

THE INFLUENCE OF IRRIGATION WITH INTENSIVE FISH FARM WATER ON THE QUALITY INDICATORS OF AEROBIC RICE (*Oryza sativa* L.)

IBADZADE, M.^{1,2*} – KUN, Á.¹ – SZÉKELY, Á.¹ – SZALÓKI, T.¹ – PENKSZA, K.² – JANCSÓ, M.¹

¹Research Institute of Irrigation and Water Management, National Agricultural Research and Innovation Centre, Anna liget u. 35, H-5540 Szarvas, Hungary

²Faculty of Agricultural and Environmental Sciences, Szent István University, Páter Károly u. 1., H-2100 Gödöllő, Hungary

*Corresponding author

e-mail: marks.ibadzade@gmail.com; phone: +36-70-245-0463

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Abstract. This study examined the effect of effluent water from an intensive fish farm on rice (*Oryza sativa* L.) grown under aerobic condition in Hungary. During the experiment four treatments were used: T₁ - effluent water; T₂ - effluent water supplemented with gypsum; T₃ - effluent water diluted with surface water and supplemented with gypsum; T_C - control treatment. A number of quality parameters (TKW - thousand kernel weight, MQP - milling quality parameters, MC - mineral content) of the selected Hungarian rice variety (M 488) were studied. While, in the TKW test no statistically significant difference was found between the treatments, MQP test showed that there was a statistically significant difference between treatments in the percentage of whole polished (white) rice. The highest percentage was in T_C with 68.5%, T₁, T₂, and T₃ had 60%, 61.1% and 59.12%, respectively. The analytical analysis of MC highlighted, that the Ca and Na contents in rice seeds were not affected by the treatments, however, under T₃ a statistically significant decrease in the P, K and Mg contents of rice seeds was observed. Altogether, irrigation with fish farm water affects some quality parameters of the chosen rice variety in different ways, this effect can remain stable while reducing stress levels.

Keywords: effluent water, environment, rice quality, water saving, water stress

Introduction

One of the necessary conditions for obtaining a high quality crop is associated with water quality that meets the standards of irrigation (Suarez, 2011; Limjuco et al., 2016). Currently, climate change and water scarcity make it difficult for farmers to access quality irrigation water (Deressa et al., 2011; Chand and Kumar, 2018). These are undesirable limiting stress factors for the growth, development, and productivity of plants (Wang et al., 2006). Stresses, such as drought and high salinity in irrigation water can damage life cycle of plants, change cell size, disrupt gas exchange, and ultimately reduce yield (Bongi and Loreto, 1989; Rhodes and Nadolska-Orczyk, 2001; Tenhaken, 2015; Chowdhury, 2016; Joshi et al., 2016; Dresselhaus and Huckelhoven, 2018).

Many researchers have focused on alternative resources, such as wastewater in order to eliminate the existing shortage and to provide plants with the necessary water in a timely manner (Haruvy, 1997; Toze, 2006; Drechsel and Evans, 2010). Since they are rich in chemical composition, in some cases, these waters can be used as fertilizers (Rahimi et al., 2012; Ryu et al., 2012). It is also possible to make some progress in increasing productivity through the use of wastewater for irrigation (Khan et al., 2009). Another progressive aspect of this is the opportunity of reuse of wastewater, which in most cases is directly discharged into rivers, seas and oceans (Nair, 2008; Kamal et al.,

2008). Eventually, this reuse will lead to environmental protection and minimization of potential damage. For instance, in recent decades, it was noted that an increase in the number of fish farms due to the disposal of waste into natural water resources has led to a disruption in the chemical and environmental balance of the water (Jones, 1990). According to a study by Ruiz-Zarzuela et al. (2009) in Northeast Spain, water from fish farms leads to a decrease in pH and dissolved oxygen in the river, which could affect water quality and aquatic life. However, the application of effluent water from fish farms in agriculture may be more suitable. According to Castro et al. (2006) the application of effluents from fish ponds greatly increased tomato yields in Northeast Brazil. Abdelraouf et al. (2014) reported in their study in Egypt, drainage water of fish ponds could be a good option for saving current water resources.

Changes at the global level, as well as existing problems also affect rice (*Oryza sativa* L.) cultivation. Rice is one of the most water-demanding crops among cereals and is the main agricultural crop that satisfies the nutritional needs of a large part of the world's population (Vergara, 1991; Muthayya et al., 2014). In addition, as the number of people increases, the demand for this product increases too (Khush, 2005). According to some researchers, the use of aerobic rice systems, which is considerably more water-efficient than the traditional method, can be an advantageous method in conditions of water scarcity (Bouman et al., 2002; Pinheiro et al., 2006). But another important factor in this event is related to the quality and yield of rice. Thus, in this study, our aim was to identify the effect of effluent water from fish farm on the development of aerobic rice by studying the qualitative characteristics and parameters of the mineral composition. In addition, we also focused on taking another step to the reduction of water demand and environmental pollution to improve a complex agricultural system.

Materials and methods

The experiment was conducted at the National Agricultural Research and Innovation Centre, Research Institute of Irrigation and Water Management (NAIK ÖVKI) Lysimeter Station in Szarvas, Hungary (46°51'48"N, 20°31'39"E). Possible changes of effluent water from the intensive catfish farm on rice was explored during the experiment. For that purpose Hungarian rice variety named M 488 was planted in 16 gravitation lysimeters under aerobic condition in May 2019. The treatments were applied by a micro sprinkler irrigation method and with four replications. The applied experimental design has been shown in *Figure 1*. Generally, lysimeters are devices used to study the dynamics of water, evapotranspiration and changes of other substances in the soil (Lanthaler, 2004). However, the reason for choosing gravitation lysimeter was to create aerobic conditions for the plants and at the same time to separate them from the vertical and horizontal effects of the surrounding environment and soil.

The non-weighted, backfilled gravitation lysimeters at the NAIK ÖVKI have the volume of 1 m³ and each of them has a surface of 1 squaremeter. Four lysimeters were installed into one block together (one treatment in irrigation studies). The bottom 10 cm of the lysimeter is a layer of gravel to collect percolated water in case of heavy rain or high amount of irrigation. The plants have 80 cm of soil for the development. The type of soil in the lysimeters was vertisol (expansive clay). The plant density was set to 40 plants/m² (*Figure 2*).

M 488		M 488		M 488		M 488	
138	139	142	143	146	147	150	151
137	140	141	144	145	148	149	152
T ₁		T ₂		T ₃		T _C	

Figure 1. The applied experimental design. T₁ - effluent water, T₂ - effluent water supplemented with gypsum, T₃ - effluent water mixed with surface water and supplemented with gypsum, T_C - river water (control). The numbers in the cells represent the identification number of the gravitational lysimeters. M 488 – Hungarian rice variety



Figure 2. Lysimeter experiment of rice developed with different quality of irrigation water

Four types of treatments have been applied during the experiment: T₁ - effluent water; T₂ - effluent water supplemented with gypsum; T₃ - effluent water diluted with surface water and supplemented with gypsum; T_C - control treatment, water from oxbow, which is a section of the Körös River in eastern Hungary. The chemical parameters of treatments are listed in the *Table 1*.

Seeds were sown on May 22, 2019. On the first and second irrigation days (22nd of May and 7th of June) all plants in lysimeters were irrigated with river water, only after that they were irrigated on the basis of treatments. On July 4, 0.5 kg of fertilizer (NH₄NO₃ + CaMg(CO₃)₂) was applied (84.4 kg N*ha⁻¹), and pesticides were not used during the experiments. The total applied irrigation water was 200 mm. Irrigation time and amount of used water are shown in the following *Table 2*.

Meteorological data were measured using meteorological equipment (Agromet-Solar automatic weather station, Boreas Ltd., Hungary) that was installed next to the experimental field. Rainfall during the growing season was 303.7 mm (*Table 3*).

Table 1. The basic chemical parameters of treatments

Chemical parameters	T ₁	T ₂	T ₃	T _C
pH	7.77	7.71	7.70	7.55
Electrical Conductivity (EC) (μS/cm)	1180	1905.00	1033.75	371.86
m-alkalinity	13.77	14.65	8.23	3.00
Bicarbonate (mg/l)	838.67	894.00	502.00	182.67
Ammonium-N (mg/l)	20.40	23.45	10.39	0.37
Nitrate-N (mg/l)	0.03	-	0.47	0.43
Nitrite-N (mg/l)	0.02	0.13	0.13	0.06
Total inorganic N (mg/l)	20.45	23.58	10.60	0.64
Total organic N (mg/l)	5.86	4.98	2.51	-
Total N (mg/l)	26.3	28.55	13.10	1.19
P-orthophosphate (mg/l)	1.72	2.55	1.38	0.12
Total P (mg/l)	2.18	2.67	1.53	0.15
Chloride (mg/l)	29.90	33.15	27.15	22.54
Sulphate (mg/l)	32.65	448.75	164.18	34.58
Ca (mg/l)	23.23	187.50	90.83	39.04
Mg (mg/l)	10.08	11.02	10.69	9.80
Na (mg/l)	249.00	266.75	131.25	28.90
K (mg/l)	6.08	6.61	5.43	3.71

T₁ - effluent water, T₂ - effluent water supplemented with gypsum, T₃ - effluent water mixed with surface water and supplemented with gypsum, T_C - river water (control)

Table 2. Irrigation dates and amount of applied water

Irrigation water applied (mm)											
Irrigation dates	22. May	07. June	14. June	02. July	04. July	12. July	18. July	26. July	12. August	22. August	Total
T ₁	20	20	20	20	20	20	20	20	20	20	200
T ₂	20	20	20	20	20	20	20	20	20	20	200
T ₃	20	20	20	20	20	20	20	20	20	20	200
T _C	20	20	20	20	20	20	20	20	20	20	200

T₁ - effluent water, T₂ - effluent water supplemented with gypsum, T₃ - effluent water mixed with surface water and supplemented with gypsum, T_C - river water (control)

Table 3. Monthly precipitations and temperatures (average, minimum and maximum) during the growing season

	Precipitation (mm)	T avg. (°C)	T min. (°C)	T max. (°C)
May	48.7	17.8	8.0	26.0
June	162.4	23.5	14.2	34.0
July	68.1	22.2	10.3	34.1
August	24.5	24.1	10.8	36.3

After the harvest (24th of September, 2019) and standard post-harvest operation (cleaning, drying, and storing) basic tests – Thousand Kernel Weight (TKW), Milling Quality Parameters (MQP) and Mineral Content (MC) of rice seeds were analysed (Table 4).

Table 4. Conducted test and used equipments

Nº	Conducted tests	Used equipments (methods)
1	Moisture content	Sartorius MA45
2	Thousand Kernel Weight (TKW)	1) Sartorius BP221S
3	Milling Quality Parameters (MQP)	2) Satake THU Laboratory Husker
4	Analysis of Mineral Content (MC)	Satake TM05 Test Mill laboratory
		1) Thermo Scientific Solaar M6 atomic absorption spectrophotometer
		2) Thermo Scientific ICAP 6000 ICP-OES

In order to begin those tests, moisture content of rice seeds from every sample was defined. At the beginning, the grains of each sample were divided into tiny particles, then by using Sartorius MA45 moisture analyser moisture content was found. The average moisture content was computed after the replications of four measurements.

For Thousand Kernel Weight (TKW) test, 100 paddy seeds were counted from each sample and weighed on Sartorius BP221S analytical balance. Afterwards, husk of seeds was removed by using Satake THU Laboratory Husker equipment and cargo (brown) rice weighed. The obtained results were multiplied by 10. After four replications of tests, the average TKW of paddy and cargo rice was determined.

100 g of rice from each sample was prepared for Milling Quality Parameter (MQP) analysis. First, a husk layer of seeds removed and cargo rice was weighed. Later, by using Satake TM05 Test Mill laboratory equipment brown rice was polished and the results were weighed. Subsequently, the percentage whole and broken white (polished) rice were calculated. The experiment was repeated five times and the average value is defined. According to the following formulas, the results were calculated (Lapis et al., 2019):

$$\% \text{ Cargo rice} = \frac{\text{weight of brown rice (g)}}{\text{weight of paddy rice (g)}} * 100 \quad (\text{Eq.1})$$

$$\% \text{ Polished rice} = \frac{\text{weight of polished rice (g)}}{\text{weight of paddy rice (g)}} * 100 \quad (\text{Eq.2})$$

$$\% \text{ Whole p.rice} = \frac{\text{weight of whole p.rice (g)}}{\text{weight of paddy rice (g)}} * 100 \quad (\text{Eq.3})$$

Mineral Content (MC) test involves determination of amount basic minerals (Ca, Mg, K, Na, and P) in rice grains. In order to carry on analyses, paddy rice from each sample were hulled with Satake THU Laboratory Husker and brown rice received. After standard procedures, every sample was wet digested in 6 ml HNO₃ and 2 ml H₂O₂. One day later, the samples were kept in a microwave oven at a temperature of 180 °C for 1.5 hours. Afterwards, samples were analysed by using AAS and ICP-OES (NAIK ÖVKI Laboratory of Environmental Analytics, Szarvas, Hungary).

Based on standard methods, Ca, Mg, K and Na content were measured by Thermo Scientific Solaar M6 atomic absorption spectrophotometer. Determination of P was done with Thermo Scientific ICAP 6000 ICP-OES inductively coupled plasma atomic emission equipment, according to MSZ EN ISO 11885:2000 international and Hungarian standard.

The collected data were subjected to the analysis of variance (ANOVA) using IBM SPSS software (version 22). The significant differences among mean values were

determined with the Tukey test at 5% level of probability. In condition of violation of homogeneity of variances (Levene's test, $p < 0.05$), Games-Howell post-hoc test was set under the terms of Welch test ($p < 0.05$).

Results and discussion

Moisture content

The general idea behind of controlling moisture content of paddy seeds to receive moisture content below 14% (International Rice Research Institute, 2013). For the experiments, samples were placed in storage room in unmonitored condition. Although, conducted experiments were done moisture free basis, in our experiments we also got results less than 14% in all samples. The moisture content of samples under T₁, T₂, T₃ and T_C was 7.97%, 7.46%, 7.69%, 7.28%, respectively.

Thousand Kernel Weight (TKW)

One of the main indicators of the vitality, quality, and productivity of rice seeds is associated with TKW (Wu et al., 2018). In many cases, the TKW of rice grains in cultivation under flooding conditions is greater than in aerobic rice systems, however, it may vary depending on the rice cultivar (Castaneda et al., 2003; Reddy et al., 2010). The results of our experiments (Table 5) show, in both paddy seeds and cargo seeds, the highest TKW between treatments was observed with T₁. Nevertheless, the result of statistical analysis indicated non-significant differences between treatments ($p > 0.05$). The absence of such a statistically significant difference specifies a similar reaction of rice to all treatments.

Table 5. Thousand kernel weight of paddy and cargo seeds of rice developed with different quality of irrigation (Szarvas, 2019)

Treatment		TKW of paddy seed (g)	TKW of cargo seed (g)
T ₁	Average	22.15a	17.88a
	CI	[21.54; 22.76]	[17.4; 18.35]
T ₂	Average	22.0a	17.68a
	CI	[20.88; 23.13]	[16.65; 18.72]
T ₃	Average	22.01a	17.76a
	CI	[21.65; 22.38]	[17.2; 18.32]
T _C	Average	21.48a	17.28a
	CI	[21.17; 21.78]	[17.19; 17.37]

T₁ - effluent water, T₂ - effluent water supplemented with gypsum, T₃ - effluent water mixed with surface water and supplemented with gypsum, T_C - river water (control). CI - confidence interval (lower and upper bound). Values with the same letter are not significantly different at $p < 0.05$

Milling Quality Parameters (MQP)

The importance of rice milling is mainly related to the percentage of whole white rice (Dhankhar et al., 2014). On the one hand, if it is connected with the tradition of consumption, on the other hand, it is closely connected with marketing goals (Dela Cruz and Khush, 2000; Zhou et al., 2019). Usually, most consumers before buying a product,

pay attention not only to the shape of the rice, but also to the colour and aroma of the rice (Rachmat et al., 2006). While in our experiment in the analysis of cargo rice percentage and polished (white) rice percentage, apparent differences were not found, in the percentage of whole polished rice there were statistically significant differences between treatments (Table 6). T₁, T₂, and T₃ had a statistically similar results ($p>0.05$), 60%, 61% and 59.12%, respectively. However, the highest percentage of whole polished rice was observed in the control treatment (68.5%) and this difference was statistically significant ($p<0.05$) between T₁, T₂, and T₃. According to the initial assumption, this difference between the results is due to the chemical composition between the control and the other treatments. One of the main indicators of the effluent water from intensive fish farm is that it contains a lot of sodium. Usually, rice cultivated under aerobic conditions and irrigated at regular intervals is subject to abiotic stresses (Jabran et al., 2017). This sensitivity to abiotic factors manifests itself as a reduction in a number of plant parameters (Singh et al., 2012; Kato and Katsura, 2014). The high salt content in the water prevents the plant from absorbing the water it needs (Ghosh et al., 2016). The greatest challenge is when the temperature is high, which causes the plant to become more stressed (Clermont-Dauphin et al., 2010; Mishra et al., 2015; Ali et al., 2019). Although the response to salinity may vary depending on the rice variety, increasing the salinity level of irrigation water at all stages of cultivation can significantly affect rice (Castillo et al., 2007; Fraga et al., 2010; Chang et al., 2019). This may ultimately affect the quality of the rice seeds.

Table 6. Milling quality parameters of cargo and polished seeds of rice developed with different quality of irrigation (Szarvas, 2019)

Treatment		Cargo (Brown) (%)	Polished (White) (%)	Whole polished rice (%)
T ₁	Average	79.2a	72a	60a
	CI	[78.16; 80.24]	[71.12; 72.88]	[54.81; 65.19]
T ₂	Average	78.2a	71.1a	61.1a
	CI	[77.65; 78.76]	[68.72; 73.48]	[58.14; 64.06]
T ₃	Average	78.8a	72.8a	59.12a
	CI	[78.19; 79.41]	[72.19; 73.41]	[57.93; 60.31]
T _C	Average	78.8a	72.9a	68.5b
	CI	[77.86; 79.74]	[71.29; 74.51]	[66.92; 70.08]

T₁ - effluent water, T₂ - effluent water supplemented with gypsum, T₃ - effluent water mixed with surface water and supplemented with gypsum, T_C - river water (control). CI - confidence interval (lower and upper bound). Values with the same letter are not significantly different at $p<0.05$

Salinity also has a direct effect on the protein content of rice grains, where protein loss can increase the rice seed breakage (Leesawatwong et al., 2004; Balindong et al., 2018). Since the decrease in protein content in salt-sensitive rice varieties is observed more distinctly (Billah et al., 2017). Moreover, according to Rao et al. (2013), salinity in the soil is another reason for the decline in head rice recovery.

Mineral Content (MC)

The content of Ca in all treatments had a statistically similar ($p>0.05$) result (Table 7). Analogous results were also noted in Na content. While there was no statistically significant difference in Mg content between the control and T₁, T₂, T₃, the difference

between T₃ and T₁, T₂ was statistically significant ($p < 0.05$). P and K content in T₃ was lower compared to the control and T₁, T₂, which was a statistically significant difference ($p < 0.05$).

Table 7. Average mineral content in M 488 rice seeds, (Szarvas, 2019)

Treatment		Ca (mg/kg dry matter)	Mg (mg/kg dry matter)	P (mg/kg dry matter)	K (mg/kg dry matter)	Na (mg/kg dry matter)
T ₁	Average	396.5a	1652.5b	4240b	3600b	200.25a
	CI	[306.71; 486.29]	[1573.07; 1731.93]	[3954.47; 4525.53]	[3327.78; 3872.22]	[165.4; 235.1]
T ₂	Average	412.75a	1717.5b	4490b	3807.5b	211.25a
	CI	[338.41; 487.09]	[1657.43; 1777.57]	[4266.85; 4713.15]	[3469.86; 4145.14]	[181.02; 241.48]
T ₃	Average	421a	1405a	3440a	3005a	226.75a
	CI	[361.7; 480.3]	[1364.96; 1445.04]	[3293.58; 3586.42]	[2807.75; 3202.25]	[208.92; 244.58]
T _C	Average	427.75a	1650ab	4297.5b	3665b	201.25a
	CI	[369.83; 485.67]	[1419.41; 1880.59]	[3469.62; 5125.38]	[3217.85; 4112.15]	[183.28; 219.22]

T₁ - effluent water, T₂ - effluent water supplemented with gypsum, T₃ - effluent water mixed with surface water and supplemented with gypsum, T_C - river water (control). CI - confidence interval (lower and upper bound). Values with the same letter are not significantly different at $p < 0.05$

The high salt content in irrigation water creates stressful conditions and negatively affects the mineral metabolism in plants (Subekti et al., 2020). In our experiments, since the salinity level was normal in control, there were no obstacles to the absorption of P, K from water. Compared to T₁, T₂, the salt content in T₃ was lower, however, due to the low P, K in T₃, the content of P and K in the brown seeds may be lower. It should be noted that under stress, the development of the roots decreases, and the absorption of minerals is weakened (Hu and Schmidhalter, 2005; Hakim et al., 2014). In general, in each part of the plant a different amount of mineral accumulates (Sperotto et al., 2017). In other words, the low transportation and accumulation of minerals in T₃ can be associated with a high salt content and a low content of P, K. Furthermore, despite the low content of minerals in control, because of optimal regime, there was no interfere to the transportation of minerals.

Conclusion

Limited water resources, problems with the use of existing water resources, droughts and various global climatic phenomena require the use of alternative irrigation methods. In the current experiment, an analysis of the quality of rice irrigated with water discharged from an intensive fish farm was made. The study showed that both the direct use of intensive fish farm water (T₁) and supplemented with additives (T₂, T₃) does not adversely affect TKW and MC of rice grains (excluding P and K during T₃ irrigation), but reduces percentage of whole polished rice. Based on general ideas, the influence of direct use of intensive fish farm water (T₁) or supplemented with additives (T₂, T₃) on the quality indicators of the studied rice variety (M 488) under conditions of minimizing the harming effects of all the stress factors is stable. Although the most important determining factor

is the amount of irrigation water and the total number of irrigation applications, to further clarify these conditions and the effect of effluent water on the development of aerobic rice, more quality parameters and more genotypes would be necessary in the upcoming experiments. But effluent water from the intensive African catfish farm could be utilized for irrigation purposes what can hinder the negative effects (mainly nutrient content) of this water for the natural water bodies. Finally, the use of effluent water in a more complex agriculture system, such as agroforestry, can also provide a natural solution for the utilization of effluents and also for the restoration and conservation of natural water resources.

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