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Ph.D Dissertation

ASSESSING THE IMPACT OF IRRIGATION WITH AGRICULTURAL WASTEWATER ON AEROBIC RICE (*Oryza sativa* L.)

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TABLE OF CONTENTS

LIST OF FIGURES:

LIST OF TABLES:

LIST OF EQUATIONS

APPENDICES

LIST OF ABBREVIATIONS

AWD	Alternate wetting and drying
AWW	Agricultural wastewater
CI	Confidence interval
FAO	Food and agriculture organization
GD	Grain dimension
GT	Gelatinization temperature
HCSO	Hungarian Central Statistical Office
IRRI	International rice research institute
MC	Mineral content
MQP	Milling quality parameters
NAIK	Nemzeti Agrárkutatási és Innovációs Központ (National Centre of Agricultural Research and Innovation)
ÖVKI	Öntözési és Vízgazdálkodási Kutatóintézet (Irrigation and Water Management Research Institute)
SAR	Sodium adsorption ratio
TKW	Thousand kernel weight
USDA	The United States Department of Agriculture

I dedicate this thesis to my parents, younger brother and sister. Nothing can replace your endless support and priceless love.

1. INTRODUCTION

The demand for high-quality food, coupled with a growing number of human population, is increasing pressure on agriculture around the world. To achieve this goal, freshwater resources and various chemicals (fertilisers, pesticides) are widely used. It is well known that agriculture is one of the largest areas that is responsible for a large amount of water consumption in the world. However, changing climatic conditions and economic costs do not always make them affordable. In the age of climate change and depletion of water resources, a new approach is needed to provide crops with sufficient water. It is especially important in climate vulnerable countries with arid and semi-arid areas, where growing plants suitable for these conditions is becoming an additional challenge for local farmers.

Rice (*Oryza sativa* L.) cultivation in many countries meets also water shortages and other environmental issues. Rice is considered the staple food that provides dozens of millions of people with essential nutrition. The main concerns of people involved in this area are associated with unstable weather conditions, lack of water and their cost, and fertilisers. Alternative sources of irrigation and methods of irrigation are seen as a way out to overcome existing problems. The continuous increase of wastewater as a result of urbanization and industrial development has become a major option for agricultural use nowadays. Besides water-saving technologies, alternative sources of irrigation water, such as wastewaters or effluent waters, are among the opportunities that can help to cope with water scarcity. Wastewater is one such alternative source in which plants can be irrigated without fertiliser application due to the nutrients present in them. In addition, the beneficial use of wastewater for irrigation can also reduce their potential environmental impact. Because, depending on the source of wastewater, it may contain hazardous elements that can be harmful to human health.

Although the use of agricultural wastewater is considered a solution to the problem of water scarcity and maintaining an ecological balance, from the point of view of food security, it is also necessary to study the impact on the quality parameters of rice.

This dissertation covers a three-year experiment conducted in 32 lysimeters, in which changes in the qualitative characteristics and parameters of the mineral composition of 2 Hungarian rice varieties irrigated by effluent water from a fish farm are studied.

For better understanding of agricultural and plant physiological processes, it is necessary to study rice grown under aerobic conditions with agricultural waste water (AWW) irrigation and to evaluate its effect on the chemical composition of plants. The primary hypothesis was that the different macro nutrients in the accessible agricultural wastewater have different influences on the development and nutrient accumulation of the aerobic rice. Beside main nutrients, the focus was on the effects of high sodium content in the irrigation water, not only because of the predicted disadvantageous effects, but because of the possible bioremediation opportunities with the aerobic rice cultivation.

The purpose of the research is to answer the following questions:

- Whether is it suitable or not to use our specific agricultural wastewater for irrigation based on the complex evaluation of crop plant responses?
- How does agricultural wastewater affect the quality parameters of rice grown under the aerobic conditions?
- What is the role of agricultural wastewater used in the circulation and accumulation of minerals in aerobic rice varieties?

In this study, Hungarian rice varieties were irrigated with traditional and alternative irrigation water in a complex lysimeter study to unravel the effects of fish farm effluents on the mineral composition of aerobic rice plants. This can lead us to the better understanding of the advantages and disadvantages of effluent irrigation. Moreover, deeper analysis of different alternative water sources and the reutilization of agricultural effluents can reduce the impact of rice production and animal husbandry on the natural water bodies and lead to good quality food and feed production too.

2. LITERATURE REVIEW

2.1. The role of irrigation

The essence of irrigation is to maintain an optimal water regime of the soil in order to provide the plants with the necessary moisture (Qahramanli et al., 2014). Irrigation has a profound effect on the soil-forming process, causing significant changes in the physical state of the soil, salt regime, chemical and microbiological processes, the rate of accumulation and decomposition of soil organic matter (Aliyev, 2009).

Since ancient times, various civilizations have obtained high yields, using a number of irrigation methods in agriculture, which have become the mainstay of their prosperity (Khan et al., 2006; Davies, 2009). Currently, the food needs of the world's population are largely dependent on products derived from irrigated lands. According to information provided by FAO-AQUASTAT (2014), in 2012 alone, in the world 324 million hectares of land were allocated for irrigation purposes. Taking into consideration that the number of population in the world continues to grow, a sharp increase in the size of irrigated land in the future is beyond doubt (Faurès et al., 2002). For comparison, in Hungary, the total area of irrigated land in 2015 was 80529 hectares, and in 2017 it was equal to 101405 hectares (HCSO, 2018).

On the one hand, if irrigation is productively, economically important, on the other hand, it is indispensable to ensure normal plant life. Water supply of plants in accordance with the schedule of irrigation causes a stronger morphological structure in plants and due to regular watering during the growing season, the water regime in the soil is maintained at a high level (Kutimskaya et al., 2011). Thus, plants are easier to absorb nutrients in the soil through their roots. In irrigation, the roots usually spread well in the upper horizons of soil and more fully utilize fertility (Turner, 1990). Moreover, irrigation creates favourable conditions for increasing the effect of organic and mineral fertilisers. Following the water application rate, not only water conservation can be done, but also make rational use of fertilisers (Fomenko and Popova, 2018).

2.2. Problems associated with irrigation

2.2.1. Difficulties faced by irrigation

The key point here is the degree of access to available water and its effective use. Despite the fact that about 71% of the Earth’s surface is covered with water, but not all of it is suitable for irrigation. The greater portion of it (Figure 1) belongs to the world oceans (Shiklomanov, 1993).

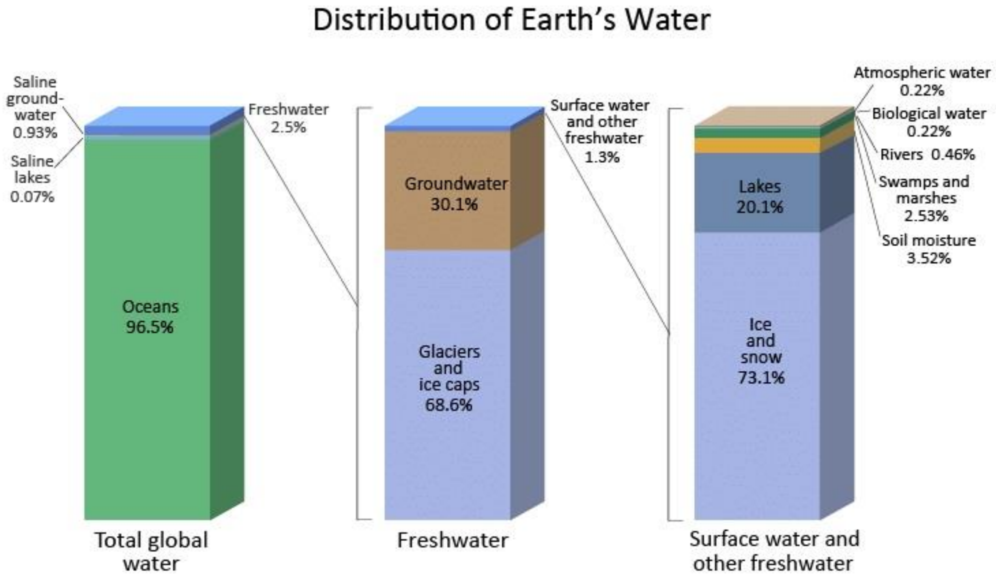

Figure 1. Distribution of Earth’s Water by Igor Shiklomanov (1993), editor Peter H. Gleick

However, irrigation water was disproportionately distributed over the land, and by 2025 (Figure 2) this situation could worsen (Shiklomanov, 2000).

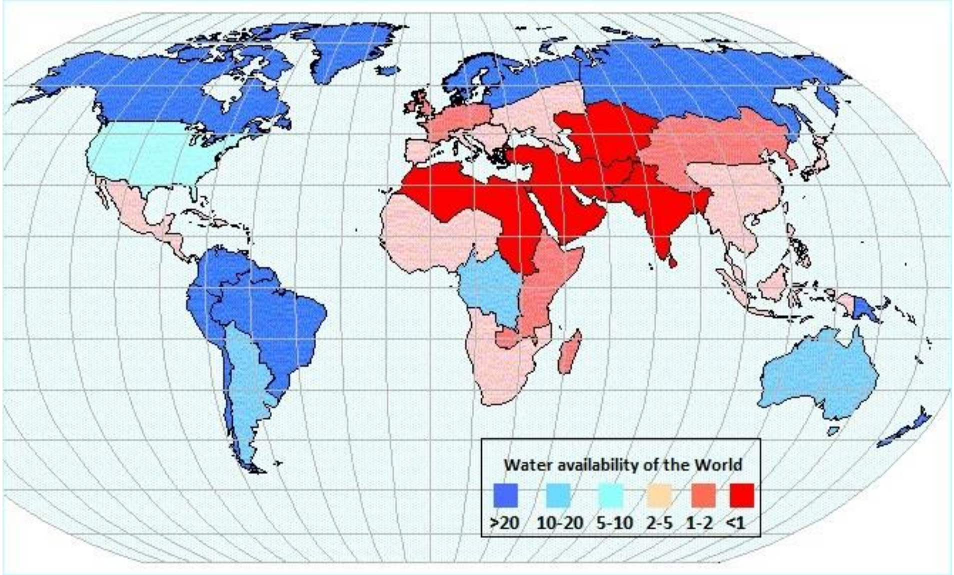

Figure 2. The distribution of water availability values by natural-economic regions of the world in 2025

As Molden (2013) already mentioned, 70% of all the freshwater in the world is used by irrigated agriculture. In some countries, especially between developed and developing countries, this number has different indicators depending on the type of cultivated plants (Kirpich et al., 1999). For instance, while the total amount of water utilized per ton of wheat cultivation in the period 1996-2005 in Hungary was 1306 m^3/t, in Pakistan was 2548 m^3/t (Mekonnen and Hoekstra, 2010). Certainly, on the one hand, if such a difference here is related to weather conditions, soil, and plant variety, and on the other hand, with irrigation systems and methods.

Irrigation systems are the basis of irrigated agriculture. Thereby, with the assistance of irrigation systems it is possible to regulate the flow, the amount of water and its schedule. According to Shrivastava (1994), up to 44% of water can be saved with drip irrigation compared to surface flood irrigation when growing tomatoes. Albaji et al. (2015) suggested that, taking into account the soil texture of the region with a sprinkler and drip irrigation, land productivity can be further increased. With drip irrigation, there is not only an increase in the efficiency of nitrogen use, but also their significant savings (Singh et al., 2007).

It should be noted that various scenarios of population growth led to the adoption of measures to organize specific programs in each part of the world (Lutz et al., 2018). These programs mainly include productivity, protect and ensure food security (Edmeades et al., 2010). China, the most populous country in the world seeks to produce 500 million tons of food per year using 320-340 milliard m^3 of water (Peng, 2011). This, in turn, will indicate a sharp absorption of water resources in the future.

2.2.2. Difficulties caused by irrigation

The difficulties caused by irrigation mainly include environmental impacts, which can have serious consequences. The main reason for the occurrence of such adverse events is, not to control the flow of water properly, and not to properly observe the irrigation rate. The biggest problems encountered in such cases are soil erosion and salinization. Soil erosion may occur for various reasons, but the most common of these is irrigation erosion or “irrigation-induced erosion” caused by direct anthropogenic factors (Lehrsch et al., 2005; Bjorneberg, 2013). Regardless of the type of water erosion (sheet, rill, and gully), the humus layer of the soil is washed out, and the productivity of the soil decreases (Bertol et al., 2003; O’geen and Schwankl, 2006). According to some studies, millions of hectares of arable land are lost every year due to erosion (Pimentel, 1995; 2006). In many countries where agriculture is the basis of economic development, this loss has dire outcomes (Rakhmatullaev et al., 2013; Bhattacharyya et al., 2015). High salt content in irrigation water can lead to soil salinity, and plants can be stressed (Brouwer et al., 1985). Improper irrigation is another reason for fertiliser leaching from the soil, which reduces the efficiency of fertiliser use (Austin et al., 1996; Burkitt, 2014). In such cases, fertilisers, especially accumulating in groundwater, can harm the environment and human health (Li et al., 2018).

2.3. Novel approaches in irrigation and water management

2.3.1. Global changes and irrigation

With the beginning of the industrial revolution from the end of the 19th century, with the rapid growth of the economies of many leading countries of the world, the world's population was about to meet a new understanding (Kasa, 2009). This term, called global warming, refers to changes in temperature on Earth atmosphere as a result of a large number of gas emissions (CO_2, CH_4, N_2O) from industrial areas (Lashof and Ahuja, 1990; Astrup et al., 2009). Kessel (2000) reports that, given the continuation of industrial activity, the temperature in the coming decades is expected to increase by 1-3.5 °C.

Although warming is just one of the symptoms of global climate change, it also includes other climatic disasters, such as drought, unexpected temperature fluctuations, melting glaciers (Mertz et al., 2009; Schuldt et al., 2011). These cases are already observed in some parts of the world. Some countries in the Andes, especially in Bolivia, are experiencing problems with the melting of mountain glaciers to meet the water needs of the people (Füssel et al., 2012; Rangecroft et al., 2013). According to Björnsson and Pálsson (2008), the melting of glaciers in Iceland will lead to an increase in sea level by 1 cm. Tchebakova et al. (2009) reported that with increasing temperature, taiga forests in Siberia will suffer and lead to a sharp reduction in vegetation. Another important problem is the formation of an ozone hole, which is exacerbated by the release of greenhouse gases into the atmosphere (Thompson et al., 2011). In this regard, the signing of the Paris Agreement is one of the most successful steps taken to prevent current and future climate change (Jacobs, 2016).

Such an increase in climate anomalies has affected many areas of human activity, including irrigation. As Döll (2002) said, climate change is not only a change in the world's water resources, it also affects the water requirements of various agricultural crops. According to calculations, a decrease in water flow in many regions of the world is directly related to changes in precipitation and total evaporation due to climate change (Turral et al., 2011). For instance, in the late 90s, droughts caused a high level of depletion of water resources in Turkey (Mengu et al., 2011). De Silva et al. (2007) noted that in the future, according to climate change modelling with decreasing rainfall, the average requirements of rice in irrigation water may increase in much of Sri Lanka. Although, according to some of the proposed scenarios of climate change, they will lead to passable damage, however, the economies of most developing countries can suffer serious losses due to increased heat (Mendelsohn, 2008). According to another study, changes in the Mediterranean climate will also affect the productivity of some major crops (Yano et al., 2007). In Nepal, where the need for irrigation mainly comes from rivers that originate from mountain glaciers with rising temperatures, it is expected to be droughts, unpredictable floods and landslides, as well as the need for farmers grow unconventional crops in the region (Thakur, 2017). According to research of Hopmans and Maurer (2008) on the western San Joaquin Valley in California, soil salinity increases if the necessary technological measures are not taken with future climate change, which, in turn, will negatively affect the productivity of crops such as tomatoes and cotton.

2.3.2. Water saving in irrigation

Limited water resources, problems with the use of existing water resources, droughts and various global climatic phenomena require the use of alternative irrigation systems and methods. The devices that are most preferred for the efficient use of water include drip irrigation, sprinkler irrigation. Drip irrigation is an irrigation method in which water and nutrients enter directly into the root zone of plants in regulated parts using emitters (Ksiksi et al., 2019). Thus, water does not penetrate into deeper soil layers, evaporation and infiltration are reduced (Boutheina and Abdelhamid, 2011). More efficient use of water resources is one of the most important features of drip irrigation. Drip irrigation has a significant advantage in improving the efficiency of water use in cotton cultivation (Ibragimov et al., 2007; Dağdelen et al., 2009). Ayars et al. (2015) in their research also mentioned that drip irrigation plays an important role in increasing both water productivity and financial costs. In addition to efficiency similar to drip irrigation, a sprinkler irrigation system can be used in more difficult terrain conditions (Narayanamoorthy, 2006; Zhang et al., 2018).

One of the methods used to create and maintain long-term soil moisture is mulching, in which coating the surface of the soil with some material. Zhang et al. (2008) have come to the conclusion that using mulching in rice cultivation can improve water use efficiency, and wheat straw mulching can increase the quality compared to plastic film mulching.

Due to water shortage, various deficit irrigation strategies have been created to provide the soil with the necessary moisture and plant water requirements (Costa et al., 2007; Fereres and Soriano, 2007; Chai et al., 2016). In terms of food security, the introduction of deficit irrigation in agriculture is already the focus of a number of leading countries, such as China (Du et al., 2015). Although deficit irrigation can lead to certain crop losses, in most cases it increases the water use efficiency (Kögler and Söffker, 2017; Al-Ghobari and Dewidar, 2018). For instance, Bell et al. (2018) proposed a managed deficit irrigation as a measure to increase the productivity of sorghum cultivation. However, in order to stabilize the yield and minimize the reduction, the application of the deficit irrigation must be carried out in accordance with the growing stage of crops too (Tari, 2016). According to another study, to prevent yield loss due to a deficit irrigation, applying biochar soil amendments may be a good approach for growing tomatoes (Agbna et al., 2017).

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 (Toze, 2006; Drechsel and Evans, 2010; Qadir et al., 2010; Petousi et al., 2019). On the one hand, the use of wastewater is considered an alternative to existing water resources, on the other hand, their use can be to maintain the ecological balance on land and minimize environmental damage (Zhang and Shen, 2019). Reuse of wastewater is becoming more and more important from the view of environmental protection, and it can also provide plants with the necessary macro and micro elements (Rahman et al., 2018). Everything here is based on the principle of what is considered waste for one area, is raw material, a treasure for another area. A 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.

Wastewater directly or indirectly affects not only people, but also the different inhabitants of a whole ecosystem, damaging their livelihoods (Siebe and Cifuentes, 1995; Akpor and Muchie, 2010). The composition of the waste in each industry consists of various chemicals. In many cases, their discharge into water sources can destroy living organisms (Suthar et al., 2010). However, direct reuse of wastewater from some areas or their use after neutralizing their chemical composition can reduce the potential harm to a certain extent (Baresel et al., 2016; Salgot and Folch, 2018).

Since wastewater are rich in chemical composition, in some cases, these waters can be used as fertilisers (Rahimi et al., 2012; Ryu et al., 2012). Recovery of some essential minerals, especially phosphorus from wastewater, is the focus of many researchers (Zhou et al., 2017; Peng et al., 2018). Here one of the main factors is the source of the water used. It is also possible to make some progress in increasing productivity through the use of wastewater for irrigation (Khan et al., 2009). Singh, P. K. et al. (2012) reported that wastewater with high nutrient content has a great advantage in increasing yield. Mekki et al. (2006) noted that olive mill wastewater with pre-treatment positively affects the growth of several plants, such as tomato, wheat, beans, and soil structure. Zavadil (2009) also observed similar results in increasing the production of certain vegetables by irrigation with primary treated wastewater.

The use of wastewater has not only environmental, but also the economic importance (Arborea et al., 2017). Haruvy claims (1997) the cost of fertiliser can be reduced by using wastewater in agriculture. According to another study, wastewater can significantly reduce the use of fertilisers (Hussain and Al-Saati, 1999).

2.4. Agricultural wastewater

Sustainable agriculture is a key factor in providing the population with quality food. Nevertheless, along with the growth of social inequality, a large part of the world's population continues to experience food shortages (Laio et al., 2016).

To tackle with this problem, since the middle of the 20th century in the form of a “green revolution", a huge portion of the land with various treatments was used for agricultural purposes (Lynch, 2007). Although it had great productivity, but it also led to a lot of side effects, such as soil erosion, loss of soil fertility, pollution (Rahman, 2015).

At present, another major issue related to intensive agriculture is wastewater. Most studies show that agriculture also plays an indisputable role in environmental pollution, like other industrial enterprises (Özerol et al., 2012; Hatfield, 2015). Basically, large agricultural wastewater (AWW) discharges come from poultry and livestock farming. Only for processing one bird with 2.3 kg on average 26.5 l of water is required (Avula et al., 2009). Moreover, according to Ran et al. (2016), livestock farming uses one third of global agricultural water sources.

In the end, usually AWW is discharged into soil or water bodies without treatment. The biggest risk factor here is that AWW often contains microbes and pathogens, chemicals, antibiotic residues and other substances that threaten the health of living organisms and nature (Yordanov, 2010; Bustillo-Lecompte et al., 2016).

There are several models that are designed to avoid these problems caused by AWW. For instance, the biogas heat storage greenhouse system suggested by Qin et al. (2019) significantly decreased water pollution. On the other hand, nutrient-rich AWW, if properly treated in irrigated agriculture, can offer great benefits too (Domashenko and Vasilyev, 2018; Villamar et al., 2018). Moreover, in advance by creating a good water management in poultry slaughterhouse, water consumption can be reduced, which was implemented in a case study of Kist et al. (2009).

2.5. Irrigation with fish farm effluent

Aquaculture is an industry engaged in fish farming, increasing fish stocks and improving the beneficial properties of fish (Fedonenko et al., 2017). Aquaculture production can take place on land, under certain conditions at the bottom of the sea or in freshwater bodies and floating structures (Lekang, 2013). Fish farming is one of the highly profitable sector aimed at growing certain types of fish in specially equipped artificial reservoirs, economic aspects and demand for seafood are key areas for the development of this industry (Naylor et al., 2000; Lee and Yoo, 2014). Alive and fresh fish are in great demand among the population, not only because fish proteins are absorbed faster and with less energy by the body, but also because fish meat contains a lot of phosphorus, magnesium, calcium, which are necessary for the metabolism of carbohydrates and the construction of nervous system tissues, brain and other organs (Das et al., 2009; Du et al. 2012). According to FAO (2018), in 2016 alone, fish production worldwide reached 171 million tons.

However, aquaculture production, like other agricultural activities, has an impact on the ecosystem, and as the fish farm grows, this impact also increases. The main causes of damage in the aquatic environment are feed residues, antibiotics, disinfectants, vaccines, vitamins, hormones and other chemicals that are mainly used in fish farming (Rico et al., 2012; Dawood et al., 2018; Hedberg et al., 2018; Lulijwa et al., 2019).

As a rule, regardless of the type of fish bred in aquaculture, a large amount of water, feed and various treatments are used (Sharma et al., 2013; Prabu et al., 2017). Although fish breeding species and systems play an important role here, there is usually a lot of phosphorus, nitrogen, and organic matter in the discharge of water from fish farms (Zhang et al., 2019; Huang et al., 2020). The main source of these is fish feeds and fertiliser, which appears after from uneaten (wasted) feed or in the form of fish feces (Cao et al., 2007; Lazzari and Baldisserotto, 2008; Zhou et al., 2011).

Aquaculture is one of the main water dependent sectors in agriculture, especially intensive aquaculture where large water volume and high protein content in feed are used. This results in a significant amount of nutrient-rich effluents (Kerepeczki et al., 2011). Management of the discharged wastewater from such systems still needs developments to lower the negative effects on natural water bodies (Csorbai and Urbányi, 2019; Tóth et al., 2020.). There are traditional and improved methods for quality treatment that significantly determine the reutilisation possibilities of output nutrients (Edwards, 2015; Ribeiro and Naval, 2019). However, aquaculture effluents that can be characterized by high sodium content need special pre-treatments before conditionally reuse them in agricultural irrigation (Kun et al., 2018).

A number of chemicals, especially antibiotics, are also used to protect and treat the health of living organisms raised in the aquatic environment (Wu, 1995; Cañada-Cañada et al., 2009). But the uncontrolled or intensive use of antibiotics contaminates the environment and threatens human health (Zuccato et al., 2010; Binh et al., 2018). For instance, according to a research by Khodabakshi and Amin (2012), the heavy use of malachite green, which are effective against a number of diseases, has led to its accumulation in water and trout tissue. Jones noted (1990) that in recent decades an increase in the number of fish farms due to the disposal of waste into water resources has led to a disruption in the chemical and environmental balance in the water. According to a study by Ruiz-Zarzuela et al. (2009) in Northeast Spain, water from fish farms directs to a decrease in pH and dissolved oxygen in the river, which could affect water quality and aquatic life. Soofiani et al. (2012) also obtained similar results and showed that the pollution effect by effluents has a high percentage during a low water level in the river.

Fish farming is a prospective area, which uses a large amount of water with the composition of various chemicals. Therefore, the discharge of water from fish ponds as a source of irrigation has been the subject of several studies. On the one hand, if this is due to the importance of reducing the environmental impact of discharged water from fish farms, on the other hand, using this is a way to save or find a solution to the problem of water shortage in irrigation water resources. 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. Maia et al. (2019) claim that effluent from a fish farm can also increase soil fertility.

According to most studies, the most important minerals that plants need can be provided with fish wastewater (Eid and Hoballah, 2014; Sikora et al., 2019; Qi et al., 2020). Like inorganic fertilisers, it has a great advantage in increasing the productivity of vegetables (Lin and Yi, 2003; Hailu et al., 2018). According to Castro et al. (2006) the application of effluents from fish ponds greatly increased tomato yields in Northeast Brazil. It should be noted that with increasing concentration of effluent, the effect on the plant also increases (Osaigbovo et al., 2010). Khater et al. (2015) noted that a high effluent flow rate has more positive effect on tomato yield. Omeir et al. (2019) mentioned in their research that the reason for enhance in the mineral composition of vegetables was effluent from fish farm. However, the effect on plant growth and development during irrigation with effluent water can depend on the variety of crops too (Silva et al., 2018).

2.6. Irrigation water quality and plant water relation

One of the main conditions for obtaining a high quality crop is associated with water quality that meets the standards of irrigation (Suarez, 2011; Limjuco et al., 2016). The main requirement for water quality is to avoid damage to the crop and soil during irrigation, and ultimately to maintain the expected productivity (Barker et al., 2003; Knox et al., 2012). In other words, high-quality irrigation water is important not only for productivity, but also for plant growth and soil protection. Water is a necessary component for the implementation of all physiological processes occurring in the plant, and regulates the temperature of plants by evaporation from the surface of the leaves (Lambers and Oliveira, 2019). However, the vital activity of plants is affected not only by quantity, but also by quality - the chemical and physical composition of water, as well as the proper functioning of irrigation systems (García-Garizábal and Causapé, 2010).

In the chemical composition of water, one of the decisive parameters is the salinity level of irrigation water. Plant roots receive water from the soil mainly as a result of osmotic pressure, which exists because plant cells contain a higher concentration of soluble salts than in the soil (Lodish et al., 2000). When water with a high concentration of salts is used for irrigation, their level in the soil increases, thereby reducing the osmotic pressure through the root membrane and, thus, reducing the absorption of water by the roots of the plant (Lawson, 2000; Flowers, 2004). According to the USDA handbook (USDA, 1969), water salinity level is summarized in 4 groups, while low salinity (C1) is suitable for all types of crops, medium (C2), high (C3), and very high (C4) saline water can have a serious negative impact on crops.

On the other hand, El-Mogy et al. (2018) claim with some level of salinity of irrigation water on the example of tomato, the quality (taste index) can improve, but there will be a decrease in yield. However, for most crops, an increase in salinity is inversely proportional to the quality (Kim et al., 2016). Regular application of salt water reduces yield and also increases soil salinity (Wang et al., 2016). Therefore, when using salt water in agriculture, it is necessary to observe a normal and reasonable watering regime (Feng et al., 2017; Yuan et al., 2019).

The presence of sodium in water is also one of the reasons that can pose a threat to the plant (Hopkins et al., 2007). The hazard of sodium arises with an excess of Na^+ in water, which leads to the destruction of soil aggregates, the formation of a soil crust, and a decrease in water permeability caused by swelling and dispersion of soil colloids (Heydari et al., 2001; Zaman et al., 2018). The evaluation of hazard created by the relationship between Na^+, Ca^{2+} and Mg^{2+} is measured using this $\mathrm{SAR} = \frac{\mathrm{Na}}{\sqrt{\frac{\mathrm{Ca+Mg}}{2}}}$ (equation 1), and is called the sodium adsorption ratio (SAR) (Ayers and Westcot, 1985). Thus, an increase in the content of sodium ions in water leads to the destruction of the plant habitat, reduces the absorption of water and nutrients.

Based on the total salt content and the proportion of chemical components in them, water quality is also evaluated depending on the risk of salinization and the toxicity of individual ions. The presence of toxic ions in the water adversely affects the growth and development of plants (Shani and Ben-Gal, 2005; Hussain et al., 2010). Boron (B) is one of the phytotoxic elements present in water in the form of anions. A small amount of B does not have a harmful effect, on the contrary, it is important for plant growth, but if its concentration is slightly higher than optimal, then B becomes toxic to plants (Imran et al., 2010; Reid, 2010). This shows that there is a very small border between its utility and harm, therefore, when applying it, it is necessary to adhere to certain standards.

The importance of irrigation water quality is associated not only with high crop yields, while not affecting soil fertility, but also with the need to ensure full-fledged operation of irrigation systems. Organic (leaves, sticks, seeds) and inorganic (sand, silt, clay) particles in water can interfere with irrigation systems and shorten their lifespan (Clark et al., 2007). These cases create serious problems, especially in micro irrigation systems due to clogging of emitters (Benham and Ross, 2002). Because of this, during irrigation it is much more desirable to use sources that do not contain physical materials. However, to prevent clogging of water in the emitters, special separation equipment, such as filters, can be used (Ribeiro et al., 2004; Nakayama et al., 2007).

2.7. The world of rice

There is no doubt that rice (*Oryza sativa* L.) is the main ingredient in the cuisine of most peoples of the world (Rejesus et al., 2012). Since rice is one of the three most widely produced agricultural plants in the world, and its production is growing every year (Maclean et al., 2013). Rice is called the queen of cereals because of its mineral wealth, high starch content, which is necessary for the human body (Anjum et al., 2007).

According to historical sources, there are different versions of the origin of rice, but South and Southeast Asia are the main regions accepted by most researchers (Awan et al., 2017). With the exception of Antarctica, rice can be cultivated on all continents of the world (Innes, 2006). Acquaintance with the rice plant in Europe is connected with the name of Alexander the Great during his expedition to India (Svanberg et al., 2010; Maclean et al., 2013). Then, over time, its cultivation began in the southern parts (Spain, Italy, Greece) of the continent (Kraehmer et al., 2017). Italy currently also has the largest share of rice production in the European Union (Bacenetti et al., 2016).

It is known that one of the main features that distinguishes rice from other grains is its function when grown in a complete aquatic environment (Prasad et al., 2017). Although it is an annual crop, rice can be cultivated as a perennial plant in a favourable climate (Hill, 2010). Two rice subspecies are well known and consumed throughout the world: *japonica*, which is stood out short grain and *indica*, with long grain (Johns and Mao, 2007). Factors that influence the selection here include its cooking methods, aroma. For example, the most popular rice subspecies among Europeans is *japonica* (Maclean et al., 2013).

Rice is very sensitive to both heat and humidity (Yan et al., 2010). Even the temperature of irrigation water affects the growth, yield of rice (Zia et al., 1994; Shimono at al., 2002). The main component of rice cultivation is the selection of healthy seeds. A healthy seed has a high viability and also protects itself from diseases and other abiotic and biotic influences (Sahu et al., 2018). Proper land preparation is another key element in successful rice cultivation. Cleaning the soil from weeds and stones, as well as proper ploughing will ensure healthy plant growth and will make it possible to improve the water level (Allard et al., 2005).

In world practice, two methods of growing rice are available: transplanting and direct seeding. Both methods have their advantages depending on the circumstances and possibilities of the farmers (Johnkutty et al., 2006). Although it requires a very high workforce, the transplanting method is preferred in many Asian countries (Ali et al., 2012).

In general, there are 4 rice ecosystems that characterize the area of rice cultivation: irrigated, rainfed lowland, rainfed upland, flood-prone (IRRI, 1993). Irrigated rice, which satisfies three quarters of global rice demand, has the highest productivity among others (Maclean et al., 2013). Although cultivation in flood-prone ecosystem is less effective in terms of yield than others, this disadvantage can be eliminated by planting more tolerant species on sulphate and saline soils (Hossain and Abedin, 2004).

2.7.1. Conditions for obtaining quality rice and challenges

Rice is not only a food crop, but also an important foundation for the economies of several developing countries (Van Dis et al., 2015). In India, according to Jena and Grote (2012), the total rice export in 2010-2011 was about 2.5 billion US dollars. According to the forecast of Seck et al. (2012), an additionally 116 million tons of rice production will be needed in order to provide the increasing demand by 2035.

As in many areas of agriculture, the main goal of rice growing is to obtain a rich and high-quality product. Ensuring the production of high-quality rice from the very beginning is a complex task that directly and indirectly depends on a number of factors. First of all, the main consumer demand is whole polished rice with a good chemical composition (Ahmad Hanis et al., 2012). This factor has a comprehensive effect on market prices (Kawamura et al. 2018). Reducing stress factors such as drought and salinization, the destruction of pests and the balanced fertiliser application during the growing season is a prerequisite (Norton et al., 2010; Pandey and Shukla, 2015; Teng et al., 2016). Another feature that determines the quality of rice is the moisture content during the harvest (Saleh and Meullenet, 2007; Grigg et al., 2016), and according to Lu et al. (1995), in order to avoid economic losses, it is necessary to maintain an optimal moisture content from 15 to 22%.

Rice goes through several production stages before going directly to the consumers' table. After harvest, mechanical drying and cleaning is often used before storage for further processing. To obtain cargo (or brown) rice, indigestible husk must be removed. During the final milling steps, bran from brown rice is polished and white rice is received (IRRI, 2013). As these steps are implemented, rice undergoes not only changes in weight and shape, but also loss of minerals (Juliano, 1993). Although brown rice has a higher mineral content, because of the easier storage and cooking ability, white rice is much more popular in most countries (Danquah and Egyir, 2014).

Getting high yields is usually associated with many difficulties (water shortage, low temperature, diseases, etc.) due to its specific production technology (Stoop et al., 2009). Limited water resources and low farm income were reported as major limiting factors for rice farming (Nguyen and Ferrero, 2006). Global climate change is also a major cause of this problem (Auffhammer et al., 2012). Therefore, at present, alternative approaches to rice production are needed to ensure rice productivity and food security. One of the methods used to meet water needs and at the same time reduce water losses is alternate wetting and drying (AWD). Although AWD has many benefits, there is still a problem of low application (Howell et al., 2015).

In this method, periodically flooded and non-flooded irrigation is applied to rice fields, and actually significant crop losses are not observed (Carrijo et al., 2017). Moreover, LaHue et al. claim (2016), in AWD the agricultural greenhouse gas (CH_4, N_2O) emissions that occur during rice cultivation are lower compared to traditional methods. According to research of Liang et al. (2016), using this method increases the irrigation water productivity and allows farmers to economically reduce costs. Eventually, one of the main terms here is the consideration of soil and climatic conditions in order to avoid excessive or incomplete irrigation (Kumar et al., 2017).

2.7.2. Rice cultivation under aerobic condition

Traditional rice cultivation methods are highly dependent on water resources. However, drought and a decrease in rainfall can also lead to depletion of water resources, which ultimately negatively affects rice growing (Korres et al., 2017). In this regard, ensuring food security and meeting the growing demand for food for people is under threat (Mohanty et al., 2013).

Aerobic breeding is a system in which rice seeds are sown in a non-flooded state, like most the agricultural crops. The aerobic rice system is one of the novel ways of rice cultivation, where water consumption is many times reduced compared to conventional rice irrigation (Bouman et al. 2002, 2005; Peng et al., 2006). Aerobic rice is grown mainly on non-saturated soils, while several irrigation techniques (e.g. alternative wetting, sprinkler irrigation, drip irrigation) can be applied. Thus, compared to the conventional paddy cultivation, it is easier to avoid water loss, but drought stress can occur more often.

It should be noted, other environmental stresses such as low temperature can also cause more serious damage in unfavourable seasons (Gombos and Simon-Kiss, 2005). Under these circumstances, sufficient varieties and nutrient supply are required to maintain plant health and yield quality. In Hungary, new rice varieties with good abiotic stress tolerance such as Janka and Ábel were released via doubled haploid production (Pauk et al., 2009). These varieties were specially developed for the colder aerobic conditions of the temperate climate (Jancsó et al., 2017).

In some circumstances, aerobic rice may have some similarities with upland rice, however, it has more advantages both in terms of treatments and in terms of productivity (Priyanka et al., 2012). For example, in their study, Huaqi et al. (2002) mentioned that the difference in yield between the aerobic rice system and the upland rice is twice as large. Another important development in aerobic rice is a decrease in the absorption of arsenic (Xu et al., 2008).

In aerobic rice systems weeds are limiting factors that can be eliminated with proper weed management (Lu et al., 2002). Aerobic rice is one of the rice growing technologies where drought stress can decline yield and quality if sufficient water supply is not maintained properly (Bouman et al., 2007). Photoperiodic sensitivity, long duration and cold sensitivity limit the direct adaptation of tropical and subtropical aerobic rice varieties (Jancsó et al., 2017). In this regard, given the future potential for saving water, it is necessary to improve aerobic rice varieties.

2.7.3. Wastewater irrigation for rice cultivation and bioremediation

The increase in wastewater in various industries, in urban areas has also increased their potential environmental risks. Consequently, the use of these sources in rice culture is an inevitable measure to avoid their harmful effects. On the one hand, if this use is associated with environmental care, on the other hand, it can be considered as an alternative to fresh water.

Water scarcity, competition for water resources, high cost of water and fertilisers have made the wastewater application attractive. Wastewater, in addition to the elements that plants need, also contain heavy metals, pathogens that can damage them. From this point of view, Soothar et al. (2018) did not suggest the direct application of wastewater in rice cultivation. Mukherjee et al. (2013) noted that the presence of lead and mercury in wastewater affected the rice plant and caused economic damage to farmers. On the other hand, during the use of wastewater, farmers have direct contact with them, which raises concerns about health issues (Pham and Watanabe, 2017). However, most researchers believe that positive results can be obtained by choosing a tolerant rice variety and proper wastewater treatment. The use of reclaimed wastewater, especially in arid and semi-arid zones, where the salinity of fresh water is higher, gives more effective results (Kaboosi and Esmailnezhad, 2018). For example, with suitable dilution in accordance with special standards, rice performance immediately increases from the initial stage (Kang et al., 2004; Dash, 2012; Gassama et al., 2015; Akhtar et al., 2018). According to some studies, reclaimed wastewater does not have a side effect on human health (Papadopoulos et al., 2009; Jang et al., 2013). Moreover, in some cases, during irrigation with wastewater, rice yield may be higher than with conventional sources of water (Yoon et al., 2001; Kang et al., 2007).

Regardless of the origin of traditional industries, the ecology is always subject to a certain level of pollution. The restoration and protection of a clean environment includes complex measures, one of which is bioremediation. Bioremediation involves the removal of undesirable hazardous elements in soil and water environment (Vidali, 2001; Dixit et al., 2015). Depending on the origin of the pollutant and the area of contamination various enzymes are proposed for bioremediation purposes (Sharma et al., 2018). Besides using enzymes for bioremediation, plant cultivation – phytoremediation is a well-known technique. In phytoremediation the absorption of elements is achieved by growing tolerant plants (Shah et al., 2018). Thus, plants through their roots absorb the minerals they need, as well as to some extent toxic compounds (Juwarkar et al., 2010).

One of the important functions of rice is the ability to accumulate heavy metals, such as As, Pb, Fe, Cr, Cd, Mn, Zn (Abbas et al., 2007; Shraim, 2017). Besides these factors, although rice is a salt-sensitive plant, rice cultivation can improve soil quality in saline and sodic soils (Singh, 2017; Xu et al., 2020). According to Li et al. (2009) paddy-rice-wetland system has significant potential for removing P from wastewater to prevent eutrophication of P. Moreover, as claimed by Kawahigashi et al. (2005), transgenic rice has a great ability to remove pesticides from contaminated soil. These features allow the use of rice as bioremediation or phytoremediation of soil and wastewater. Other reasons for planting rice here also include its short life cycle, resistance to anoxia, cultivation on dry and wet lands, a fibrous root system (Sebastian and Prasad, 2016).

Irrigation has always been a guarantee of high yields in agriculture, but depletion of water resources threatens the future of food supplies. These problems, in addition to focusing on water conservation, stimulate the search for alternative sources of irrigation. Worldwide, nutrient-rich agricultural wastewater is considered one of the alternative resources for irrigation. Water especially plays an indispensable role in rice cultivation, as rice is one of the most water-intensive crops among cereals. Growing rice under aerobic conditions is a unique approach that saves water without significantly reducing yields. One of the main requirements for this production is the supply of nutrients, which can be provided through the use of agricultural wastewater. However, another important factor in this event is related to the quality of rice. Thus, in this study, the 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, I also focused on taking another step to the reduction of water demand and environmental pollution to improve a complex agricultural system.

3. MATERIALS AND METHODS

3.1. Experimental site and design

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) (*Appendix 1*) in the growing seasons of 2017, 2018, and 2019.

In the experiments, 32 non-weighing backfilled gravitation lysimeters with a volume of 1 m^3 each were used. Every lysimeter has a surface of 1x1 m and a depth of 1 m, placed in a square sector (*Appendix 2*). 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, and the following 80 cm is a layer of soil. The type of soil in the lysimeter ponds was vertisol (expansive clay).

The main reason for choosing a non-weighing gravitation lysimeter was to create aerobic conditions for rice and at the same time to separate them from the vertical and horizontal effects of the surrounding environment and soil. During the experiment the outflow of percolation water was not detected.

3.2. Treatment methods

Possible changes of effluent water from the intensive catfish farm on rice was explored during the experiment. Four types of treatments have been applied throughout the experiments: T_1 - raw effluent water; T_2 - effluent water supplemented with gypsum; T_3 - effluent water diluted with river water and supplemented with gypsum; T_C - control treatment, water from oxbow lake, which is a section of the Körös River in eastern Hungary (46°51′38.6″ N 20°31′28.0″ E, Szarvas). The distribution of irrigation treatments was done according to the following schematic diagram (Figure 3):

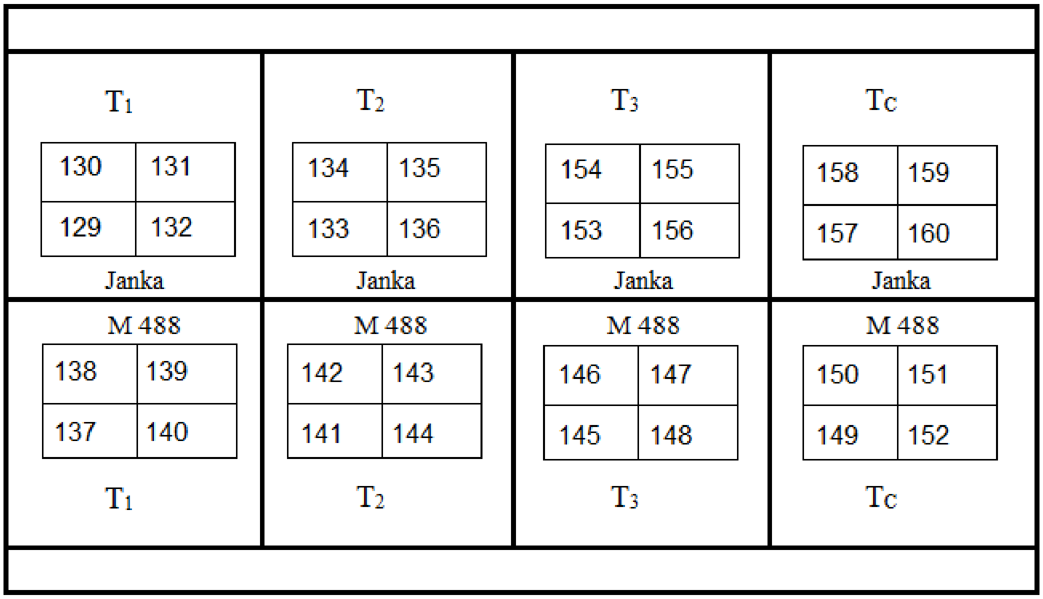

Figure 3. Schematic representation of the study. T_1 *- effluent water;* T_2 *- effluent water supplemented with gypsum;* T_3 *- effluent water diluted with river water and supplemented with gypsum;* T_C *- river water (control). M 488 and Janka - Hungarian rice varieties*

The treatments were applied by a micro sprinkler irrigation method and with four replications. The key indicators of water quality are listed in the Table 1. The effluent water was obtained from an intensive fish farm near the experimental site. Here, a geothermal well from a confined aquifer was the main source of fish ponds. The main factor that is notable in effluent water (T_1) is its high total dissolved salt content. Because of that, given the potential harm to the soil and plants, supplementations were applied in T_2 and T_3.

Table 1. The chemical parameters of water used in the experiment

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	1033.75	371.86
m-alkalinity	13.77	14.65	8.23	3
Bicarbonate (mg/l)	838.67	894	502	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

T_1 - effluent water; T_2 - effluent water supplemented with gypsum; T_3 - effluent water diluted with river water and supplemented with gypsum; T_C - river water (control)

In this study gypsum addition for T_2 and T_3 treatments was done based on the work Kun (2017), and following equation was used to calculate amount of gypsum (Filep, 2010):

Equation 2. Quantity of gypsum

$$x = Sz_e * E$$

Where, x – quantity of gypsum (mg/l); Sz_e – residual sodium carbonate index; E – equivalent gypsum weight (86.1 g).

3.3. Experimental plants

The Hungarian rice varieties called "M 488" and "Janka" were chosen as model plants for experiments. Both of them are *temperate japonica* varieties and are very famous among Hungarian farmers. In contradistinction to M 488, Janka is not considered an aerobic rice variety. However, because of its good resistance to drought and the intensive growth of seedlings, it can grow in aerobic conditions too. According to Székely et al. (2016) in germination phase these varieties have showed medium reactions to increased salinity. Other important parameters of rice varieties are listed in the Table 2 below:

Table 2. The main characteristics of rice varieties recognized by the Hungarian state

Species	***Release year***	***Growing season, days^{I}***	***Plant height, cm***	***TKW^{II}, g***	***L/W ratio^{II}***	***Blast resistance^{III}***	***Amylose, %***
M 488	1996	128-134	60-65	28-30	2.2	6	22-23
Janka	2002	133-137	70-75	27-30	2.8	6	23-24

I – From the first date of sowing;

II – Thousand Kernel Weight (paddy seed), Length/Width ratio seed (cargo);

III – Leaf and neck blast (According to Roumen et al. (1997) scale from 1 to 6, where 1 is fully stable, 6 highly sensitive).

3.4. Experimental procedure and meteorological data

Growing season 2017: Seeds were sown manually on April 25. On June 13, 1 kg of fertiliser (NH_4NO_3 + $CaMg(CO_3)_2$) was applied (84.4 kg $N*ha^{-1}$). Rainfall during the growing season was 192.6 mm. The irrigation water amount was 360 mm. Plants were harvested on September 12.

Growing season 2018: Seeds were sown manually on April 25. Rainfall during the growing season was 143.8 mm. Due to technological issues this year, it was not possible to fully utilize effluent water for irrigation, and fertiliser was not applied. The amount of irrigation water was only 60 mm. However, the same irrigation scheme was applied for the rice crop of previous year that resulted especially the higher amount of sodium in the soil of effluent water lysimeters. Plants were harvested on August 22.

Growing season 2019: Seeds were sown manually on April 29. On July 4, 1 kg of fertiliser (NH_4NO_3 + $CaMg(CO_3)_2$) was applied (84.4 kg $N*ha^{-1}$). Rainfall during the growing season was 333.7 mm. The irrigation water amount was 160 mm. Harvesting was organized on September 24.

Microplots in the lysimeters were treated according to standard aerobic rice production technology. After direct dry sowing, pre-emergent herbicide (pendimethaline) was applied to suppress weed development. Later, during the growing season only mechanical weeding was used. Other plant protection interventions were not necessary. Commercially available micro-sprinkler irrigation system (Rivulis Rondo) with precision water meters was set up to the experimental site. All the irrigation treatments were applied in the same amount and in the same time schedule during the irrigation season. Irrigation frequency and thus the gross irrigation amount per season were adjusted for weather conditions. The plant density was set to 40 plants/m^2 (*Appendix 3*).

Meteorological data were measured using meteorological equipment (Agromet-Solar automatic weather station, Boreas Ltd., Hungary) that was installed next to the experimental field. During the growing seasons, the temperature in each year was relatively similar, but in 2019 the amount of precipitation was significantly higher compared to previous years (Figure 4).

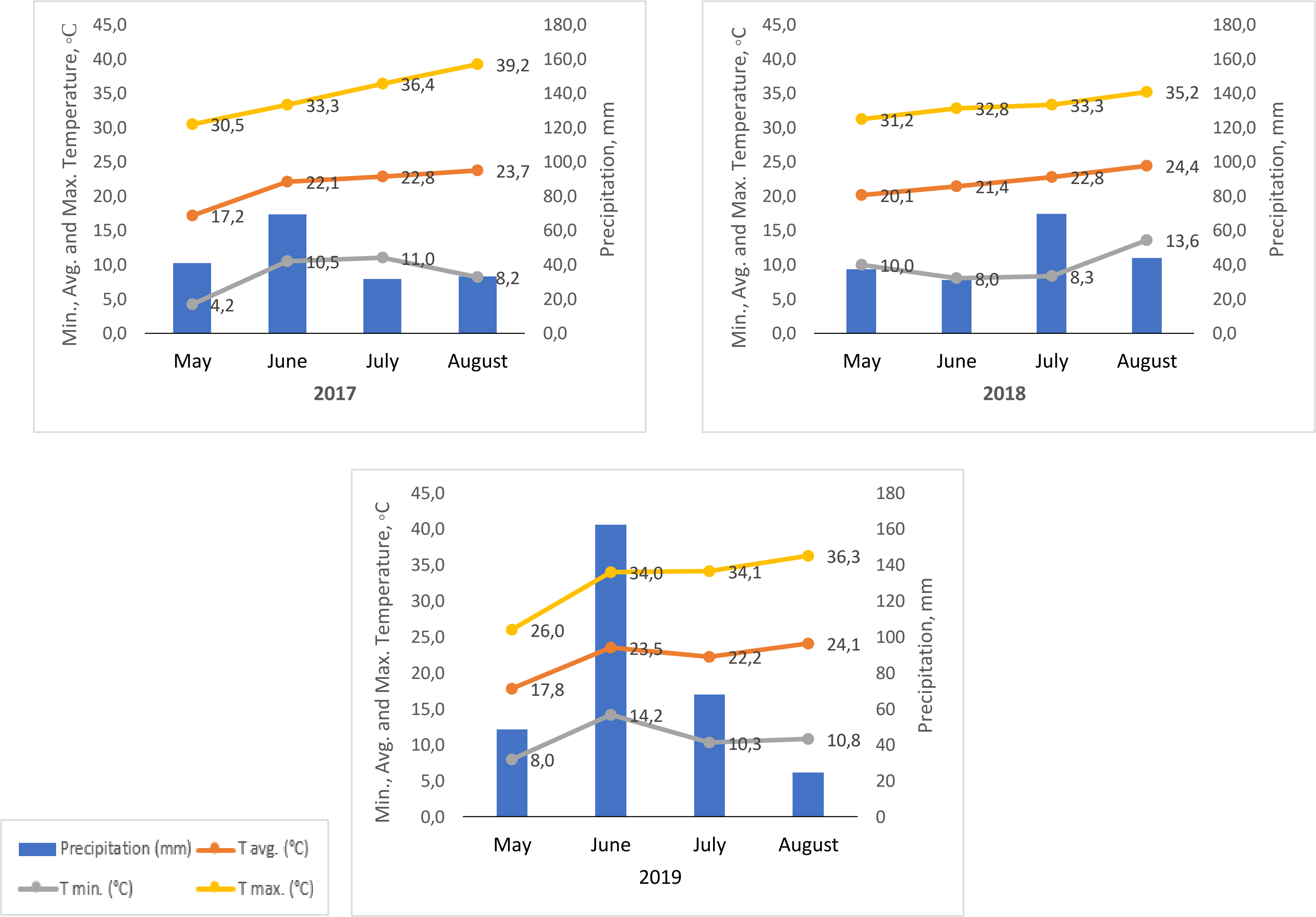

Figure 4. Monthly precipitation; Average, Minimum and Maximum temperature

3.5. Monitoring and data analysis

Rice was harvested by hand (Figure 5). After the implementation of standard post-harvest operations (cleaning, drying, storing), the basic quality tests – Thousand Kernel Weight (TKW), Milling Quality Parameters (MQP), Mineral Content (MC), Gelatinization Temperature (GT), Grain Dimensions (GD) tests were analysed. In addition, the average chemical properties of the soil in individual block lysimeters were calculated after a three-year experiment (*Appendix 4*).

Figure 5. Manual rice harvesting (Photo by Székely, 2019).

3.5.1. Moisture content of rice

In order to begin tests listed above, moisture content of rice seeds from every sample was defined. At the beginning, a small number of 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.

3.5.2. Thousand Kernel Weight (TKW)

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.

3.5.3. Milling Quality Parameters (MQP)

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. Thereafter, whole white (polished) rice were separated from all white rice sample, and weighed. The experiment was repeated four times and the average value is defined. According to the following formulas, the results were calculated (Lapis et al. 2019):

Equation 3. Percentage of cargo rice

$$\%\, Cargo\, rice = \frac{weight\ of\ brown\, rice\ (g)}{weight\ of\ paddy\ rice\ (g)} * 100$$

Equation 4. Polished rice

$$\%\, Polished\, rice = \frac{weight\ of\ polished\, rice\ (g)}{weight\ of\ paddy\ rice\ (g)} * 100$$

Equation 5. Whole polished rice

$$\%\, Whole\ polished\, rice = \frac{weight\ of\ whole\ polished\, rice\ (g)}{weight\ of\ paddy\ rice\ (g)} * 100$$

3.5.4. Grain Dimensions (GD)

In order to measure grain size and shape, 100 seeds from every sample were counted and scanned using “Readiris” program in the “tiff” format. The scanned pictures were transferred to “Jpg” format, and later were analysed using “SmartGrain” software (Figure 6). These steps were repeated four times for each sample and the average Length, Width and L/W ratio were calculated.

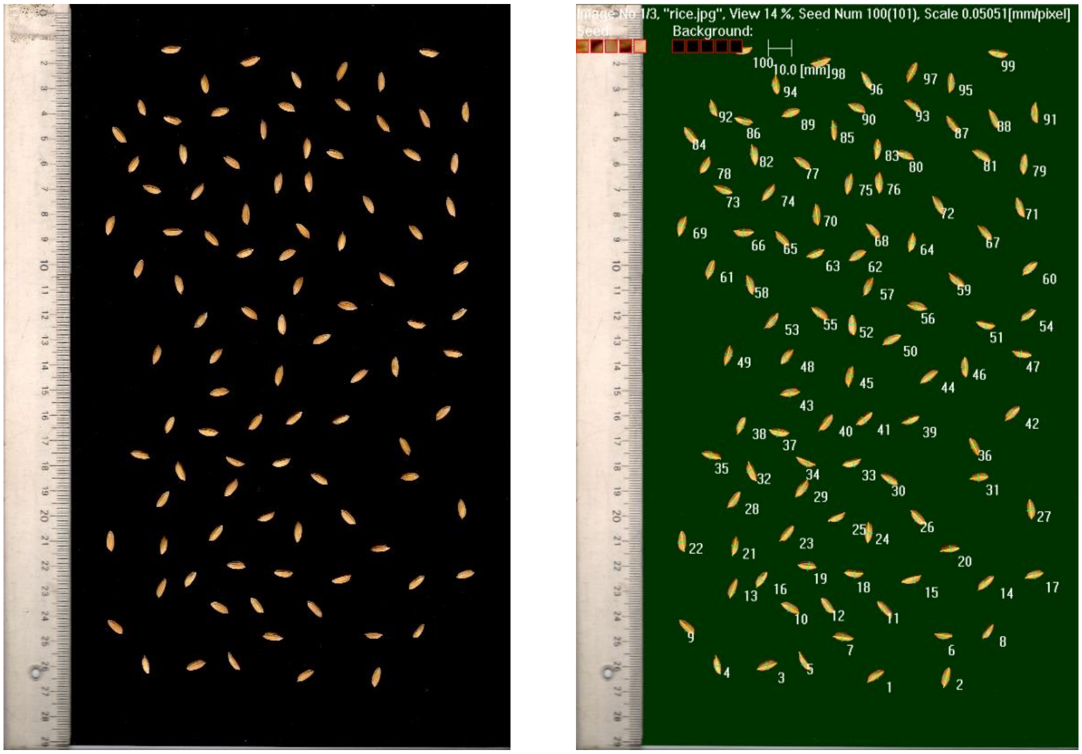

Figure 6. Grain Dimensions measurement

3.5.5. Gelatinization Temperature (GT)

Gelatinization Temperature (GT) test was carried out in accordance with the procedures proposed by Little et al. (1958). Dehulled and milled rice samples soaked in 1.7% KOH and was stored in the thermostatic cabinet at 30 °C for 23 hours (Figure 7). The results were evaluated according to the table below (Table 3):

Table 3. The degree of spreading (Little et al., 1958)

Scale	**Alkali Spreading Value**
1. grain not affected 2. grain swollen 3. grain swollen, collar incomplete and narrow 4. grain swollen, collar complete and wide 5. grain split or segmented, collar complete and wide 6. grain dispersed, merging with collar 7. grain completely dispersed and intermingled	• "1-2" – high (74.5-80 °C) • "3" – high intermediate • "4-5" – intermediate (70-74 °C) • "6-7" – low (<70 °C)

Figure 7. Gelatinization Temperature measurement (Photo by Szėkely, 2018)

3.5.6. Mineral Content (MC)

Effects of different irrigation water types on the chemical composition of rice varieties were analysed at the NAIK ÖVKI Laboratory for Environmental Analytics (Szarvas, Hungary). Mineral Content (MC) test involves determination of amount basic minerals (Ca, Mg, K, Na, and P) in rice grains and aboveground biomass. In order to carry on analyses, after the harvest paddy rice from each sample were first hulled with Satake THU Laboratory Husker and brown rice received. Meanwhile whole aboveground parts of the rice plant were cut into small particles and careful drying, samples were collected in paper bags, stored at room temperature.

After standard procedures (cleaning and drying), every sample was wet digested in 6 ml HNO_3 and 2 ml H_2O_2. 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.

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 standards.

3.6. Statistical analysis

Basic mathematical analyses were calculated using Microsoft Excel. The collected data were subjected to the analysis of variance (ANOVA) using IBM SPSS Statistics software (version 22.0) for Windows.

The main conditions for the implementation of this statistical test are the normal distribution of data and the homogeneity of variance across groups. To fulfil this condition, the Shapiro-Wilk normality test was first performed. Afterwards the assumption of homogeneity of variances was done by the Levene test ($p \geq 0.05$).

The significant differences among mean values were determined with the Tukey test at the 0.1%, 1%, 5% levels of probability, respectively.

The following equations were also conducted to detect outliers in the data (Tukey, 1977). This was done in order to eliminate extremely high and extremely low values in the dataset that cross the upper and lower bounds.

Equation 6. Upper bound

$$Upper\ Bound = Q3 + \left(1.5 * (Q3 - Q1)\right)$$

Equation 7. Lower bound

$$Lower\ Bound = Q1 - (1.5 * (Q3 - Q1))$$

Where, Q – quartiles.

In condition of violation of homogeneity of variances (Levene’s test, $p \leq 0.05$), Games-Howell Post hoc test was set under the terms of the Welch test ($p \leq 0.05$).

4. RESULTS AND DISCUSSIONS

As mentioned earlier, two varieties of rice were planted during the experiment: M 488 and Janka. However, because of early agrotechnical problems in the first growing season, apart from Mineral Content test of aboveground biomass, other tests could not be implemented with Janka variety. In addition, due to the lack of a sample, in the first growing season, Mineral Content tests of seeds could not be carried out with M 488 variety either.

4.1. Moisture Content

It is known that one of the parameters that determines the quality of rice is moisture content (Bell et al., 2000). The moisture content directly affects the shelf life of any type of seed (Hanson, 1985). The general idea behind of controlling moisture content of paddy seeds to receive moisture content below 14% (IRRI, 2013). Usually seeds' moisture content less than 14% are more desirable for storage purposes (Asea et al., 2010). It is also known that the ability to increase the development of insects is restricted in a condition less than 12% moisture content (Befikadu, 2014).

Here, quality experiments were carried out without the intervention of moisture content, under normal conditions of the moisture content of rice. Because of this, the seeds were kept in an uncontrolled, unmonitored, natural state. The basic goal was to directly investigate the effect of water used on rice and to conduct a test regardless of the moisture content in rice. Although, conducted experiments were done moisture free basis, in these experiments we also got results less than 14% in all samples.

In the first growing season, moisture content of M 488 variety under T_1, T_2, T_3 and T_C was 8.39%, 8.11%, 6.98%, 7.5%, respectively. In the second growing season, moisture content of M 488 variety under T_1, T_2, T_3 and T_C was 6.83%, 6.45%, 6.87%, 7.08%, respectively. In the third growing season, moisture content of M 488 variety under T_1, T_2, T_3 and T_C was 7.97%, 7.46%, 7.69%, 7.28%, respectively (Table 4).

In the second growing season, moisture content of Janka variety under T_1, T_2, T_3 and T_C was 7.6%, 7.31%, 7.37%, 7.03%, respectively. In the third growing season, moisture content of Janka variety under T_1, T_2, T_3 and T_C was 9.16%, 8.86%, 8.52%, 8.29%, respectively (Table 4).

Table 4. Average (n = 4) moisture content of paddy seeds of M 488 and Janka, %

Year	***Variety***	T_1	T_2	T_3	T_C
2017	***M 488***	8.39	8.11	6.98	7.50
2018	***M 488***	6.83	6.45	6.87	7.08
	Janka	7.60	7.31	7.37	7.03
2019	***M 488***	7.97	7.46	7.69	7.28
	Janka	9.16	8.86	8.52	8.29

T_1 - effluent water, T_2 - effluent water supplemented with gypsum, T_3 - effluent water diluted with river water and supplemented with gypsum, T_C - river water (control)

4.2. Analyse of grain weight

The Thousand Kernel Weight (TKW) is an important economic feature that characterizes the quality of the seed. TKW is associated with the size and completeness of the seeds. Large, heavy seeds have a large supply of nutrients, and therefore well-developed plants give a high yield. So, determining TKW allows to evaluate the nutrient reserves in the seeds (Bhattacharya, 2011). Obviously, the larger the grain, the higher TKW. 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).

TKW is highly dependent on moisture content, and it is generally accepted experience that TKW is calculated at 14% (IRRI, 2013). Therefore, in these experiments calculation of TKW was performed by converting the data based on 14% moisture content.

Table 5. The TKW (g) of paddy and cargo seeds of M 488 rice developed with different quality of irrigation

Treatments		***2017***		***2018***		***2019***	
		TKW of paddy seed	***TKW of cargo seed***	***TKW of paddy seed***	***TKW of cargo seed***	***TKW of paddy seed***	***TKW of cargo seed***
T_1	***M***	25.35a	18.46a*	23.87a	18.62a	23.70a	19.13a
	95% CI	[21.03; 29.67]	[17.06; 19.86]	[23.08; 24.65]	[17.61; 19.63]	[23.05; 24.36]	[18.62; 19.64]
T_2	***M***	24.51a	19.34ab	23.86a	18.76a	23.68a	18.72a
	95% CI	[24.19; 24.81]	[18.51; 20.17]	[23.35; 24.38]	[18.19; 19.34]	[22.47; 24.89]	[17.69; 19.76]
T_3	***M***	25.85a	20.30b	23.75a	18.43a	23.63a	19.07a
	95% CI	[25.14; 26.57]	[19.47; 21.14]	[23.03; 24.47]	[17.59; 19.27]	[23.24; 24.02]	[18.46; 19.67]
T_C	***M***	25.79a	20.04b	23.40a	17.64a	23.15a	18.64a
	95% CI	[25.35; 26.23]	[19.58; 20.49]	[22.88; 23.92]	[16.65; 18.63]	[22.82; 23.48]	[18.54; 18.73]

M - mean. CI - confidence interval (lower and upper bound). The letters represent a significant difference between treatments, values followed by the same letter do not differ significantly from each other at the 0.05 level. * *- the mean difference is significant from* T_C *at the 0.05 level*

The results of TKW tests of paddy and cargo seed of M 488 rice variety that conducted during the experiment years are illustrated in Table 5. In the first experimental year, the TKW of paddy seed was not effected significantly by treatments at the 0.05 level [$F(3, 12) = 0.80$, $p = 0.52$]. But the ANOVA test showed a statistically significant result in TKW of cargo seeds [$F(3, 12) = 7.69$, $p = 0.004$]. Post hoc comparisons using the Tukey HSD test found that (Table 5) the mean score T_1 irrigation ($M = 18.46$ g) was significantly different than control irrigation ($M = 20.04$ g, $p \leq 0.05$). Neither T_2 nor T_3 irrigations had a significant effect ($p \geq 0.05$) on TKW of cargo seeds. The mean value of T_1 (Table 5) was also significantly lower than T_3 ($M = 20.30$ g, $p \leq 0.05$).

In the second experimental year (Table 5), after the treatments both the TKW of the paddy and cargo seeds of M 488 was not statistically significant ($p \geq 0.05$) from the values of the control irrigation.

In the third experimental year (Table 5), as in the second year, significant differences between treatments and control irrigation were not observed ($p \geq 0.05$).

Table 6. The TKW (g) of paddy and cargo seeds of Janka rice developed with different quality of irrigation

Treatments		***2018***		***2019***	
		TKW of paddy seed	***TKW of cargo seed***	***TKW of paddy seed***	***TKW of cargo seed***
T_1	***M***	26.06a**	20.84a**	25.98a***	21.18a***
	95% CI	[25.21; 26.92]	[19.91; 21.77]	[25.04; 26.91]	[20.47; 21.89]
T_2	***M***	26.84a*	20.53a***	27.64b	22.42b
	95% CI	[24.94; 28.74]	[19.22; 21.85]	[27.14; 28.14]	[21.79; 23.04]
T_3	***M***	26.34a**	21.33a*	27.51b	22.26b
	95% CI	[25.61; 27.06]	[20.53; 22.12]	[26.74; 28.28]	[21.54; 22.98]
T_C	***M***	28.58b	23.07b	28.21b	22.72b
	95% CI	[27.37; 29.79]	[21.96; 24.18]	[27.65; 28.76]	[22.03; 23.40]

M - mean. CI - confidence interval (lower and upper bound). The letters represent a significant difference between treatments, values followed by the same letter do not differ significantly from each other at the 0.05 level. *, **, *** *- the mean difference is significant from* T_C *at the 0.05, 0.01 and 0.001 levels, respectively*

In 2018, the TKW test result of Janka variety was completely different compared to M 488. There was a significant effect on TKW of paddy seeds at the $p \leq 0.05$ level [$F(3, 12) = 8.19$, $p = 0.003$]. Post hoc comparisons test showed (Table 6) that the mean score T_1 ($M = 26.06$ g, $p \leq 0.01$), T_2 ($M = 26.84$ g, $p \leq 0.05$) and T_3 ($M = 26.34$ g, $p \leq 0.01$) was significantly different than T_C irrigation ($M = 28.58$ g).

A statistically significant effect was also noticed in TKW of cargo seeds of Janka, $F(3, 12) = 11.65$, $p = 0.001$. There was a statistically significant difference (Table 6) between control irrigation ($M = 23.07$ g) and T_1 ($M = 20.84$ g, $p \leq 0.01$), T_2 ($M = 20.53$ g, $p \leq 0.001$), T_3 ($M = 21.33$ g, $p \leq 0.05$).

In 2019, the ANOVA test showed a significant results [$F(3, 12) = 18.14$, $p < 0.001$] for TKW of paddy seeds of Janka. Apart from T_1 ($M = 25.98$ g), the effect of irrigation with T_2 ($M = 27.64$ g) and T_3 ($M = 27.51$ g) on the TKW of paddy seeds (Table 6) was statistically similar ($p \geq 0.05$) to the T_C ($M = 28.21$ g). There was a statistically significant difference between T_1 and T_C ($p \leq 0.001$), T_2 ($p \leq 0.05$), T_3 ($p \leq 0.05$).

The similar considerable effect was also noticed on the TKW of cargo seeds which was detected by the ANOVA test [$F(3, 12) = 9.73$, $p = 0.002$]. While there was no statistically significant difference ($p \geq 0.05$) between T_2 ($M = 22.42$ g), T_3 ($M = 22.26$ g) and T_C ($M = 22.72$ g); between T_1 ($M = 21.18$ g, $p \leq 0.01$) and T_C difference was statistically significant (Table 6). The statistically significant difference was also noted between T_1 ($p \leq 0.05$) and T_2, T_3 irrigation (Table 6).

Additional statistical analysis of combined data from both varieties was also conducted during the study. Despite some differences among treatments, the results were statistically similar ($p \geq 0.05$) to the control irrigation (Table 7).

Table 7. The TKW (g) of paddy and cargo seeds of rice (combined) developed with different quality of irrigation

Treatments	***2018***		***2019***	
	TKW of paddy seed	***TKW of cargo seed***	***TKW of paddy seed***	***TKW of cargo seed***
T_1	24.97a	19.73a	24.84a	20.15a
T_2	25.35a	19.65a	25.66a	20.72a
T_3	25.04a	19.88a	25.57a	20.66a
T_C	25.81a	20.35a	25.68a	20.68a

The letters represent a significant difference between treatments, values followed by the same letter do not differ significantly from each other at the 0.05 level

Preliminary results indicate that both varieties reacted differently to irrigation treatments over the years. The similarity between the two varieties was that a significant effect led to a decrease in TKW. This situation is more pronounced in the case of Janka.

This kind of TKW loss in some cases indicates that the plants may have experienced stress. In an environment with optimal nutrition, like most plants, rice also responds positively by developing growth parameters (Jahan et al., 2017). According to some researchers, P and N fertilisers in different concentrations play a positive role in increasing TKW (Hasanuzzaman et al., 2012; Yosef Tabar, 2012). On the other hand, despite the rich mineral composition of the wastewater, Kaboosi and Esmailnezhad (2018) reported that they did not notice significant changes in the TKW in their experiment. The similar trend was also observed by Duy Pham et al. (2019) under continuous irrigation with treated wastewater. However, Rahman et al. (2017) have stated that the decline in the yield attributes of rice is the reason for the high percentage of Na that may be present in irrigation water. In our experiments, a decrease in these values can also be explained by the presence of Na in effluent water. Especially, under the conditions of using effluent water without any treatment and dilution had a more explicit effect. The similar outcome of the reduction in TKW also reported by Abdullah et al. (2002). Nevertheless, it should be noted that this decrease is typical particularly for salt-sensitive rice varieties (Chunthaburee et al., 2015). As noted in the experiments, the TKW loss was observed predominantly in Janka rice variety. These results suggest that the notable TKW loss in Janka may be due to its intolerance to saline conditions that occur during effluent water irrigation.

4.3. Head rice recovery

The importance of rice milling is mainly related to the percentage of whole white (polished) rice (Dhankhar et al., 2014). On the one hand, if the value of whole polished rice is connected with the tradition of consumption, on the other hand, it is closely connected with marketing goals (Dela Cruz and Khush, 2000; Kawamura et al., 2018; Zhou et al., 2019). Since the demand in the markets is mainly directed to whole polished rice. In addition, 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).

In the current experiment, the data obtained at all stages of the rice milling fraction were subjected to statistical analysis. However, since the area of interest is the whole polished rice, the experiments here focused specifically on the percentage of the whole polished rice.

In the first experimental year, in M 488 rice variety treatments did not have a statistically significant effect on the percentage of cargo and polished rice. The ANOVA results for cargo seeds were $F(3, 12) = 1.30$, $p = 0.32$ and for polished seeds were $F(3, 12) = 2.62$, $p = 0.09$. However, the One-Way ANOVA test found a statistically significant result on the percentage of whole polished rice [$F(3, 12) = 14.85$, $p < 0.001$]. While there was no significant ($p \geq 0.05$) difference between T_2 ($M = 62.00\%$), T_3 ($M = 63.75\%$) and T_C ($M = 61.55\%$), but the difference between T_1 ($M = 57.68\%$) and T_2 ($p \leq 0.05$), T_3 ($p \leq 0.05$), T_C ($p \leq 0.01$) was statistically significant (Table 8).

In the second experimental year (Table 8), all treatments did not make any statistical changes on the percentage of rice milling fraction ($p \geq 0.05$). The ANOVA results were [$F(3, 10) = 2.83$, $p = 0.09$], [$F(3, 12) = 1.63$, $p = 0.23$] and [$F(3, 12) = 0.33$, $p = 0.81$] for the percentage of cargo, polished and whole polished rice, respectively.

Table 8. The milling fraction (in %) of M 488 rice seeds developed with different quality of irrigation

Treatments		***2017***			***2018***			***2019***		
		Cargo	***Polished***	***Whole***	***Cargo***	***Polished***	***Whole***	***Cargo***	***Polished***	***Whole***
T_1	***M***	80.15a	70.00a	57.68a**	78.15a	67.15a	55.90a	79.20a	72.00a	60.00a*
	95% CI	[79.69; 80.61]	[69.41; 70.59]	[54.89; 60.45]	[76.49; 79.80]	[64.89; 69.41]	[52.77; 59.03]	[78.16; 80.24]	[71.12; 72.88]	[54.81; 65.19]
T_2	***M***	80.08a	70.65a	62.00b	79.30a	69.90a	56.95a	78.20a	71.10a	61.10a**
	95% CI	[79.88; 80.28]	[69.59; 71.70]	[60.46; 63.54]	[78.89; 79.71]	[66.76; 73.05]	[53.01; 60.89]	[77.65; 78.76]	[68.72; 73.48]	[58.14; 64.06
T_3	***M***	79.93a	70.05a	63.75b	78.90a	69.18a	57.00a	78.80a	72.80a	59.12a***
	95% CI	[79.77; 80.08]	[69.38; 70.72]	[62.19; 65.30]	[77.51; 80.29]	[65.78; 72.57]	[53.02; 60.98]	[78.19; 79.41]	[72.19; 73.41]	[57.93; 60.31]
T_C	***M***	79.95a	69.58a	61.55b	77.60a	68.70a	55.40a	78.80a	72.90a	68.50b
	95% CI	[79.67; 80.23]	[68.52; 70.63]	[59.22; 63.88]	[72.52; 82.68]	[66.03; 71.37]	[49.36; 61.44]	[77.86; 79.74]	[71.29; 74.51]	[66.92; 70.08]

M - mean. CI - confidence interval (lower and upper bound). The letters represent a significant difference between treatments, values followed by the same letter do not differ significantly from each other at the 0.05 level. *, **, *** *- the mean difference is significant from* T_C *at the 0.05, 0.01 and 0.001 levels, respectively*

In the third experimental year (Table 8), according to the ANOVA test treatments did not cause a statistical change on the percentage of cargo rice [$F(3, 12) = 1.98$, $p = 0.16$] and on the percentage of whole rice [$F(3, 11) = 1.59$, $p = 0.23$], however there was a statistically significant effect on the percentage of whole polished rice [$F(3, 12) = 14.32$, $p < 0.001$]. We have observed a statistically significant difference between treatments and control irrigation, irrigation with T_1 ($M = 60.00\%$, $p \leq 0.05$), T_2 ($M = 61.10\%$, $p \leq 0.01$) and T_3 ($M = 59.12\%$, $p \leq 0.001$) caused a decrease in the average whole polished rice.

Table 9. The milling fraction (in %) of Janka rice seeds developed with different quality of irrigation

Treatments		***2018***			***2019***		
		Cargo	***Polished***	***Whole***	***Cargo***	***Polished***	***Whole***
T_1	***M***	78.80ab**	66.80ab**	52.70a	77.92a	67.44a	52.08bc
	95% CI	[78.28; 79.32]	[65.86; 67.74]	[49.75; 55.65]	[76.63; 79.21]	[65.56; 69.32]	[46.95; 57.21]
T_2	***M***	78.40a***	64.90a***	53.80a	77.44a	67.20a	42.64a***
	95% CI	[77.50; 79.30]	[61.72; 68.08]	[49.19; 58.40]	[76.77; 78.11]	[66.85; 67.55]	[39.49; 45.79]
T_3	***M***	79.20b**	68.00bc	49.65a	78.64a	68.96a	47.12ab*
	95% CI	[78.75; 79.65]	[66.55; 69.45]	[48.63; 50.67]	[77.81; 79.47]	[67.62; 70.30]	[40.33; 53.91]
T_C	***M***	80.25c	70.60c	51.80a	78.64a	68.80a	56.08c
	95% CI	[79.85; 80.65]	[68.82; 72.38]	[48.79; 54.81]	[76.97; 80.31]	[66.72; 70.88]	[52.04; 60.12]

M - mean. CI - confidence interval (lower and upper bound). The letters represent a significant difference between treatments, values followed by the same letter do not differ significantly from each other at the 0.05 level. *, **, *** *- the mean difference is significant from* T_C *at the 0.05, 0.01 and 0.001 levels, respectively*

In 2018, statistically significant results were detected in the percentage of cargo [$F(3, 12) = 17.75$, $p < 0.001$] and polished rice [$F(3, 12) = 14.21$, $p < 0.001$] of Janka, which indicates notable difference between control irrigation and treatments. There was a significant decrease in the percentage of cargo rice after T_1 ($M = 78.80\%$, $p \leq 0.01$), T_2 ($M = 78.40\%$, $p \leq 0.001$) and T_3 ($M = 79.20\%$, $p \leq 0.01$) irrigation (Table 9). Meanwhile, there was a statistically significant difference ($p \leq 0.05$) between T_2 and T_3. Similarly, except T_3 irrigation ($M = 68.00\%$, $p \geq 0.05$) the percentage of polished rice was also reduced significantly after T_1 ($M = 66.80\%$, $p \leq 0.01$) and T_2 ($M = 64.90\%$, $p \leq 0.001$) irrigation. The decrease under T_2 was statistically ($p \leq 0.05$) lower than T_3 too (Table 9). However, the most important milling parameter remained statistically unchanged and ANOVA result for whole polished rice was $F(3, 12) = 3.14$, $p = 0.07$.

In 2019, the effect of irrigation treatments was not statistically significant for the percentage of cargo [$F(3, 12) = 1.91$, $p = 0.17$] and polished rice [$F(3, 12) = 2.60$, $p = 0.09$] of Janka variety. Only, based on statistical analysis, significant differences in whole polished rice percentage were determined [$F(3, 12) = 10.698$, $p < 0.001$]. Irrigation with T_2 and T_3 reduced the percentage of whole polished rice, and there was a statistically significant difference between the control ($M = 56.08$) and T_2 ($M = 42.64\%$, $p \leq 0.001$), T_3 ($M = 47.12\%$, $p \leq 0.05$), and although after T_1 ($M = 52.08\%$) irrigation whole polished rice percentage was lower, but between T_1 and T_C there was a statistically non-significant difference ($p \geq 0.05$) (Table 9). Moreover, between T_1 and T_2 irrigation a statistically significant ($p \leq 0.05$) difference was detected (Table 9).

Table 10. The milling fraction (in %) of rice seeds (combined) developed with different quality of irrigation

Treatments	***2018***			***2019***		
	Cargo	***Polished***	***Whole***	***Cargo***	***Polished***	***Whole***
T_1	77.48a	66.98a	54.30a	78.56a	69.72a	56.04a
T_2	78.85a	67.40a	55.38a	77.82a	69.15a	51.87a
T_3	79.05a	68.59a	53.33a	78.72a	70.88a	53.12a
T_C	79.37a	69.65a	53.60a	78.72a	70.85a	62.29a

The letters represent a significant difference between treatments, values followed by the same letter do not differ significantly from each other at the 0.05 level

As a continuation of analysis, statistical test of combined data was carried on, but it did not show any statistical changes (Table 10). However, we have observed decrease in the milling fraction percentages.

From the source results, it is clear that both rice varieties reacted differently to the treatments. The main effect of treatments for both M 488 and Janka is related to the loss of whole polished rice percentage. Both varieties faced significant decline after the application of treatments, especially in the last experimental year. Even though the statistical analysis did not show significant changes after T_1 irrigation in Janka, the percentage reduction was evident. Here the decline is related to both severe weather conditions such as heat stress and the chemical composition of the irrigation source.

It should be noted, in general, rice plants cultivated under aerobic conditions is subject to abiotic stresses (Jabran et al., 2017). According to some studies, along with this sensitivity to abiotic factors, a decrease in a number of vital plant parameters is observed (Singh, N. et al., 2012; Kato and Katsura, 2014). Moreover, the water of the intensive fish farm was distinguished by a high total dissolved salt. In itself, this is another disadvantageous situation for plants, because the high salt content in the water does not allow plants to absorb the essential elements they need (Ghosh et al. 2016). The biggest challenge starts with a rise in temperature, which ultimately leads to severe stress (Clermont-Dauphin et al., 2010; Mishra et al., 2015; Ali et al., 2019). The response to salinity of each rice genotype may be different, but an increase in the amount of salinity in irrigation water can drastically affect plants at all stages of growing (Castillo et al., 2007; Fraga et al., 2010; Chang et al. 2019). Thus, these factors led to a decrease in quality of rice seeds.

In particular, during the ripening stage, sudden changes in weather, temperature and precipitation fluctuations at a high level can lead to a decrease in the percentage of whole polished rice (Jin et al., 2005; Nokkoul and Wichitparp, 2014). For instance according to Counce et al. (2005) high temperatures at night above 24 °C can be one of the important reasons for decrease of the whole polished rice percentage. As Rao et al. (2013) reported earlier salinity is another reason for the increase of rice grain breakage. Because 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). Moreover, the decrease in protein content in salt-sensitive rice varieties is observed more distinctly (Billah et al., 2017).

4.4. The size of rice grains

One of the main factors affecting the high quality of the product is the size of the seeds. In this regard, the main goal of farmers in sowing is the use of large seeds with high varietal and sowing qualities. Because only seeds that meet certain standards can withstand external stress factors.

For three years of research, seed size was also investigated. The parameters to consider here were the length, width and L/W ratio of the seeds.

Table 11. The size (mm) of paddy seeds of M 488 rice developed with different quality of irrigation

Treatments		***2017***		***2018***		***2019***	
		Length	***Width***	***Length***	***Width***	***Length***	***Width***
T_1	***M***	7.95a***	3.17a	8.01a***	3.11b	8.19b	3.07a**
	95% CI	[7.90; 7.99]	[3.15; 3.19]	[7.97; 8.05]	[3.09; 3.13]	[8.15; 8.22]	[3.05; 3.09]
T_2	***M***	7.92a***	3.16a	8.02a***	3.12b	8.04a***	3.12bc
	95% CI	[7.87; 7.96]	[3.14; 3.18]	[7.98; 8.06]	[3.09; 3.15]	[8.00; 8.08]	[3.09; 3.14]
T_3	***M***	7.89a***	3.21b	8.13b	3.09a**	8.19b	3.08ab*
	95% CI	[7.85; 7.93]	[3.19; 3.23]	[8.09; 8.17]	[3.07; 3.11]	[8.16; 8.24]	[3.06; 3.11]
T_C	***M***	8.10b	3.19ab	8.15b	3.14b	8.15b	3.13c
	95% CI	[8.06; 8.14]	[3.17; 3.22]	[8.11; 8.19]	[3.12; 3.16]	[8.11; 8.19]	[3.10; 3.15]

M - mean. CI - confidence interval (lower and upper bound). The letters represent a significant difference between treatments, values followed by the same letter do not differ significantly from each other at the 0.05 level. *, **, *** - the mean difference is significant from T_C at the 0.05, 0.01 and 0.001 levels, respectively

In the first experimental year, there was a significant effect of treatments on length of M 488 rice paddy seeds which was detected by the One-Way ANOVA test [$F(3, 1585) = 18.73$, $p < 0.001$]. The significant reduction of seed length was observed (Table 11) after the irrigation with T_1 ($M = 7.95$ mm, $p \leq 0.001$), T_2 ($M = 7.92$ mm, $p \leq 0.001$) and T_3 ($M = 7.89$ mm, $p \leq 0.001$). In the case of rice width, irrigation treatments did not cause significant changes compared to the T_C irrigation. However, there was a statistically significant ($p \leq 0.05$) difference between T_3 ($M = 3.21$ mm) and T_1 ($M = 3.17$ mm), T_2 ($M = 3.16$ mm).

In the second experimental year, the ANOVA test yielded a significant effect of treatments on seed length of M 488 [$F(3, 1573) = 12.97$, $p < 0.001$]. The average length of seeds decreased after the irrigation with T_1, T_2. While the difference between T_C ($M = 8.15$ mm) and T_1 ($M = 8.01$ mm, $p \leq 0.001$), T_2 ($M = 8.02$ mm, $p \leq 0.001$) was statistically significant, but between T_C and T_3 ($M = 8.13$ mm, $p \geq 0.05$) there was not any statistically significant differences (Table 11). In addition, between T_3 and T_1, T_2 irrigation there was a statistically significant ($p \leq 0.05$) difference too (Table 11). A statistically significant difference was found when analysing the seed width [$F(3, 1557) = 3.62$, $p = 0.01$]. Only T_3 ($M = 3.09$ mm, $p \leq 0.01$) reduced significantly the width of seeds, other treatments (T_1, T_2) had a statistically similar result ($p \geq 0.05$) with the control irrigation ($M = 3.14$ mm), despite the fact that the width of seeds was also low (Table 11), moreover the mean value after T_3 was also statistically lower than T_1, T_2.

In the third experimental year, a statistically significant effect of ANOVA test for M 488 seed length was in the following order: $F(3, 1572) = 15.84$, $p < 0.001$. Unlike T_2 irrigation ($M = 8.04$ mm, $p \leq 0.001$), other treatments (Table 11) showed statistically similar ($p \geq 0.05$) result to T_C ($M = 8.15$ mm). The average length of seeds after T_2 was also statistically ($p \leq 0.05$) lower than T_1 ($M = 8.19$ mm) and T_3 ($M = 8.19$ mm). The ANOVA results of seed width was also significant [$F(3, 1541) = 15.84$, $p = 0.001$]. There was a statistically significant difference not only between T_1 ($M = 3.07$ mm, $p \leq 0.01$), T_3 ($M = 3.08$ mm, $p \leq 0.05$) and T_C ($M = 3.13$ mm), but also between T_1 and T_2 ($M = 3.12$, $p \leq 0.05$) (Table 11).

In 2018, based on statistical analysis significant results were obtained in length of Janka rice paddy seeds [$F(3, 1581) = 17.58$, $p < 0.001$]. The length of seeds (Table 12) significantly reduced in case of T_1 ($M = 9.27$ mm, $p \leq 0.001$) and T_3 ($M = 9.26$ mm, $p \leq 0.001$) irrigation, only the result of irrigation with T_2 ($M = 9.47$ mm, $p \geq 0.05$) was statistically similar to control method ($M = 9.46$ mm). However, under T_2 irrigation the average length was statistically higher than T_1 and T_3 (Table 12). Meanwhile, all treatments had a negative impact on width of seeds. The ANOVA test showed a statistically significant result in seed width [$F(3, 1573) = 27.39$, $p < 0.001$]. The average seed width was 2.85 mm ($p \leq 0.001$), 2.87 mm ($p \leq 0.001$), 2.87 mm ($p \leq 0.001$) and 2.99 mm for T_1, T_2, T_3 and T_C, respectively (Table 12).

Table 12. The size (mm) of paddy seeds of Janka rice developed with different quality of irrigation

Treatments		***2018***		***2019***	
		Length	***Width***	***Length***	***Width***
T_1	***M***	9.27a***	2.85a***	9.49a***	2.93ab*
	95% CI	[9.22; 9.33]	[2.83; 2.87]	[9.44; 9.54]	[2.91; 2.96]
T_2	***M***	9.47b	2.87a***	9.68b*	2.89a***
	95% CI	[9.42; 9.53]	[2.84; 2.89]	[9.63; 9.73]	[2.87; 2.92]
T_3	***M***	9.26a***	2.87a***	9.64b***	2.94bc
	95% CI	[9.19; 9.31]	[2.85; 2.89]	[9.59; 9.68]	[2.92; 2.96]
T_C	***M***	9.46b	2.99b	9.78c	2.99c
	95% CI	[9.41; 9.51]	[2.97; 3.01]	[9.74; 9.83]	[2.96; 3.01]

M - mean. CI - confidence interval (lower and upper bound). The letters represent a significant difference between treatments, values followed by the same letter do not differ significantly from each other at the 0.05 level. *, **, *** *- the mean difference is significant at the 0.05, 0.01 and 0.001 levels, respectively*

In 2019, analyses showed a significant reduction of length after the irrigation with treatments [$F(3, 1578) = 24.01$, $p < 0.001$]. Post hoc test (Table 12) indicated that the grain length was statistically lower after the irrigation with T_1 ($M = 9.49$ mm, $p \leq 0.001$), T_2 ($M = 9.68$ mm, $p \leq 0.05$) and T_3 ($M = 9.64$ mm, $p \leq 0.001$). The decrease after T_1 was statistically significant ($p \leq 0.05$) than T_2 and T_3. The One-Way ANOVA test displayed that grain width of Janka rice was also affected by irrigation [$F(3, 1586) = 8.38$, $p < 0.001$]. The average grain width after T_1 ($M = 2.93$ mm, $p \leq 0.05$) and T_2 ($M = 2.89$ mm, $p \leq 0.001$) irrigation was significantly lower compared to control irrigation ($M = 2.99$ mm). The effect of T_3 ($M = 2.94$ mm) irrigation on grain width was insignificant ($p = 0.051$). Meanwhile, the mean value of T_3 was statistically ($p \leq 0.05$) higher than T_2 irrigation.

Table 13 shows L/W ratio for M 488 and Janka paddy seeds. The role of treatments in the grain ratio was estimated based on the relationship between the average length and the average width of the grains, detected earlier in the course of statistical analysis. The ratio is calculated by simply dividing the mean length by the mean width, and was not subjected to statistical analysis.

Table 13. The paddy seed L/W ratio of M 488 and Janka rice developed with different quality of irrigation

Treatments	***M 488***			***Janka***	
	2017	***2018***	***2019***	***2018***	***2019***
T_1	2.51	2.58	2.67	3.25	3.24
T_2	2.51	2.57	2.58	3.30	3.35
T_3	2.46	2.63	2.66	3.23	3.28
T_C	2.54	2.60	2.60	3.16	3.27

In the first year of experiment, treatment showed a decreasing result in ratio. The L/W ratio of M 488 was 2.51, 2.51, 2.46 and 2.54 for T_1, T_2, T_3 and T_C, respectively (Table 13). In the second year of experiment, except T_3 (2.63) irrigation, under T_1 (2.58), T_2 (2.57) L/W ratio of M 488 was lower than T_C (2.60). Meanwhile, in the same year, the ratio of Janka under T_1 (3.25), T_2 (3.30), and T_3 (3.23) was greater than T_C (3.16). In the third year of experiment, the ratio of M 488 only after T_2 irrigation (2.58) was lower than control (2.60), but after T_1 (2.67) and T_3 (2.66) ratio was higher. This year, for Janka only under T_1 (3.24) the ratio was lower than control irrigation (3.27), under other treatments (T_2 = 3.35; T_3 = 3.28) was bigger.

In general, over the years of the experiment, different results of the ratio were obtained depending on the length and width. The above results show that significant changes in size parameters also affected seed ratio in both varieties. Especially, a significant decrease in width led to a change in L/W ratio. During the experiments, as a rule, both low and high seed ratio were observed. However, here, the high grain ratio is mainly associated with a significant decrease of grain width.

The analysis of combined data also showed the statistical differences between treatments and control irrigation (Table 14). All observed changes indicate some extent reduction of grain dimension.

Table 14. The size (mm) of paddy seeds of rice (combined) developed with different quality of irrigation

Treatments	***2018***		***2019***	
	Length	***Width***	***Length***	***Width***
T_1	8.64a***	2.98a***	8.84a**	3.00a***
T_2	8.75b	2.99a**	8.86ab	3.01a**
T_3	8.69a*	3.00a*	8.92b	3.01a**
T_C	8.81b	3.04b	8.97b	3.06b

The letters represent a significant difference between treatments, values followed by the same letter do not differ significantly from each other at the 0.05 level. *, **, *** *- the mean difference is significant from* T_C *at the 0.05, 0.01 and 0.001 levels, respectively*

Once again it can also be verified that the composition of water plays an important role in this analysis. An interesting nuance was that all treatments did not affect either the length or width of the seeds at the same level. On the contrary, at least one of the factors investigated was adversely affected after irrigation with treatments. This case was observed in both M 488 and Janka varieties. Apparently, along with other parameters due to a stressful condition, the grain dimensions encountered to negative changes. The analysis of the combined data (Table 14) indicated that the width of rice more prone for decrease. In addition, under the direct application of effluent water (T_1) length, width and ratio decreases significantly (Table 14).

As Khatun et al. (1995) previously reported, salinization slows down the flowering phase of rice, having a major impact on seed formation. According to study of Fabre et al. (2005) the stressful condition created by high salinity one of the main reason of the reduced paddy seed size. Under stress, the plant faces difficulties during the growing season, which ultimately affects the seeds. Despite its nutrient content, the high total dissolved salt content of the effluent water was a critical factor affecting grain dimension. Saline conditions are dangerous even for salt tolerant rice genotypes (Rao et al., 2013).

4.5. Cooking quality of rice

Each consumer's one of the main desires is the use of high-quality rice in food. There are several criteria that influence the choice of rice by consumers, one of which is the time interval required for cooking. Different types of rice are preferred in the cuisine of each nation and are prepared in different ways depending on taste (Maclean et al., 2013). The gelatinization temperature (GT) of starch is an important indicator that affects the quality of rice cooking. This is important because the GT is directly related to the cooking time of the rice (Mutters and Thompson, 2009).

In this experiment GT was measured with alkali spreading value method. Then the results were compared on the basis of a seven-point scale (see Table 3) of the degree of spreading of grains. The results are illustrated in the Figure 8 and 9.

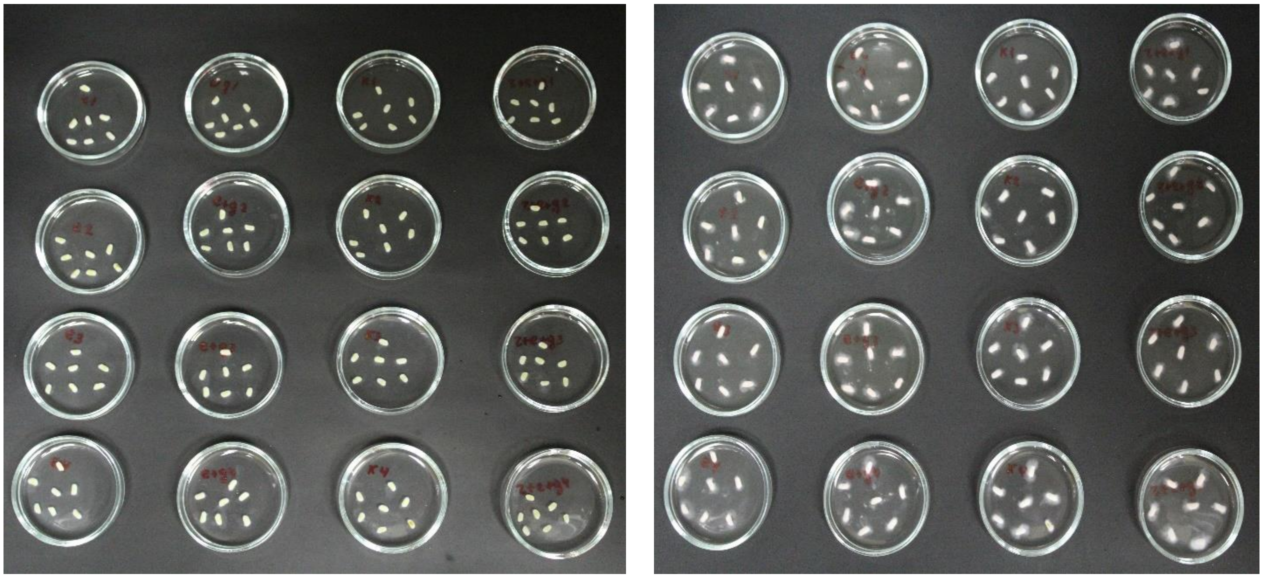

Figure 8. The measurement of GT of M 488 rice variety, before (left) and after (right). Location of grain samples from left to right: T_1, T_2, T_3, T_C.

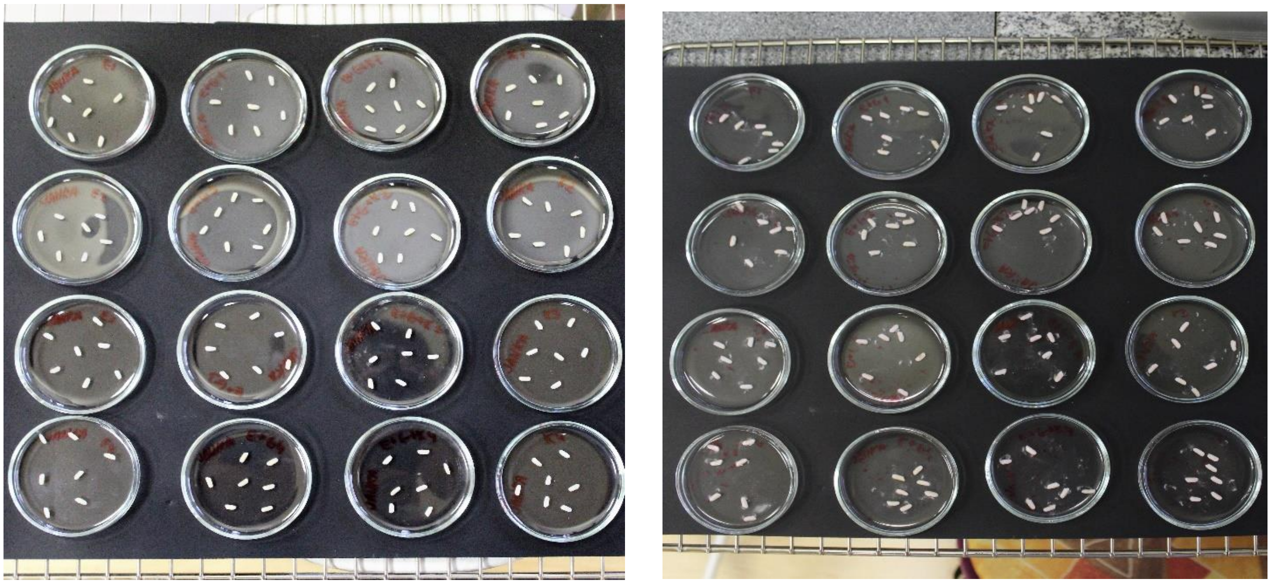

Figure 9. The measurement of GT of Janka rice variety, before (left) and after (right). Location of grain samples from left to right: T_1, T_2, T_3, T_C.

Because of technical issues first year GT test of Janka rice variety was not conducted. Within all experimental years, all samples of both rice varieties (M 488 and Janka) from every treatments gave similar result. The obtained results showed that grains from each rice variety irrigated by treatments and the control method were exposed to the solution. All results correspond to the third scale: grain swollen, collar incomplete and narrow. This result indicates a high intermediate temperature of rice gelatinization.

High intermediate GT is very common among rice genotypes (Székely et al., 2018). In this experiment, none of the irrigation treatments have been able to change this characteristic disposition for either M 488 or Janka, which shows there was not any difference between control and treatments. However, a distinctive feature of a high intermediate GT rice grain is that it takes a lot of time and water to prepare it (Pang et al., 2016).

4.6. Mineral uptake of rice

The normal life cycle of a plant organism requires certain groups of nutrients, and their function in a plant cannot be replaced by other chemical elements. In this regard, the role of high fertility soils and fertilisers in agriculture is very important. In most studies, when it comes to the use of wastewater in irrigated agriculture, their macro and micro element composition comes to the fore (Mohammad and Ayadi, 2004; Gassama et al., 2015; Matheyarasu et al., 2016). The contribution of these resources to healthy plant growth and productivity is often noted. The reason these ideas come forward is because they contain nutrients such as nitrogen and phosphorus that plants need. Nevertheless, in our work, the main attention was paid to the role of treatments for the transfer and accumulation of minerals in aboveground biomass and grains of individual rice varieties to verify the possible bioremediation characteristics of aerobic rice.

4.6.1. Mineral Content (MC) of aboveground biomass of rice

In the first experimental year, the ANOVA test showed significant result on Ca absorption of M 488 rice variety [$F(3, 12) = 5.33$, $p = 0.01$]. However, only between T_2 ($M = 4967$ mg*kg^{-1}, $p \leq 0.01$) and T_C ($M = 3527$ mg*kg^{-1}) we have observed a statistically significant difference (Table 15), the increase in T_1 ($M = 4092$ mg*kg^{-1}, $p \geq 0.05$) and T_3 ($M = 4055$ mg*kg^{-1}, $p \geq 0.05$) irrigation was not significant compared to T_C. According to the statistical analysis neither the amount of Mg [$F(3, 12) = 2.98$, $p = 0.07$], nor K [$F(3, 12) = 0.92$, $p = 0.46$] in aboveground biomass of M 488 was statistically affected by treatments. However, a notable change was observed (Table 15) in case of Mg content after T_2 irrigation ($M = 3035$ mg*kg^{-1}, $p = 0.06$) compared to the control method. The ANOVA test showed a significant effect on P content of rice aboveground biomass [$F(3, 12) = 7.94$, $p = 0.003$]. Despite the high percentage of P in effluent water, the amount of P (Table 15) was statistically lower after the irrigation with T_1 ($M = 1575$ mg*kg^{-1}, $p \leq 0.05$) and T_2 ($M = 1445$ mg*kg^{-1}, $p \leq 0.01$). The largest changes were recorded in the amount of Na. The result of the One-Way ANOVA test was in following order: $F(3, 12) = 143.91$, $p < 0.001$. After the irrigation with T_1 ($M = 1155$ mg*kg^{-1}, $p \leq 0.001$), T_2 ($M = 1057$ mg*kg^{-1}, $p \leq 0.001$) and T_3 ($M = 685$ mg*kg^{-1}, $p \leq 0.01$) amount of Na in aboveground biomass of M 488 has increased (Table 15). The increase under T_1, T_2 was also statistically ($p \leq 0.05$) higher than T_3.

Table 15. Average (n = 4) MC (mg*kg^{-1}) in aboveground biomass of M 488 rice variety developed with different quality of irrigation, 2017

Treatments		***2017***				
		Ca	***Mg***	***P***	***K***	***Na***
T_1	***M***	4092ab	2902a	1575a*	10795a	1155c***
	95% CI	[3086; 5098]	[2393; 3411]	[1413; 1736]	[9504; 12085]	[1035; 1274]
T_2	***M***	4967b**	3035a	1445a**	10180a	1057c***
	95% CI	[4101; 5833]	[2822; 3247]	[1204; 1907]	[9044; 11315]	[1027; 1087]
T_3	***M***	4055ab	2770a	1675ab	10372a	685b**
	95% CI	[3318; 4791]	[2523; 3016]	[1442; 1907]	[9260; 11484]	[636; 735]
T_C	***M***	3527a	2635a	2027b	10900a	404a
	95% CI	[2894; 4160]	[2441; 2828]	[1603; 2451]	[9933; 11866]	[277; 530]

M - mean. CI - confidence interval (lower and upper bound). The letters represent a significant difference between treatments, values followed by the same letter do not differ significantly from each other at the 0.05 level. *, **, *** *- the mean difference is significant from* T_C *at the 0.05, 0.01 and 0.001 levels, respectively*

In the second experimental year, compared to the previous year the amount of Ca [$F(3, 12) = 0.60$, $p = 0.63$], Mg [$F(3, 11) = 1.87$, $p = 0.19$], P [$F(3, 12) = 1.75$, $p = 0.21$] and K [$F(3, 11) = 1.11$, $p = 0.39$] has remained statistically unchanged. Despite the non-statistical difference, after all treatments a low level of P in the aboveground biomass of M 488 was noticed (Table 16). Moreover, as a result of T_1 ($M = 14057$ mg*kg^{-1}) and T_3 ($M = 13186$ mg*kg^{-1}), the amount of K (Table 16) was noticeably higher than T_C ($M = 11817$ mg*kg^{-1}). Like last year the amount of Na in aboveground biomass is also increased, at which these indicators were statistically significant compared to the control method [$F(3, 12) = 12.92$, $p < 0.001$]. The average Na was 1006 mg*kg^{-1}, 885 mg*kg^{-1}, 982 mg*kg^{-1}, and 344 mg*kg^{-1} for T_1, T_2, T_3, and T_C irrigation, respectively (Table 16).

Table 16. Average (n = 4) MC (mg*kg^{-1}) in aboveground biomass of M 488 rice variety developed with different quality of irrigation, 2018

Treatments		***2018***				
		Ca	***Mg***	***P***	***K***	***Na***
T_1	***M***	2455a	2180a	2242a	14057a	$1006b^{**}$
	95% CI	[1816; 3093]	[1791; 2568]	[1595; 2889]	[9663; 18451]	[673; 1338]
T_2	***M***	2432a	1890a	2382a	11892a	$885b^{**}$
	95% CI	[1726; 3139]	[1573; 2206]	[2026; 2738]	[9507; 14277]	[553; 1217]
T_3	***M***	2825a	2212a	2100a	13186a	$982b^{**}$
	95% CI	[2164; 3486]	[1748; 2676]	[1829; 2370]	[10106; 16266]	[708; 1256]
T_C	***M***	2655a	2217a	2605a	11817a	344a
	95% CI	[1674; 3635]	[1857; 2577]	[1929; 3280]	[8510; 15124]	[256; 432]

M - mean. CI - confidence interval (lower and upper bound). The letters represent a significant difference between treatments, values followed by the same letter do not differ significantly from each other at the 0.05 level. *, **, *** *- the mean difference is significant from* T_C *at the 0.05, 0.01 and 0.001 levels, respectively*

In the third experimental year, the outcome of ANOVA test for Ca content of aboveground biomass content of M 488 was in the following order: [$F(3, 12) = 136.68$, $p < 0.001$]. Only T_1 irrigation ($M = 4872$ mg*kg^{-1}, $p \leq 0.001$) had a statistically significant effect on Ca level (Table 17). Meanwhile, there was a statistically significant difference ($p \leq 0.05$) between T_1 and T_2; T_1 and T_3; T_2 and T_3. The analysis of Mg content also showed significant result [$F(3, 12) = 12.94$, $p < 0.001$]. Although, there was a statistical difference only between T_2 ($M = 2602$ mg*kg^{-1}, $p \leq 0.001$) and T_C ($M = 2067$ mg*kg^{-1}), but T_1 ($M = 2285$ mg*kg^{-1}) and T_3 ($M = 2160$ mg*kg^{-1}) also had visible changes on Mg content (Table 17). The outcome of statistical analysis also showed a significant difference between T_2 and T_1, T_3. The ANOVA test showed a statistical significance in P content analysis [F(3,

12) = 4.98, $p = 0.02$]. However, there was a statistically significant ($p \leq 0.05$) difference only between T_1 (M = 1970 mg*kg^{-1}) and T_3 (M = 1495 mg*kg^{-1}) irrigation (Table 17).

Table 17. Average (n = 4) MC (mg*kg^{-1}) in aboveground biomass of M 488 rice variety developed with different quality of irrigation, 2019

Treatments		***2019***				
		Ca	***Mg***	***P***	***K***	***Na***
T_1	***M***	4872c***	2285a	1970b	7095c***	352c**
	95% CI	[4689; 5055]	[2084; 2485]	[1571; 2368]	[6784; 7405]	[187; 516]
T_2	***M***	3792a	2602b***	1797ab	7260c***	355c**
	95% CI	[3746; 3838]	[2301; 2903]	[1662; 1932];	[6949; 7570]	[232; 478]
T_3	***M***	4035b	2160a	1495a	5187b**	184b*
	95% CI	[3942; 4127]	[1974; 2345]	[1362; 1627]	[4799; 5575]	[162; 206]
T_C	***M***	3867ab	2067a	1785ab	3712a	131a
	95% CI	[3696; 4039]	[1993; 2141]	[1437; 2132]	[3173; 4251]	[108; 154]

M - mean. CI - confidence interval (lower and upper bound). The letters represent a significant difference between treatments, values followed by the same letter do not differ significantly from each other at the 0.05 level. *, **, *** *- the mean difference is significant from* T_C *at the 0.05, 0.01 and 0.001 levels, respectively*

This year, all treatment led to a considerable increase in the content of K [$F(3, 12) = 181.85$, $p < 0.001$] and Na [$F(3, 12) = 12.43$, $p = 0.001$] in the aboveground biomass of M 488. The average K (Table 17) was 7095 mg*kg^{-1}, 7260 mg*kg^{-1}, 5187 mg*kg^{-1}, and 3712 mg*kg^{-1} for T_1, T_2, T_3, and T_C irrigation, respectively. The average Na (Table 17) was 352 mg*kg^{-1}, 355 mg*kg^{-1}, 184 mg*kg^{-1}, and 131 mg*kg^{-1}for T_1, T_2, T_3, and T_C irrigation, respectively. In addition, both in K and Na content after T_1 and T_2 irrigation the difference was statistically significant ($p \leq 0.05$) than T_3 too (Table 17).

Table 18. Average (n = 4) MC (mg*kg^{-1}) in aboveground biomass of Janka rice variety developed with different quality of irrigation, 2017

Treatments		***2017***				
		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	***M***	3782ab	2940a	1500a**	10587a	1062b***
	95% CI	[3102; 4462]	[2655; 3224]	[1388; 1611]	[9427; 11747]	[944; 1130]
T_2	***M***	4335b	2852a	1595ab	10277a	967b*
	95% CI	[3616; 5043]	[2475; 3229]	[1186; 2003];	[9125; 11429]	[622; 1312]
T_3	***M***	3380a	2587a	2045b	11205a	528a
	95% CI	[2939; 3820]	[2456; 2718]	[1983; 2016]	[10547; 11862]	[370; 685]
T_C	***M***	3587ab	2652a	2097b	11802a	361a
	95% CI	[2927; 4247]	[2103; 3201]	[1875; 2319]	[9111; 14493]	[290; 432]

M - mean. CI - confidence interval (lower and upper bound). The letters represent a significant difference between treatments, values followed by the same letter do not differ significantly from each other at the 0.05 level. *, **, *** *- the mean difference is significant from* T_C *at the 0.05, 0.01 and 0.001 levels, respectively*

In the first experimental year (Table 18), after the T_1, T_2 and T_3 irrigation, visible changes in the amount of Ca [$F(3, 12) = 4.278$, $p = 0.003$], Mg [$F(3, 12) = 2.05$, $p = 0.16$], K [$F(3, 12) = 1.79$, $p = 0.20$] of aboveground biomass of Janka rice variety is also noted, but these changes were not statistically significant compared to the control irrigation. Only, in Ca content there was a statistically significant difference ($p \leq 0.05$) between T_2 and T_3 irrigation (Table 18). As with M 488, there was no increase in P [$F(3, 12) = 16.29$, $p < 0.001$] in aboveground biomass of Janka, although treatments contained high levels of P. The average P was 1500 mg*kg^{-1} and 2097 mg*kg^{-1} for T_1 ($p \leq 0.01$) and T_C irrigation, respectively (Table 18). Under the T_2 irrigation (M = 1595 mg*kg^{-1}), the P content in

Janka was lower, but there was no statistical ($p = 0.07$) difference. Meanwhile, the average P after T_1 was also statistically ($p \leq 0.05$) lower than T_3 (Table 18).

Table 19. Average (n = 4) MC (mg*kg^{-1}) in aboveground biomass of Janka rice variety developed with different quality of irrigation, 2018

Treatments		***2018***				
		Ca	***Mg***	***P***	***K***	***Na***
T_1	***M***	2297a	2437a	2472a	13392b**	1051c***
	95% CI	[1943; 2651]	[1926; 2948]	[2295; 2649]	[12443; 14341]	[918; 1184]
T_2	***M***	2727a	2362a	2187a	11535ab	884bc***
	95% CI	[2034; 3420]	2047; 2677]	[1772; 2602]	[9316; 13754]	[628; 1139]
T_3	***M***	2410a	2145a	2217a	10567a	776b**
	95% CI	[2101; 2718]	[1816; 2473]	[1774; 2660]	[9754; 11380]	[711; 840]
T_C	***M***	2715a	2135a	2277a	10002a	395a
	95% CI	[2072; 3357]	[1714; 2555]	[2032; 2522]	[8055; 11949]	[284; 506]

M - mean. CI - confidence interval (lower and upper bound). The letters represent a significant difference between treatments, values followed by the same letter do not differ significantly from each other at the 0.05 level. *, **, *** *- the mean difference is significant from* T_C *at the 0.05, 0.01 and 0.001 levels, respectively*

Na content was also influenced by irrigation treatments [$F(3, 12) = 30.255$, $p < 0.001$]. Here, the amount of Na in aboveground biomass of Janka increased as a result of irrigation with T_1 ($M = 1062$ mg*kg^{-1}, $p \leq 0.001$) and T_2 ($M = 967$ mg*kg^{-1}, $p \leq 0.05$), only the application of the T_3 ($M = 528$ mg*kg^{-1}, $p \geq 0.05$) irrigation gave a statistically similar result with T_C ($M = 361$ mg*kg^{-1}). But the effect of T_1 and T_2 irrigation was statistically higher than T_3 (Table 18).

In the second experimental year, the amount of Ca [$F(3, 12) = 1.72$, $p = 0.22$], Mg [$F(3, 12) = 1.48$, $p = 0.27$], and P [$F(3, 12) = 1.45$, $p = 0.28$] did not change statistically after the irrigation with treatments (Table 19), their amount after the irrigation with T_1, T_2 and T_3 was statistically similar to control irrigation. Meanwhile, there was a statistical ANOVA result of K content [$F(3, 12) = 8.72$, $p = 0.002$]. An increase in the amount of K (Table 19) in aboveground biomass of Janka was noted after T_1 irrigation ($M = 13392$ mg*kg^{-1}), and this increase was not only significant than control irrigation ($p \leq 0.01$), but also than T_3. The absorption of Na by Janka like in M 488 was also higher after irrigation with T_1, T_2 and T_3 [$F(3, 12) = 31.52$, $p < 0.001$]. There was a statistically significant difference (Table 19) between control irrigation ($M = 395$ mg*kg^{-1}) and T_1 ($M = 1051$ mg*kg^{-1}, $p \leq 0.001$), T_2 ($M = 884$ mg*kg^{-1}, $p \leq 0.001$), T_3 ($M = 776$ mg*kg^{-1}, $p \leq 0.01$). Moreover, there was also a statistically significant ($p \leq 0.05$) difference between T_1 and T_3.

In the third experimental year, there was a significant effect of treatments on Ca content of aboveground biomass of Janka [$F(3, 12) = 58.78$, $p < 0.001$]. Post hoc comparisons test showed (Table 20) that the mean score T_1 ($M = 4512$ mg*kg^{-1}, $p \leq 0.001$), T_2 ($M = 4965$ mg*kg^{-1}, $p \leq 0.001$) and T_3 ($M = 4505$ mg*kg^{-1}, $p \leq 0.01$) irrigation was significantly different than control irrigation ($M = 4230$ mg*kg^{-1}). The average Ca content after T_2 was also significantly ($p \leq 0.05$) higher than T_1 and T_3. Like Ca, P content of Janka aboveground biomass also increased significantly after treatments [$F(3, 12) = 57.09$, $p < 0.001$]. The average P content (Table 20) was 1450 mg*kg^{-1}, 1470 mg*kg^{-1}, 1925 mg*kg^{-1} and 1142 mg*kg^{-1} for T_1 ($p \leq 0.01$), T_2 ($p \leq 0.01$), T_3 ($p \leq 0.001$) and T_C irrigation. Moreover, the increase after T_3 was statistically ($p \leq 0.05$) higher than T_1 and T_2 too. The ANOVA test result for K content was in the following order: $F(3, 12) = 53.75$, $p < 0.001$. After the T_1 ($M = 3652$ mg*kg^{-1}, $p \leq 0.001$), T_2 ($M = 4907$ mg*kg^{-1}, $p \leq 0.001$) and T_3 ($M = 4687$ mg*kg^{-1}, $p \leq 0.001$) irrigation K content in the aboveground biomass of the Janka variety greatly reduced (Table 20). The mean value of K under T_1 was statistically ($p \leq 0.05$) lower than T_2 and T_3. The ANOVA test did not show significant result for Mg content [$F(3, 11) = 1.47$, $p = 0.28$], despite after the T_2 ($M = 2567$ mg*kg^{-1}) and T_3 ($M = 2590$ mg*kg^{-1}) irrigation the average Mg content (Table 20) was higher than control ($M = 2375$ mg*kg^{-1}). Another important result was recorded in the amount of Na [$F(3, 12) = 10.90$, $p = 0.001$]. While between control ($M = 165$ mg*kg^{-1}) and T_1 ($M = 249$ mg*kg^{-1}, $p \leq 0.01$), T_3 ($M = 285$ mg*kg^{-1}, $p \leq 0.01$) difference was statistically significant, but between T_2 ($M = 197$ mg*kg^{-1}, $p \geq 0.05$) statistically similar (Table 20). However, after T_2 irrigation the average Na content was much higher.

Table 20. Average (n = 4) MC (mg*kg^{-1}) in aboveground biomass of Janka rice variety developed with different quality of irrigation, 2019

Treatments		***2019***				
		Ca	***Mg***	***P***	***K***	***Na***
T_1	***M***	4512b**	2336a	1450b**	3652a***	249b**
	95% CI	[4407; 4617]	[1264; 3408]	[1296; 1603]	[3228; 4076]	[185; 313]
T_2	***M***	4965c***	2567a	1470b**	4907b***	197a
	95% CI	[4786; 5143]	[2309; 2825]	[1306; 1633];	[4028; 5786]	[168; 226]
T_3	***M***	4505b**	2590a	1925c***	4687b***	285b**
	95% CI	[4484; 4525]	[2517; 2662]	[1811; 2038]	[4576; 4798]	[259; 310]
T_C	***M***	4230a	2375a	1142a	6940c	165a
	95% CI	[4086; 4373]	[2327; 2422]	[1040; 1244]	[6260; 7619]	[152; 179]

M - mean. CI - confidence interval (lower and upper bound). The letters represent a significant difference between treatments, values followed by the same letter do not differ significantly from each other at the 0.05 level. *, **, *** *- the mean difference is significant from T_C at the 0.05, 0.01 and 0.001 levels, respectively*

In addition, the percentage change in mineral content of both varieties aboveground biomass for each experimental year is included in the *Appendix 5*.

Statistical analysis of the combined data of varieties from 2017 shows that rice response varied markedly under different irrigation treatments. The Ca content of rice aboveground biomass (Table 21) increased significantly ($p \leq 0.001$) after T_2 irrigation, similarly to the Mg content ($p \leq 0.05$). While T_1 and T_2 irrigation did not have a significant effect on these elements, although the Mg content was also higher after T_1 irrigation, the difference was statistically insignificant ($p = 0.06$). After T_1 and T_3 irrigation, a significant ($p \leq 0.001$) decrease (Table 21) in the P content was observed. At the same time, all the treatments had no significant ($p \geq 0.05$) effect on the K content (Table 21). Na was one of the main targets of the analysis, and after T_1 ($p \leq 0.001$), T_2 ($p \leq 0.001$) and even T_3 ($p \leq 0.01$) irrigation the Na content increased significantly (Table 21).

Table 21. The MC (mg*kg^{-1}) of aboveground biomass of rice (combined) developed with different quality of irrigation, 2017

Treatments	***Ca***	***Mg***	***P***	***K***	***Na***
T_1	3938a	2921ab	1538a***	10691a	1109c***
T_2	4651b***	2944b*	1520a***	10229a	1013c***
T_3	3718a	2679ab	1860b	10789a	607b**
T_C	3558a	2644a	2063b	11567a	383a

The letters represent a significant difference between treatments, values followed by the same letter do not differ significantly from each other at the 0.05 level. *, **, *** *- the mean difference is significant from* T_C *at the 0.05, 0.01 and 0.001 levels, respectively*

In combined data of 2018, none of the treatments significantly ($p \geq 0.05$) influenced the Ca, Mg and P content of rice aboveground biomass (Table 22). After T_1 irrigation, the K content statistically (M = 13725 mg*kg^{-1}, $p \leq 0.05$) increased, but the other treatments did not cause significant ($p \geq 0.05$) changes (Table 22). As in the previous year, the Na content was statistically ($p \leq 0.001$) higher in case of all effluent water containing treatments (Table 22).

Table 22. The MC (mg*kg^{-1}) of aboveground biomass of rice (combined) developed with different quality of irrigation, 2018

Treatments	***Ca***	***Mg***	***P***	***K***	***Na***
T_1	2376a	2327a	2358a	13725b*	1029b***
T_2	2580a	2126a	2285a	11714ab	885b***
T_3	2618a	2179a	2159a	11690ab	879b***
T_C	2685a	2176a	2441a	10910a	370a

The letters represent a significant difference between treatments, values followed by the same letter do not differ significantly from each other at the 0.05 level. *, **, *** *- the mean difference is significant from* T_C *at the 0.05, 0.01 and 0.001 levels, respectively*

Table 23. The MC ($mg*kg^{-1}$) of aboveground biomass of rice (combined) developed with different quality of irrigation, 2019

Treatments	***Ca***	***Mg***	***P***	***K***	***Na***
T_1	4692b***	2245a	1710a	5373b	300b*
T_2	4378a	2585b**	1633a	6083b	276b*
T_3	4270a	2375a	1710a	4937a	234b*
T_C	4048a	2221a	1463a	5326ab	148a

The letters represent a significant difference between treatments, values followed by the same letter do not differ significantly from each other at the 0.05 level. *, **, *** *- the mean difference is significant from* T_C *at the 0.05, 0.01 and 0.001 levels, respectively*

In combined data of 2019, the average Ca content (Table 23) was higher after all treatments, but the analysis showed statistical difference between T_1 (M = 4692 $mg*kg^{-1}$, $p \leq 0.001$) and T_C (M = 4048 $mg*kg^{-1}$). Although P content after all treatments got high number, there was no statistically significant ($p \geq 0.05$) difference between control irrigation (Table 23). Among treatments only T_2 (M = 2585 $mg*kg^{-1}$, $p \leq 0.01$) had a statistically significant change in Mg content (Table 22). In case of K content (Table 23), the effect of treatments was statistically similar ($p \geq 0.05$) to T_C. Here, as in the previous two years, after T_1 (M = 300 $mg*kg^{-1}$, $p \leq 0.05$) T_2 (M = 276 $mg*kg^{-1}$, $p \leq 0.05$) and T_3 (M = 234 $mg*kg^{-1}$, $p \leq 0.05$) the Na content (Table 23) in the aboveground biomass of rice was notably higher compared to the control irrigation T_C (M = 148 $mg*kg^{-1}$).

Table 24 indicates the correlation analysis of minerals in aboveground biomass of rice. This experiment showed Na correlated negatively only with Ca (-0.323**), between Mg (0.376**), P (0.201**) and K (0.712**) positively. It should be noted correlation between Na and P was weak. Meanwhile, Ca had a positive moderate correlation between Mg (0.432**), but with P (-0.741**) and K (-0.604**) negative correlation. While analysis of correlation did not find a statistically significant correlation between Mg and K (0.142), between Mg and P (-0.377**) showed moderate negative correlation at 1% level of significance. Finally, correlation of P and K (0.533**) was moderate positive.

Table 24. The correlation coefficients between minerals in rice aboveground biomass

MC	***Ca***	***Mg***	***P***	***K***	***Na***
Ca	1.000				
Mg	0.432**	1.000			
P	-0.741**	-0.377**	1.000		
K	-0.604**	0.142	0.533**	1.000	
Na	-0.323**	0.376**	0.201*	0.712**	1.000

*, ** - *significant at the 0.05 and 0.01 levels, respectively*

Although the levels of minerals in varieties differ depending on the amount of irrigation and environmental conditions in different experimental years, the main nuance that attracted attention was the increase in the amount of sodium in aboveground biomass. If one of the reasons for this is the high amount of Na in the treatments, then the other reason is that the mechanism for the supply of other elements in plants is very different from the supply mechanism of Na (Ochiai and Matoh, 2002; Goel et al., 2011; Tanoi et al., 2011; Yang et al., 2014; Sasaki et al., 2016; Kant et al., 2018). The plant protection system allows rice to avoid the accumulation of Na in the reproductive organs as much as possible, however, depending on the amount of this toxic element, it settles mainly in the vegetative organs (Marschner, 1995; Asch et al., 1999; Reddy et al., 2017). Moreover, according to some research given the stress levels caused by salinity, this can limit the absorption and uptake of other important minerals in the rice plant (Hussain et al., 2017; Razzaq et al., 2020), which has also been found in the current study. Apparently, in the current experiment the presence of sodium in the irrigation water created an imbalance in nutrition, which affected the disproportionate accumulation of other elements in the aboveground biomass of genotypes. The overall end result of three years of experience shows that irrigation treatments has affected the mineral composition of aboveground biomass of both genotypes.

4.6.2. Mineral Content (MC) of rice seeds

In 2018, based on statistical analysis, significant differences in Ca content in M 488 seeds were determined [$F(3, 12) = 19.57$, $p < 0.001$]. There was a statistically ($p \leq 0.05$) significant difference between T_1 ($M = 479$ mg*kg^{-1}), T_3 ($M = 521$ mg*kg^{-1}) and T_C ($M = 603$ mg*kg^{-1}); T_1, T_3 and T_2 ($M = 627$ mg*kg^{-1}) irrigation (Table 25). The P content of seeds significantly declined [$F(3, 12) = 16.12$, $p < 0.001$]. The P content was 3867 mg*kg^{-1} ($p \leq 0.001$), 4102 mg*kg^{-1} ($p \leq 0.05$), 4120 mg*kg^{-1} ($p \leq 0.05$) and 4325 mg*kg^{-1} for T_1, T_2, T_3 and T_C, respectively (Table 25). After the T_1 the P content was significantly lower ($p \leq 0.05$) than T_2 and T_3 (Table 25). The Mg content was also had a significant ANOVA result [$F(3, 12) = 11.06$, $p = 0.001$]. Although after the T_2 ($M = 1710$ mg*kg^{-1}, $p \geq 0.05$) and T_3 ($M = 1652$ mg*kg^{-1}, $p \geq 0.05$) irrigation the average Mg content (Table 25) in the M 488 rice seeds remains statistically unchanged, but a statistically significant decrease was noted after the T_1 ($M = 1572$ mg*kg^{-1}, $p \leq 0.01$) irrigation. Moreover, this result was also statistically ($p \leq 0.05$) lower than T_2. The ANOVA result of K content was in the following order: $F(3, 12) = 7.61$, $p = 0.004$. There was a statistically significant decline of K content (Table 25) after T_1 ($M = 3300$ mg*kg^{-1}, $p \leq 0.05$) and T_3 ($M = 3227$ mg*kg^{-1}, $p \leq 0.01$). The result of K after T_3 ($M = 3472$ mg*kg^{-1}) was also low, but it was statistically similar to control irrigation ($M = 3600$ mg*kg^{-1}). The significant changes were also found in the content of Na [$F(3, 12) = 13.76$, $p < 0.001$]. The Na content (Table 25) of the M 488 rice seeds increased significantly after irrigation with the T_1 ($M = 146$ mg*kg^{-1}, $p \leq 0.001$), T_2 ($M = 128$ mg*kg^{-1}, $p \leq 0.01$) and T_3 ($M = 125$ mg*kg^{-1}, $p \leq 0.05$). It should be noted, all minerals faced some reduction, except Na, especially under T_1 irrigation.

In 2019, the ANOVA test did not show a statistical result in Ca [$F(3, 12) = 0.36$, $p = 0.78$] and Na [$F(3, 12) = 2.21$, $p = 0.14$] content. While the ANOVA test found statistically significant result in Mg [$F(3, 12) = 11.88$, $p = 0.001$] content, but none of the treatments was significantly different from control irrigation (Table 26). On the contrary, there was a statistically significant ($p \leq 0.05$) difference between T_3 and T_1 and T_2 (Table 26).

The P content significantly reduced after T_3 irrigation [*F*(3, 12) = 10.39, *p* = 0.001]. There was a statistically significant difference (Table 26) between T_3 (*M* = 3440 mg*kg^{-1}) and T_1 (*M* = 4240 mg*kg^{-1}, $p \leq 0.05$), T_2 (*M* = 4490 mg*kg^{-1}, $p \leq 0.05$), T_C (*M* = 4298 mg*kg^{-1}, $p \leq 0.01$). The similar result was also observed in K content [*F*(3, 12) = 11.87, *p* = 0.001]. After T_3 (*M* = 3005 mg*kg^{-1}) irrigation K content in M 488 seeds decreased significantly (Table 26) compared to T_1 (*M* = 3600 mg*kg^{-1}), T_2 (*M* = 3808 mg*kg^{-1}) and T_C (*M* = 3665 mg*kg^{-1}).

Table 25. Average (n = 4) MC (mg*kg^{-1}) in seeds of M 488 rice variety developed with different quality of irrigation, 2018

Treatments		***2018***				
		Ca	***Mg***	***P***	***K***	***Na***
T_1	***M***	479a**	1572a**	3867a***	3300a*	146b***
	95% CI	[442; 515]	[1518; 1626]	[3681; 4053]	[3159; 3440]	[111; 180]
T_2	***M***	627b	1710b	4102b*	3472ab	128b**
	95% CI	[564; 690]	[1630; 1789]	[3984; 4220];	[3290; 3654]	[118; 139]
T_3	***M***	521a*	1652ab	4120b*	3227a**	125b*
	95% CI	[457; 586]	[1591; 1713]	[3972; 4267]	[3069; 3385]	[116; 134]
T_C	***M***	603b	1745b	4325c	3600b	92a
	95% CI	[580; 626]	[1656; 1833]	[4191; 4458]	[3329; 3870]	[82; 101]

M - mean. CI - confidence interval (lower and upper bound). The letters represent a significant difference between treatments, values followed by the same letter do not differ significantly from each other at the 0.05 level. *, **, *** *- the mean difference is significant from* T_C *at the 0.05, 0.01 and 0.001 levels, respectively*

Table 26. Average (n = 4) MC (mg*kg^{-1}) in seeds of M 488 rice variety developed with different quality of irrigation, 2019

Treatments		***2019***				
		Ca	***Mg***	***P***	***K***	***Na***
T_1	***M***	397a	1653b	4240b	3600b	200a
	95% CI	[307; 486]	[1573; 1732]	[3955; 4526]	[3328; 3872]	[165; 235]
T_2	***M***	413a	1718b	4490b	3808b	211a
	95% CI	[338; 487]	[1657; 1778]	[4267; 4713]	[3469; 4145]	[181; 242]
T_3	***M***	421a	1405a	3440a**	3005a**	227a
	95% CI	[362; 480]	[1365; 1445]	[3294; 3586]	[2808; 3202]	[208; 245]
T_C	***M***	428a	1650ab	4298b	3665b	201a
	95% CI	[369; 486]	[1419; 1881]	[3469; 5125]	[3218; 4112]	[183; 219]

M - mean. CI - confidence interval (lower and upper bound). The letters represent a significant difference between treatments, values followed by the same letter do not differ significantly from each other at the 0.05 level. ** *- the mean difference is significant from* T_C *at the 0.05 level*

In 2018, Mg [$F(3, 12) = 2.82$, $p = 0.09$] and P [$F(3, 12) = 1.26$, $p = 0.33$] content of Janka seeds remained statistically unchanged (Table 27). The Ca content (Table 27) after all treatments was statistically similar to T_C, despite significant ANOVA result, [$F(3, 12) = 4.89$, $p = 0.02$]. There was only a significant ($p \leq 0.05$) difference between T_1 (M = 546 mg*kg^{-1}) and T_2 (M = 494 mg*kg^{-1}), T_3 (M = 497 mg*kg^{-1}). All treatments had a significant effect on K content of Janka seeds [$F(3, 12) = 11.04$, $p = 0.001$]. After the T_1 (M = 3200 mg*kg^{-1}, $p \leq 0.01$), T_2 (M = 3197 mg*kg^{-1}, $p \leq 0.01$) and T_3 (M = 3210 mg*kg^{-1}, $p \leq 0.01$) K content (Table 27) significantly lower than T_C (M = 3382 mg*kg^{-1}). On the contrary, Na content increased significantly and Na content was 162 mg*kg^{-1} ($p \leq 0.01$), 131 mg*kg^{-1} ($p \leq 0.01$), 128 mg*kg^{-1} ($p \leq 0.01$) and 86 mg*kg^{-1} for T_1, T_2, T_3 and T_C irrigation, respectively (Table 27). The average value of T_1 irrigation was also statistically ($p \leq 0.05$) higher than T_2 and T_3.

Table 27. Average (n = 4) MC (mg*kg^{-1}) in seeds of Janka rice variety developed with different quality of irrigation, 2018

Treatments		***2018***				
		Ca	***Mg***	***P***	***K***	***Na***
T_1	***M***	546b	1653a	4210a	3200a**	162c***
	95% CI	[531; 561]	[1559; 1747]	[3974; 4445]	[3092; 3307]	[151; 173]
T_2	***M***	494a	1575a	4067a	3197a**	131b***
	95% CI	[466; 523]	[1500; 1649]	[3976; 4158];	[3124; 3270]	[117; 146]
T_3	***M***	497a	1570a	4087a	3210a**	128b***
	95% CI	[481; 513]	[1516; 1623]	[4024; 4150]	[3098; 3321]	[120; 136]
T_C	***M***	513ab	1575a	4165a	3382b	86a
	95% CI	[455; 570]	[1496; 1653]	[3892; 4437]	[3355; 3409]	[77; 95]

M - mean. CI - confidence interval (lower and upper bound). The letters represent a significant difference between treatments, values followed by the same letter do not differ significantly from each other at the 0.05 level. **, *** *- the mean difference is significant from* T_C *at the 0.01 and 0.001 levels, respectively*

In 2019, treatments did not have a statistically significant effect on Ca [$F(3, 12) = 0.42$, $p = 0.74$], Mg [$F(3, 12) = 2.71$, $p = 0.09$] and Na [$F(3, 12) = 1.04$, $p = 0.41$] content of seeds of Janka variety (Table 28). Although, the ANOVA result of P [$F(3, 12) = 3.79$, $p = 0.04$] and K [$F(3, 12) = 4.69$, $p = 0.02$] was significant, Post hoc comparisons test showed statistically similar relationship between control irrigation and treatments (Table 28). However, after T_3 irrigation the mean value of P (M = 3810 mg*kg^{-1}) and K (M = 3190 mg*kg^{-1}) was statistically ($p \leq 0.05$) different than T_1 (Table 28).

Similarly, the percentage change in mineral content of both varieties seeds for each experimental year is also included in the *Appendix 6*.

Table 28. Average (n = 4) MC (mg*kg^{-1}) in seeds of Janka rice variety developed with different quality of irrigation, 2019

Treatments		***2019***				
		Ca	***Mg***	***P***	***K***	***Na***
T_1	***M***	399a	1390a	3365a	2743a	201a
	95% CI	[295; 504]	[1300; 1479]	[3109; 3620]	[2609; 2875]	[135; 266]
T_2	***M***	409a	1400a	3585ab	3065ab	229a
	95% CI	[339; 478]	[1282; 1517]	[3153; 4016]	[2674; 3455]	[137; 321]
T_3	***M***	435a	1470a	3810b	3190b	260a
	95% CI	[309; 561]	[1389; 1550]	[3457; 4162]	[2873; 3506]	[163; 355]
T_C	***M***	437a	1475a	3700ab	3025ab	237a
	95% CI	[389; 484]	[1429; 1520]	[3596; 3803]	[2829; 3220]	[206; 268]

M - mean. CI - confidence interval (lower and upper bound). The letters represent a significant difference between treatments, values followed by the same letter do not differ significantly from each other at the 0.05 level

The analysis of combined data of 2018 (Table 29) showed statistically changes in K and Na content, other minerals remained statistically unchanged. After T_1 (M = 3250 mg*kg^{-1}) and T_3 (M = 3218 mg*kg^{-1}) irrigation K uptake decreased significantly ($p \leq 0.05$). But Na content increased significantly under the T_1 (M = 154 mg*kg^{-1}, $p \leq 0.001$), T_2 (M = 130 mg*kg^{-1}, $p \leq 0.001$) and T_3 (M = 126 mg*kg^{-1}, $p \leq 0.001$) irrigation.

On the contrary, the 2019 combined data (Table 30) analysis did not show any statistical changes ($p \geq 0.05$).

Table 29. The MC (mg*kg^{-1}) in seeds of rice (combined) developed with different quality of irrigation, 2018

Treatments	***Ca***	***Mg***	***P***	***K***	***Na***
T_1	512a	1622a	4085a	3250a*	154c***
T_2	561a	1642a	4085a	3335ab	130b***
T_3	509a	1611a	4103a	3218a*	126b***
T_C	558a	1660a	4245a	3458b	89a

The letters represent a significant difference between treatments, values followed by the same letter do not differ significantly from each other at the 0.05 level. *, *** *- the mean difference is significant from* T_C *at the 0.05 and 0.001 levels, respectively*

Table 30. The MC (mg*kg^{-1}) in seeds of rice (combined) developed with different quality of irrigation, 2019

Treatments	***Ca***	***Mg***	***P***	***K***	***Na***
T_1	398a	1521a	3802a	3171a	200a
T_2	410a	1558a	4037a	3436a	220a
T_3	428a	1437a	3625a	3097a	229a
T_C	432a	1562a	3998a	3345a	219a

The letters represent a significant difference between treatments, values followed by the same letter do not differ significantly from each other at the 0.05 level

Table 31. The correlation coefficients between minerals in rice seeds

MC	***Ca***	***Mg***	***P***	***K***	***Na***
Ca	1.000				
Mg	0.453**	1.000			
P	0.289*	0.855**	1.000		
K	0.178	0.760**	0.801**	1.000	
Na	-0.594**	-0.456**	-0.420**	-0.327**	1.000

*, ** *- significant at the 0.05 and 0.01 levels, respectively*

The correlation analysis of minerals in seed (Table 31) showed Na had a moderate negative correlation at 1% level of significance between all minerals. Between Ca and Mg (0.453^{**}) correlation was moderate positive, between P weak positive (0.289^{*}), but between K (0.178) no correlation was found. Mg had a strong positive correlation both with P (0.855^{**}) and K (0.760^{**}) at 1% level of significance. Similar trend was observed between K and P (0.801^{**}).

In general, from a statistical point of view, treatments had remarkable impact on the seed mineral composition of both varieties only in 2018 experiment. The concentration of P, K, Mg minerals in our rice seeds was similar to the results obtained by Orasen (2018) in an experiment with 281 international rice varieties. Although, as Mir et al. (2017) pointed out, the distribution of indicators can vary significantly depending on the rice variety. Greatest changes was observed in 2018 experimental year. Although due to technical problems, only a small amount of irrigation was carried out in 2018, the reaction was visible from both rice plants. Nevertheless, it is necessary to note the role of properties that can change in the soil as a result of the experience of the previous year. In seeds of both genotypes composition of Na increased considerably. In 2018, direct application of effluent water had a significant impact on M 488 seeds. Under T_1 irrigation, while Na content increased markedly, the average amount of Ca, Mg, P and K decreased sharply compared to the control irrigation (T_C).

In the last experimental year, while after T_1, T_2 irrigation, the MC of M 488 rice seeds did not statistically change, but only after T_3 irrigation, the average content of P and K decreased. This is most likely due to the concentration of T_3 irrigation or due to the lack of access of plants to the mineral in the field. Meanwhile, non-significant changes in the MC of Janka seeds indicate a similar response of plants to treatments. Also, this stable result can be the reason for the successful protection of plant from stress factors, avoiding the transport of Na to the reproductive organs.

These results again show that the MC of plants is closely related to water quality, and excessive salt in water can reduce the absorption of minerals from the soil (El-Sharkawi et al., 2004). Na^+ has a profound effect on the absorption of a number of ions (Akter and Oue, 2018). A decrease in the absorption of certain minerals by rice is characteristic of both salt sensitive and salt tolerant rice varieties. As Saleethong et al. (2013) have already mentioned, a salt tolerant rice such as Pokkali and a salt sensitive rice such as KDML105 may experience a decrease in mineral accumulation under saline conditions.

5. NEW SCIENTIFIC RESULTS

1. In general, the thousand kernel weight (TKW) of the M 488 variety has remained constant throughout study years after these treatments used here. But in case of Janka variety, regardless of treatment type (T_1, T_2 and T_3), the TKW remarkably decreased.

2. The direct application of effluent water from intensive catfish farm (T_1) significantly reduced the percentage of whole polished grains of M 488 variety.

3. Regardless of the type of irrigation treatment, namely after the direct application of effluent water from intensive catfish farm (T_1), the use of effluent water with the addition of gypsum (T_2) and the use of effluent water diluted with river water and supplemented with gypsum (T_3), significantly reduced the seed size of both rice varieties.

4. None of the treatments had a significant impact on gelatinization temperature (GT). After the direct application of effluent water from intensive catfish farm (T_1), the use of effluent water with the addition of gypsum (T_2) and the use of effluent water diluted with river water and supplemented with gypsum (T_3), the GT did not change, and the result was similar to the control irrigation (T_C) result.

5. The study found that under the direct application of effluent water from intensive catfish farm (T_1) Ca, Mg, P and K content of M 488 rice seeds significantly decreased, and Na significantly increased.

6. During the experimental years, the mineral content of both rice varieties in the aboveground biomass was also influenced by treatments (T_1, T_2 and T_3). Both M 488 and Janka are particularly good at storing large amounts of Na in the aboveground biomass. Planting these varieties for bioremediation purposes to reduce soil salinization can give positive results.

7. The conducted experiments proved that under the stress of Na, accumulation of other minerals are reduced.

6. CONCLUSIONS

One of our main goals was the evaluation of different water types as irrigation water. Since different agricultural effluents have different quality parameters (e.g. salinity, nutrients, microbiological properties, etc.) that can significantly affect their suitability for irrigation, I have implemented a three-year lysimeter research with aerobic rice to determine the applicability of our specific fish farm effluent. Based on the primary water quality parameters (see Table 1), I have calculated the total amount of applied macronutrients and sodium per seasons (Table 32).

Table 32. Average amount of macronutrients and sodium in the irrigation water treatments applied in three consecutive growing seasons (2017-2019)

Treatments	*Year*	*Amount of irrigation (mm aka. L)*	*Total N/m^2 (g)*	*Total P/m^2 (g)*	*Total K/m^2 (g)*	*Na/m^2 (g)*	*Total N/ha (kg)*	*Total P/ha (kg)*	*Total K/ha (kg)*	*Na/ha (kg)*
T_1	2017	360	9.47	0.78	2.19	89.6	94.7	7.8	21.9	896.4
T_2		360	10.28	0.96	2.38	96.0	102.8	9.6	23.8	960.3
T_3		360	4.72	0.55	1.95	47.3	47.2	5.5	19.5	472.5
T_C		360	0.43	0.05	1.34	10.4	4.3	0.5	13.4	104.0
T_1	2018	60	1.58	0.13	0.36	14.9	15.8	1.3	3.6	149.4
T_2		60	1.71	0.16	0.40	16.0	17.1	1.6	4.0	160.1
T_3		60	0.79	0.09	0.33	7.9	7.9	0.9	3.3	78.8
T_C		60	0.07	0.01	0.22	1.7	0.7	0.1	2.2	17.3
T_1	2019	160	4.21	0.35	0.97	39.8	42.1	3.5	9.7	398.4
T_2		160	4.57	0.43	1.06	42.7	45.7	4.3	10.6	426.8
T_3		160	2.10	0.24	0.87	21.0	21.0	2.4	8.7	210.0
T_C		160	0.19	0.02	0.59	4.6	1.9	0.2	5.9	46.2

The most characteristic property of the fish farm effluent is the high sodium content what was detected in T_1 and T_2 treatments. Even under low-doses of irrigation, more than 14.9 g*m^{-2} and 16.0 g*m^{-2} of sodium was applied in 2018. This parameter made the chosen effluent water potentially harmful for the rice plants. Positive effect of macronutrients was predicted based on the higher Nitrogen and Potassium content of the effluent water. With higher irrigation regimes in 2017, Nitrogen application in the T_1, T_2 and T_3 were significant as 9.47 g*m^{-2}, 10.28 g*m^{-2} and 4.72 g*m^{-2}, respectively.

Overall, the effect of the treatments varied between genotypes. The current study has shown that direct use of effluent water from intensive catfish farm in aerobic rice production has a high impact in terms of Na accumulation (*Appendix 4*). Long-term irrigation with this effluent increased Na accumulation in the soil. The accumulation of Na, especially in the root zone, presents a potential risk to crops that can cause stress and ultimately affect plant health. Although Na uptake and accumulation was also observed with all irrigation treatments, but it was the lowest under T_3 irrigation (effluent water diluted with river water and supplemented with gypsum). It can be assumed that further development of this treatment (T_3) can give the desired effective result.

I have followed the effects of different irrigation treatments on the aerobic rice plants in three consecutive years. Different milling quality parameters and the nutrient uptake of rice plants were measured and statistically analysed. Based on the previous detailed analyses, the complex comparison of agricultural usability of the different irrigation treatments was done and it is shown in Table 33.

Table 33. The comparison of three irrigation (T_1, T_2 and T_3) water on the examined parameters in case of two rice varieties

Treatments	***Variety***	***TKW***	***GT***	***MQP***	***Minerals***
T_1	M 488	ns. (3 years)	ns. (3 years)	-cargo and polished are ns. (3 years); -whole grain is sig. **decline** (2 years)	High Na (3 years)
	Janka	sig. **decline** (2 years)	ns. (2 years)	-cargo and polished are sig. **decline** (1 year) -whole grain is ns. (2 years)	High Na (2 years)
T_2	M 488	ns. (3 years)	ns. (3 years)	-cargo and polished are ns. (3 years); -whole grain is sig. **decline** (1 year)	-Lower Na (2 years) -Highest Ca (1 year)
	Janka	sig. **decline** (1 year)	ns. (2 years)	-cargo, polished and whole are sig. **decline** (1 year)	-Lower Na content (3 years) -Ca increase (2 years)
T_3	M 488	ns. (3 years)	ns. (3 years)	-cargo and polished are ns. (3years); -whole grain is sig. **decline** (1 year)	Lowest Na content (2 years)
	Janka	sig. **decline** (1 year)	ns. (2 years)	-cargo and whole grain are sig. **decline** (1 year)	Lowest Na content (1 year)

ns. - non significant effect; sig. - significant effect. Its reliability is indicated in brackets.

We have found that the two Hungarian rice varieties showed different tolerance levels to the salinity in the irrigation water under aerobic conditions. Long-term experience has shown that during irrigation with treatments, the TKW of rice tends to stable in M 488 and reduction in case of Janka, both in paddy and cargo seeds. Similar situation was also noticed in MQP of both varieties. M488 was more resistant to irrigation water quality than Janka. In general, over the years of the experiment, different results of the ratio were obtained depending on the changes of grain length and width. Our results show that significant changes in size parameters also affected seed ratio in both varieties. Especially, a significant decrease in width led to a change in L/W ratio. Gelatinization temperature of the rice varieties was found stable and after the irrigation with the treatments, the GT did not change significantly compared to the control irrigation. The treatments did not change the composition of starch properties of seeds.

The highest detected impact on both rice varieties was the higher level of Na uptake in the aboveground biomass and seed too (based on T_1 and T_2 treatment). However, the negative effect of Na and the higher accumulation by the plants were effectively reduced by the application of the diluted effluent (T_3). This was found one of the most important factors affecting the accumulation of other minerals and led to nutrient imbalance, especially Ca content. The added gypsum (T_2 and T_3) improved the nutrient balance, but there were no noticeable effects on the concentration of the other elements in the aboveground biomass. Therefore, the gypsum supplementation of the wastewater was found a good practise to change Ca content of biomass.

The irrigation water quality does not affect significantly the magnesium content of biomass and seed. The future studies will be focused on to proof this kind of usability.

The correlation among the minerals shows that the amount of different elements has different correlations. The most remarkable interaction was visible between the sodium and the other measured minerals. The correlation between them was significantly negative. On the other hand we found significant strong correlation between Mg-P relations.

7. SUMMARY

Agricultural wastewater (AWW) is considered as a potential solution for irrigated agriculture under water-scarce conditions. AWW has a high potential, because beside water supply it is usually contains different proportion of nutrients. Thus, the application of AWW can markedly reduce the cost of minerals and fertilisers. On the other hand, in terms of environmental protection, the reuse of AWW can avoid harmful effects on nature.

It is well known that rice requires a large amount of water for stable growth compared to other crops. Growing rice under aerobic conditions is a promising opportunity for saving water. Because it has been proven that cultivating rice under aerobic conditions saves more precious water than the conventional cultivation method. The presence of various nutrients in AWW can greatly simplify this practice.

Understanding the current situation, it is necessary to study the irrigation of rice plants grown under aerobic conditions with such AWW. In our experiment, the reaction of two selected Hungarian rice varieties (M 488, Janka) irrigated with the effluent water from an intensive fish farm was studied. These varieties were planted in 32 lysimeters with an area of 1 m^2 in three consecutive years. Irrigation was carried out in accordance with the following settings: effluent water (T_1), effluent water supplemented with gypsum (T_2), effluent water diluted with river water and supplemented with gypsum (T_3) and natural river water (T_C) as control irrigation. It should be noted that along with the essential minerals (P, K, and N) that plants need, high concentration of Na was also found. For the reduction of the potential harmful effect of the effluent water on the soil and on the plant development, supplementations were applied in T_2 and T_3.

The implementation of the experiment in an open field allowed us to analyse the complex effect of irrigation factor in the aerobic cultivation of rice plants. The overall result of three years of experience shows that during irrigation with the effluent treatments, the yield and quality parameters of the rice (TKW, MQP) either remain partially stable or decrease. Gelatinization Temperature (GT) was statistically similar after these treatments. The most noticeable change was recorded in case of seed size. Since, the size of both M 488 and Janka seeds has declined significantly.

Significant accumulation of large amounts of Na in the aboveground biomass of both rice varieties was found. Most likely, this was directly related to the composition of the effluent water. Although the mineral content (MC) of the seeds varied from year to year, irrigation with treatments tended to have a more negative effect on M 488 rice grains than on Janka rice in 2018. Mostly, after direct use of effluent water (T_1), the average values of Ca, Mg, P and K in grains of M 488 decreased sharply. This negative effect can be modified by gypsum supplementation.

We have found that the two Hungarian rice varieties showed different tolerance levels to the salinity in the irrigation water under aerobic conditions. Our results showed that both types of rice are exposed to irrigation treatments, and this effect manifests itself in the form of stress in plants. Although vital minerals were present in effluent water from intensive fish farm, Na, acting as a limiting factor, played an important role in increasing plant stress levels. In general, the treatments had the same effect on M 488 and Janka in terms of the mineral content of aboveground biomass or seeds. The correlation analysis among the minerals shows that the amount of different elements has different correlations. The most remarkable interaction was visible between the sodium and the other measured minerals. The correlation between them was significantly negative. On the other hand we found significant strong correlation between Mg-P relations. However, irrigation of rice plants with the unconventional water sources did not automatically hinder the development, decreasing quality of salinity sensitive varieties and potential negative environmental effects must be considered before application.

8. SCOPE FOR FUTURE RESEARCH

The recommendations below are the scope for future research:

1. Examine other important rice grain quality parameters, such as protein or amylose content.
2. Study the involvement of heavy metals in the vegetative and reproductive organs of rice.
3. Study in detail the mineral transport system of plants under sodium intervention.
4. Estimate the full economic cost of applying fish farm effluent water for irrigation.
5. In order to develop treatments, along with new additives, it is also necessary to take into account the different ratio of gypsum in effluent water.

9. ÖSSZEFOGLALÁS

A vízhiányos területeken az öntözéses gazdálkodás egyik fontos alapja lehet a jövőben a mezőgazdasági eredetű szennyvizek (AWW) felhasználása. Az AWW alkalmazásában nagy lehetőségek rejlenek, hiszen nem csak öntözővizet, de gyakran tápanyagokat is biztosítanak a termeléshez. Így az AWW felhasználásával jelentősen csökkenthető a mesterségesen pótolt tápanyagok mennyisége és költsége is. Emellett a környezetvédelmi szempontoknak is jobban megfelelhetünk, hiszen bizonyos esetekben csökkenthetőek a természeti környezetre gyakorolt negatív hatások is (pl. eutrofizáció csökkentése).

A rizs köztudottan nagy mennyiségű vizet igényel a zavartalan fejlődéséhez. Azonban az árasztás nélküli (aerob) rizstermesztés jelentős potenciált jelent a víztakarékos termelési rendszerek között. Az AWW aerob rizstermesztésben való alkalmazása pedig a vízpótlás mellett számos tápelem kijuttatásában is segíthet attól függően, hogy milyen minőségű és mekkora mennyiségű szennyvizet használunk.

Az AWW aerob rizstermesztésben való biztonságos alkalmazásához alapvetően fontos, hogy megfelelő előtanulmányok álljanak rendelkezésünkre. Ezért a kísérletsorozatom három vizsgálati éve során egy intenzív halnevelő gazdaságból származó elfolyóvíz hatását elemeztem gravitációs liziméterekben. A kísérletekhez két magyar nemesítésű rizsfajtát, az M 488-at és a Jankát használtam fel. A vizsgálatokhoz azért választottuk a 32 db 1 m^3-es lizimétert, hogy az öntözővizek hatását a környező talajszelvénytől elzártan, a horizontális és a vertikális hatások kizárásával végezhessem el és lehetőségem legyen az esetlegesen kialakuló átfolyóvíz mérésére és elemzésére is.

Az öntözéses kezelések a következők voltak: kezelés nélküli elfolyóvíz (T_1), elfolyóvíz gipsz hozzáadásával (T_2), folyóvízzel hígított elfolyóvíz gipsz hozzáadásával (T_3) és kontrollként a közelben lévő folyó vize (T_C). Az elfolyóvízben a növények számára fontos makroelemek (P, N, K) mellett magas nátrium koncentrációt is mértünk, ezért volt fontos, hogy a T_2 és T_3 kezelések esetében a gipsz és a természetes víz hozzáadásával csökkentsük a talajra és a növényekre gyakorolt esetleges negatív hatásokat.

A liziméterek alkalmazása lehetővé tette, hogy a szántóföldi környezethez hasonló komplex körülmények között vizsgálhassuk az öntözés hatását. A hároméves kísérlet alatt az öntözéses kezelések hatására a termést jellemző mennyiségi (pl. EMT) és minőségi paraméterek (pl. zselatinizációs hőmérséklet) alapvetően nem változtak, néhány esetben pedig csökkentek (pl. szem hosszúsága és szélessége). A legjelentősebb változásokat a magméretek esetében mértem, mind az M 488, mind a Janka fajták esetében jelentős csökkenést figyeltem meg. Az elemvizsgálatok rámutattak, hogy mindkét rizsfajta esetében jelentős Na felhalmozódás történt a hajtásrészekben. Az akkumuláció mértéke szoros összefüggésben volt az alkalmazott öntözővíz minőségi jellemzőivel. Habár a termés elemtartalma évről évre változott, az elfolyóvíz káros hatását 2018-ban mutattuk ki leginkább. Az elfolyóvíz közvetlen alkalmazása esetében a K, P, Ca és Mg tartalom átlagos értékei az M 488 szemtermésében jelentősen csökkentek. Szoros összefüggést a P és a Mg akkumulációs között mutattam ki.

Az eredményeim alapján elmondható, hogy bár az elfolyóvíz tartalmazott lényeges tápelemeket, a jelen lévő nátrium negatív hatása lényegesen jelentősebb volt és korlátozó tényezőként szerepelt a kísérletben. A magasabb nátrium tartalom növelte a növények stressz-szintjét, ezért és a dolgozatomban nem vizsgált talajra gyakorolt negatív hatások miatt a vizsgált elfolyóvíz csak fenntartásokkal és kezelt formában használható öntözésre.

10. LIST OF PUBLICATIONS

Peer-reviewed articles with impact factor

- Ibadzade, M., Kun, Á., Székely, Á., Szalóki, T., Penksza, K., Jancsó, M. (2020). The influence of irrigation with intensive fish farm water on the quality indicators of aerobic rice (*Oryza sativa* L.). Applied Ecology and Environmental Research, 18(5): 7077-7088. http://dx.doi.org/10.15666/aeer/1805_70777088

- Ibadzade, M., Kun, Á., Székely, Á., Szalóki, T., Penksza, K., Jancsó, M. (2020). The role of effluent water irrigation in the mineral absorption of aerobic rice varieties (*Oryza sativa* L.). Cereal Research Communications, 1-9. https://doi.org/10.1007/s42976-020-00117-x

- Székely, Á., Szalóki, T., Ibadzade, M., Pauk, J., Lantos, Cs., Jancsó, M. (2021). Germination dynamics of European rice varieties under salinity stress. Pakistan Journal of Agricultural Sciences, Vol. 58(1), 1-5. DOI: 10.21162/PAKJAS/21.464.

Peer-reviewed articles (in English)

- Ibadzade, M., Székely, Á., Penksza, K., Jancsó, M. (2018). Effects of water quality on the milling characteristics of aerobic rice. Alkalmazkodó vízgazdálkodás: lehetőségek és kockázatok, 267-272.

- Ibadzade, M., Székely, Á., Szalóki, T., Penksza, K., Jancsó, M. (under review) Reuse of wastewater from fish farm for irrigation in aerobic rice (Oryza sativa L.) cultivation.

Conference abstracts (in English)

- Ibadzade, M., Székely, Á., Szalóki, T., Penksza, K., Jancsó, M. (2019). Quality changes of rice under different irrigations in lysimeters. 18th Alps-Adria Scientific Workshop, april 1-6. Cattolica, Italy.

- Jancsó, M., Kun, Á., Székely, Á., Szalóki, T., Ibadzade, M., Bozán, Cs. (2019). New developments at the Lysimeter Station in Szarvas. Lysimeter - a perfect tool for quantifying fluxes of water, nutrients and pollutants, 18. Gumpensteiner Lysimetertagung, 155-156. ISBN: 978-3-902849-64-9

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13. APPENDICES:

Appendix 1. Location of Lysimeter Station

Appendix 2. Diagram of gravitation lysimeters and measuring cellars (Source: Jancsó M., NAIK ÖVKI)

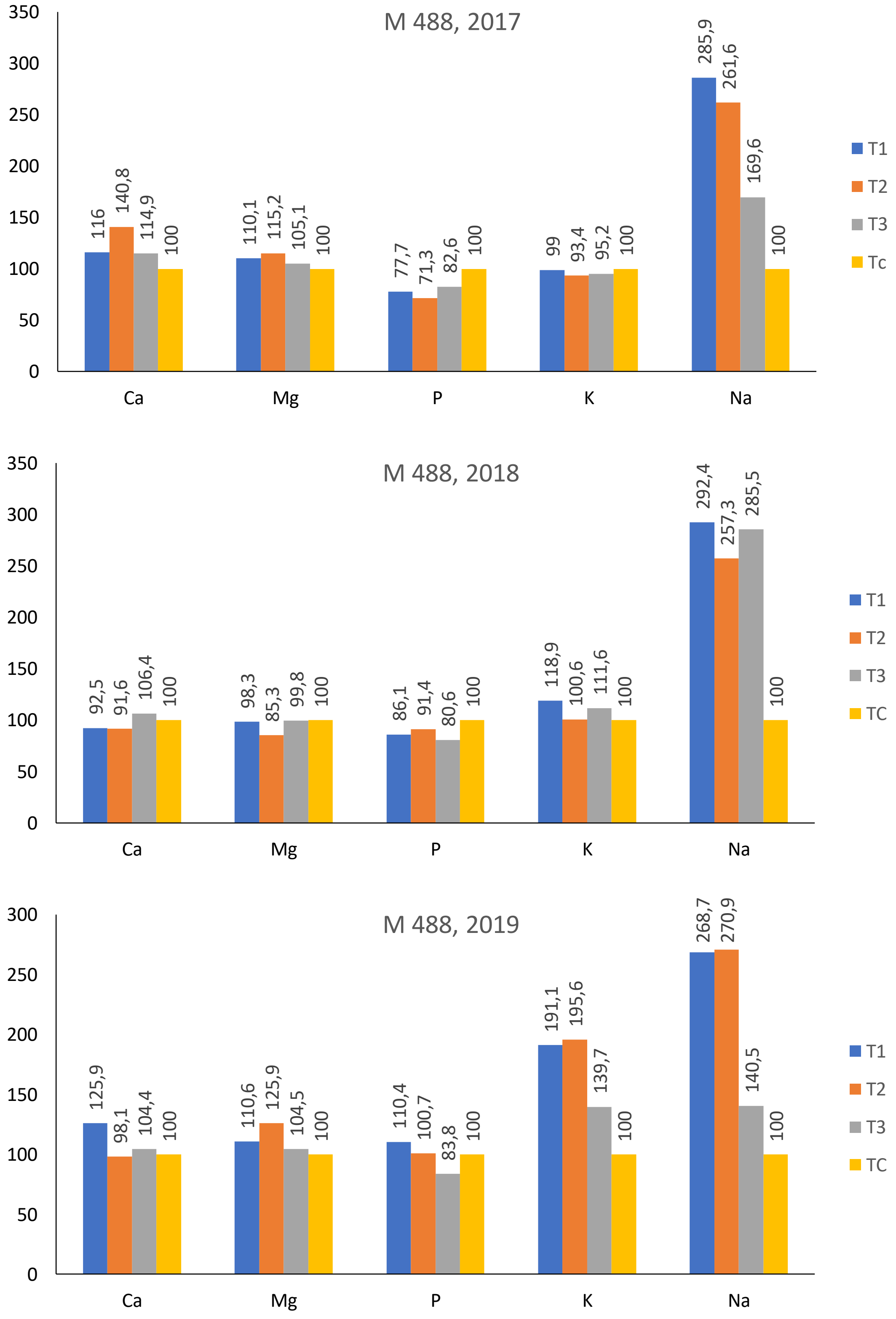
Appendix 3. Lysimeter experiment of rice developed with different quality of irrigation water (Photo by Jancsó and Ibadzade, 2018)

Appendix 4. Average (n = 4) chemical properties of the soil in individual block lysimeters after a three-year experiment (2019)

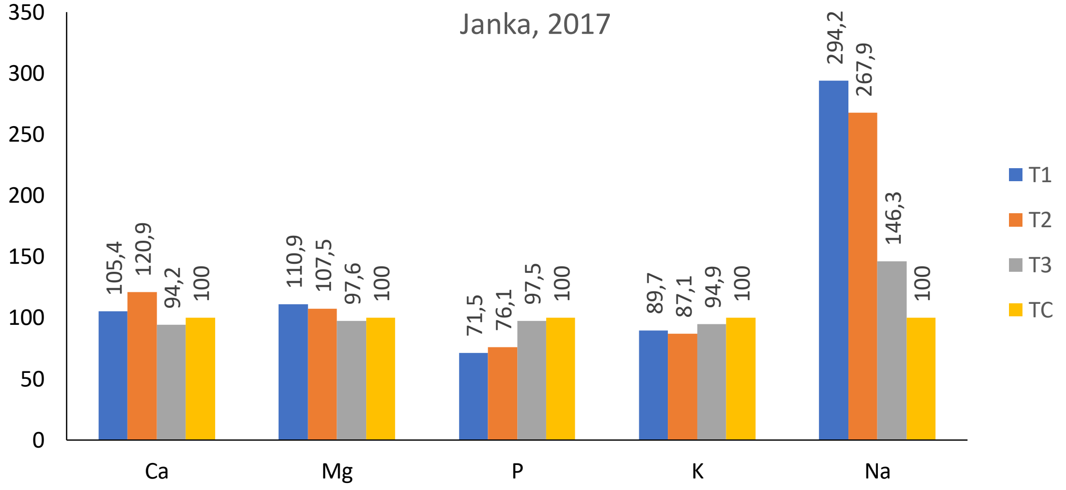
Lysimeters		***T_1***		***T_2***		***T_3***		***T_C***	
Depth of the sample (cm)		***0-45***	***45-90***	***0-45***	***45-90***	***0-45***	***45-90***	***0-45***	***45-90***
pH (KCl)		6.7	6.4	6.7	6.4	6.8	6.7	6.8	6.7
Phosphorus-pentoxide (AL-P_2O_5) m/m%		587	410.5	643	554.5	632.7	620	713.7	933
Potassium-oxide (AL-K_2O) m/m%		458.8	401.7	449	426.5	437	423.3	433.3	405
Exchangeable cations	***Na ($BaCl_2$) meq/100g***	1.6	1.5	1.4	1.3	1.2	1.1	0.9	0.9
	K ($BaCl_2$) meq/100g	0.9	0.8	0.8	0.8	0.8	0.8	0.8	0.9
	Ca ($BaCl_2$) meq/100g	25.2	37.8	21.7	26.1	30.6	18.3	25.8	15.1
	Mg ($BaCl_2$) meq/100g	8.2	8.9	8.2	8.9	8.3	8.6	8.1	7.9

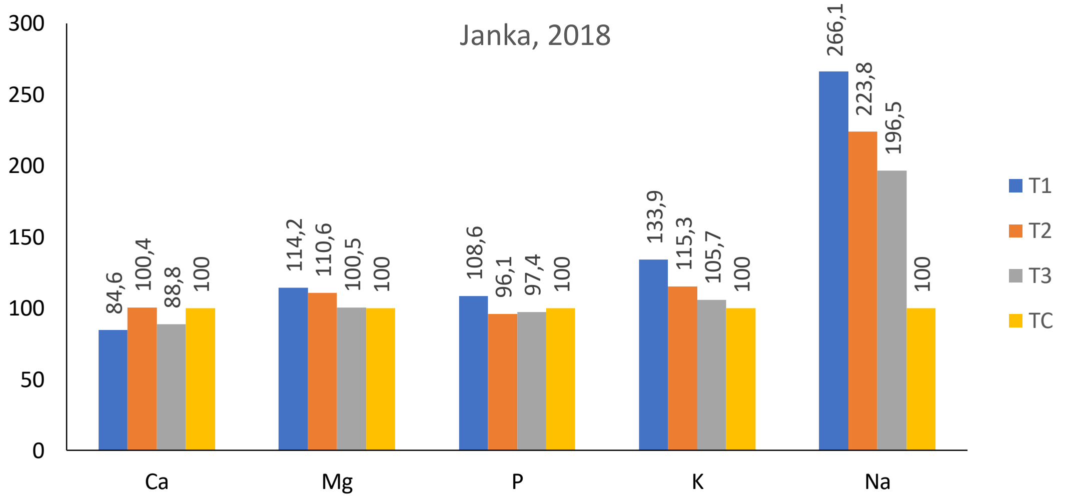
T_1 - effluent water, T_2 - effluent water supplemented with gypsum, T_3 - effluent water diluted with river water and supplemented with gypsum, T_C - river water (control)

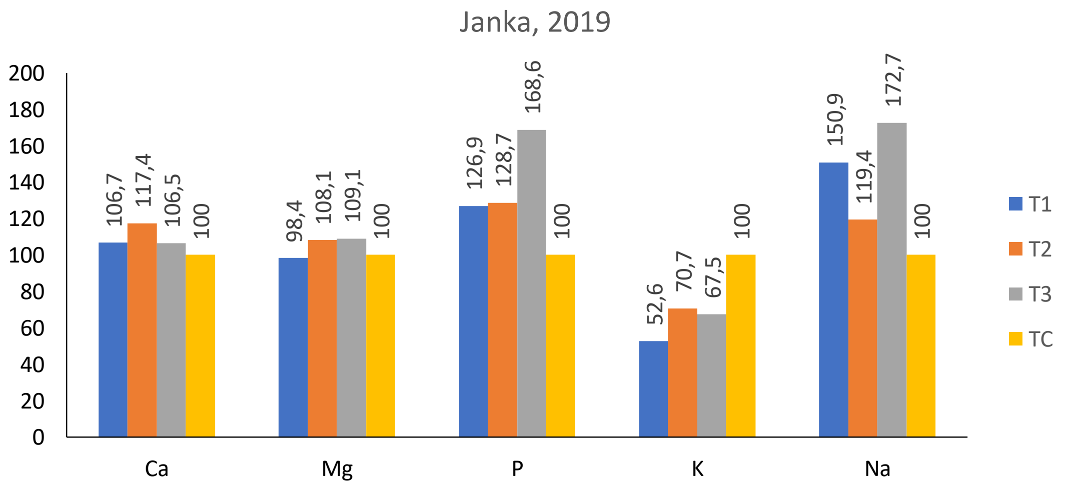
Appendix 5. The percentage difference* between treatments and control irrigation in aboveground biomass of M 488 and Janka



…continuation







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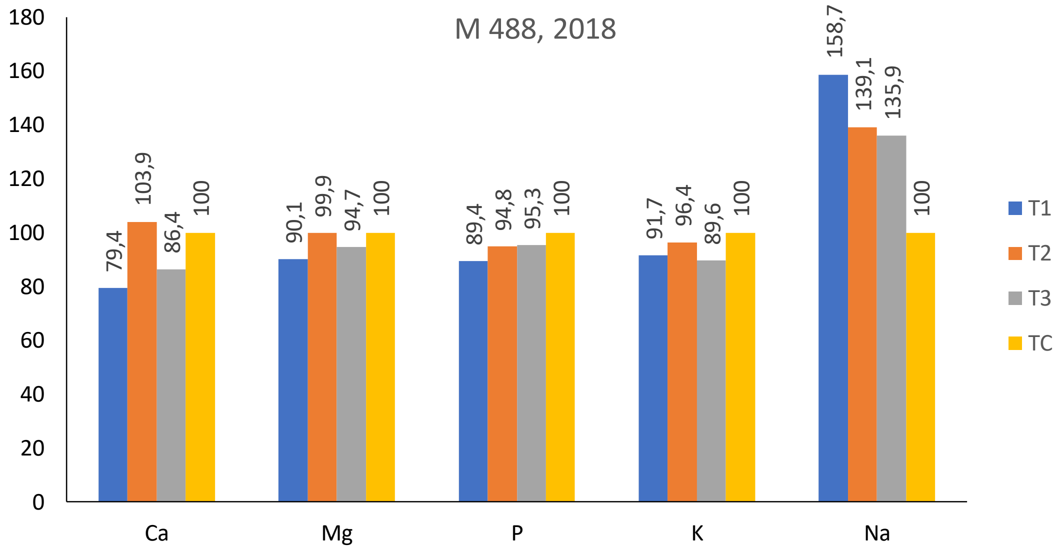
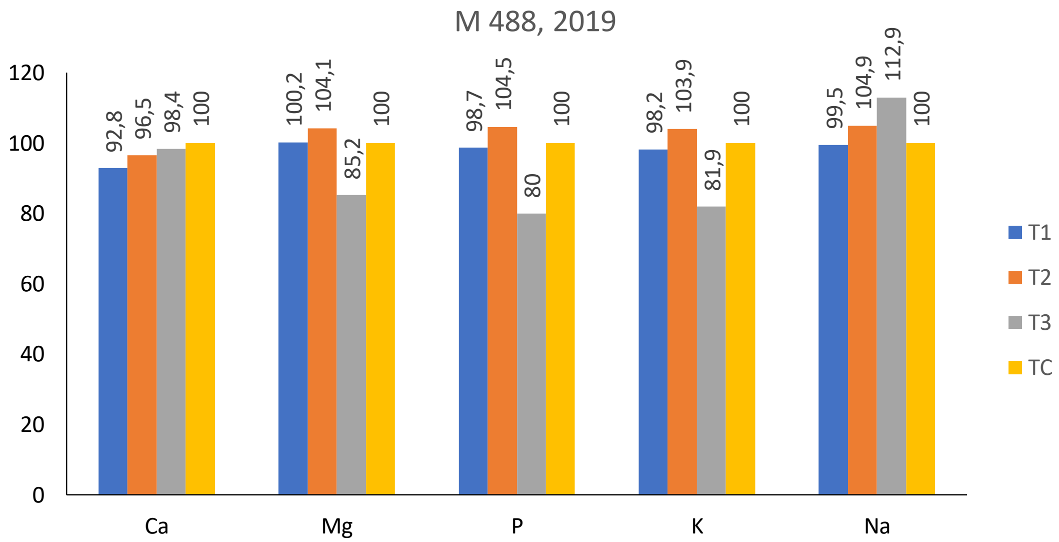
[*] *- for instance, 116% means that the difference between T_1 and T_C was 16%, and under T_1 Ca content of M 488 increased by 16%*

Appendix 6. The percentage difference between treatments and control irrigation in seeds of M 488 and Janka





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