance to process data which was obtained in the experiments [16].

The study devoted to rice productivity was carried out during 2012-2015 years on the rice irrigation systems of the Institute of Rice of the National Academy of Agrarian Sciences of Ukraine (village Antonivka, Skadovsk district, Kherson region; experimental field coordinates are: 46°08′34″N, 32°57′15″E, 8 m above sea level). We studied the impact of two agricultural factors (irrigation water quality and cultivar) on the rice yields, to wit:

Factor A (Irrigation water quality):

- pure water of the Dnipro river;
- mixed water (75% of the Dnipro river water plus 25% of the effluent and drainage water from the rice irrigation system).

Factor B (Cultivar):

- early-ripening – Prestyzh and Serpnevyi;
- middle-ripening – Ontario and Vikont.

Prestyzh is an early-ripening rice cultivar with vegetation period of 105 days and potential grain yield of 6.5 t/ha. The cultivar is recommended for cultivation in the Steppe zone. Serpnevyi is an early-ripening rice cultivar with vegetation period of 115 days and potential grain yield of 7.0 t/ha. Ontario is a middle-ripening rice cultivar with vegetation period of 120 days and potential grain yield of 8.5 t/ha. Vikont is a middle-ripening rice cultivar with vegetation period of 120 days and potential grain yield of 8.5 t/ha. The cultivars are recommended for cultivation in the Steppe zone of Ukraine. All the studied cultivars of rice were originated at the Institute of Rice of the NAAS of Ukraine.

The field experiments were carried out by using the current recommendations on the field experiments conduction in agronomy under the irrigated conditions in the South of Ukraine [16].

Rice cultivation technology was standard for the Steppe zone of Ukraine. The previous crop was alfalfa. We conducted double-harrowing with BDV-7 machine in the second decade of April in pre-sowing period. Soil leveling was conducted after harrowing by the means of long-based planner D-719, bolsters were rolled by the bulldozer T-150. Additional leveling and planning of the soil surface in the rice check was made by the VP-10 machine. The soil cultivation at the depth of 5-7 cm combined with application of mineral fertilizers (ammonium sulphate in the dose of 288 kg/ha, simple superphosphate in the dose of 156 kg/ha) followed after leveling. Rice was sown at the depth of 1-2 cm with the inter-row spacing of 15 cm and seed rate of 9 million seeds per hectare.

After sowing the rice checks were flooded with water for 5-10 days period. Then the soil was dried until the sprouting of the crop which was followed by flooding the check again with a water layer of 10-15 cm. The water layer was decreased for conduction of mechanized works in the rice checks only [19]. Rice crops chemical protection included spraying with preparation mixtures of Ordram 6E (active substance – molinate) in dose of 5-6 L/ha and Sirius (active substance - pyrazosulfuron-ethyl) in dose of 0.2 kg/ha against weeds. We also used fungicides Derozal (active substance - carbendazim) in dose of 1 L/ha and Impact K (active substance – carbendazim and flutriafol) in dose of 1 L/ha against rice piricularia disease. At the stage of tillering we gave the crop additional foliar fertilization with 156 kg/ha of urea.

Yields of rice grain were estimated by using the entire harvesting method. We used Don-1500 self-propelled combine harvester to perform grain yield determination. Harvesting was conducted at the optimal stage of ripeness for each cultivar.

The yield data was processed by using the analysis of variance and statistical methods within MS Excel and Statistica 5.0 software applications.

Water samples were collected each month within the period of the crop vegetation. The collected water samples were analyzed in the certified laboratory of the Institute of Rice of the NAAS by the generally accepted procedures [1, 18].

The sodium adsorption ratio (SAR) was calculated by using the formula 1 [2]:

$$SAR = \frac{Na}{\sqrt{\frac{Ca+Mg}{2}}}, \qquad (1)$$

where SAR is the sodium adsorption ratio, me/L; Na, Ca, Mg – ions content expressed in me/L.

The adjusted sodium adsorption ratio (SAR) was calculated by using the formulas 2 and 3 [2]:

$$SAR_{(adjusted)} = SAR \times [1 + (8.4 - pH_c)], \qquad (2)$$

$$pH_c = (pK_2 - pK_c) + pCa + pAlk, \quad (3)$$

where pK_2 is a negative logarithm of the second dissociation constant of H_2CO_3 corrected for an ionic strength; pK_c is a negative logarithm of the solubility constant of $CaCO_3$ corrected for an ionic strength; pCa is a negative logarithm of the Calcium ions concentration expressed in me/L; pAlk is a negative logarithm of the bicarbonates ions concentration expressed in me/L.

RESULTS AND DISCUSSION

Agricultural indexes of the irrigation water quality used in the experiments are given in the Table 1.

With accordance to the classification of A.N. Kostiakov the Dnipro river water belongs to the first class water for irrigation, and the effluent and drainage water belongs to the second class and is unfavorable for irrigation use without previous amelioration because of higher contents of dissolved solids and toxic ions [8]. However, effluent and drainage water has some nutritional value, and contains 2.22 mg/L of nitrates that means that with 100 mm of the applied water nearly 2 kg/ha of pure nitrogen fertilization comes to the irrigated soil.

Table 1: Irrigation water quality in the field experiments (average values of the indexes for the period from 2012 to 2015 ± standard deviation)

Quality indexes	Water sources and the water quality			The highest permissible values
	The Dnipro river water	The rice systems water		
		Effluent and drainage water	Mixed water (3:1)	
Power of Hydrogen (pH)	8.30±0.08	7.8±0.09	8.1±0.09	6.5–8.5
Dissolved solids, mg/L	379±12.2	695±25.3	467.3±17.2	1000
Bicarbonates, mg/L	168.4±15.9	228±16.4	186.0±27.4	219
Sulphates, mg/L	82.0±14.0	122.5±10.4	94.0±14.9	500
Chlorides, mg/L	40.8±7.3	52.6±9.9	45.1±7.7	350
Calcium, mg/L	44.2±3.2	51.7±0.8	47.0±3.4	180
Magnesium, mg/L	24.3±6.5	40.9±5.2	29.0±6.9	40
Sodium, mg/L	32.9±6.8	40.8±1.8	36.0±4.9	68
Ammonium nitrogen, mg/L	0.15±0.005	0.33±0.04	0.21±0.01	2.0
Nitrates, mg/L	0.99±0.07	2.22±0.03	1.36±0.07	10.34
Phosphorus, mg/L	0.12±0.006	0.29±0.05	0.18±0.02	0.22
Potassium, mg/L	0.21±0.01	0.45±0.03	0.28±0.01	50.0
SAR	0.98±0.41	0.88±0.23	1.02±0.29	2-4
$SAR_{(adjusted)}$	2.45±1.00	2.20±0.65	2.55±0.67	2-4

Note: the mixed water is the Dnipro river water (75%) diluted by the effluent and drainage water (25%).

SAR values were very close to each other in all the studied samples of the irrigation water. SAR index fluctuated from 0.88 to 1.02 (or from 2.20 to 2.55 for SAR adjusted), and the water with such SAR value can be considered as favorable for irrigation without any limitations. There is no soil salinization hazard in use of the mixed water or even non-ameliorated effluent and drainage water of the rice systems because SAR values do not exceed the highest permissible rates [10].

Yields of the rice grain obtained in the field experiments are represented in the Table 2.

Table 2: Rice grain yields in tonnes per hectare depending on the irrigation water quality and cultivars (average for the period from 2012 to 2015 ± standard deviation)

Irrigation water used (Factor A)	Cultivars of rice (Factor B)			
	Prestyzh	Serpnevyi	Ontario	Vikont
Pure water of the Dnipro river	8.09±1.45a	9.76±1.42b	8.97±2.51a	10.26±1.45b
Mixed water (75% of the Dnipro river water + 25% of the rice system effluent and drainage water)	7.73±1.40a	9.23±1.41b	8.52±2.38a	9.73±1.40b

Note: The least significant difference at reliability level of 95% (LSD at p<0.05) is:
Factor A: 0.93 t/ha;
Factor B: 1.32 t/ha;
Interaction of the factors AB: 1.87 t/ha.

Different letters mean that the variants are significantly different in the grain yields.

The results of the analysis of variance showed significant increase of the crop productivity due to the cultivar. It was proved that middle-ripening variety Vikont provides the best yielding performance that averaged to 10.26 t/ha under the irrigation with the Dnipro river water, and 9.73 t/ha under the irrigation with mixed water. Comparatively high grain productivity was provided by the early-ripening cultivar Serpnevyi (9.76 and 9.23 t/ha, respectively). The lowest grain yields were obtained in the variant with Prestyzh early-ripening cultivar that is considered to be the most unfavorable for cultivation in the modern climatic conditions of the Steppe zone of Ukraine [9].

The results of the analysis of variance showed that the effect of the irrigation water with different quality parameters on the rice grain yields was insignificant. In the contrary to some other researches in this scope [12], yields decrease was very slight (down to 0.53 t/ha) and loss of the productivity of the crop was estimated as insufficient (Table 3).

Table 3: Rice grain yields losses due to the irrigation with mixed water (average for the period from 2012 to 2015 ± standard deviation)

Studied cultivars	Yields losses	
	t/ha	%
Prestyzh	0.36	4.45
Serpnevyi	0.53	5.43
Vikont	0.53	5.17
Ontario	0.45	5.02

We agree with previously established peculiarities of rice productivity formation that considerable decrease in rice grain yields is possible on some types of soils under the severe salinity of the irrigation water used [3]. Moderate salinity stress is usually kept up well by the crop.

Reuse of the effluent and drainage water mixed with the pure water of the Dnipro river for irrigation of rice does not cause significant decrease of the crops yield but provides ecologically safe solution for the miscellaneous water utilization and helps to improve environmental conditions of the coastal areas of the Black Sea.

CONCLUSIONS

Effluent and drainage water of the rice irrigation systems have unfavorable quality and lead to the deterioration of the ecological state of the Black Sea coastal areas.

Utilization of the effluent and drainage water should be performed by reuse of them in the rice systems for irrigation. Our study proved insignificant rice grain yield losses due to the irrigation with mixed water that contains 25% of the effluents. Rice grain yields decrease down to the maximum of 5.43% but at the same time reuse of the effluents helps to improve the environmental conditions of the Black Sea coastal area. Besides, reuse of the effluent and drainage water improves economic efficiency of the crop production due to the water-saving and decreasing the costs for diverting and taking the effluents away.

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