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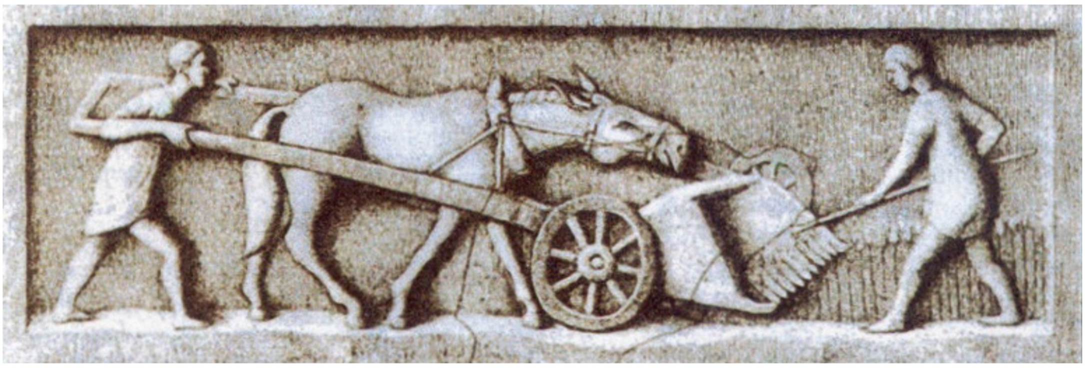

Includes works presented at the
5th International Scientific Conference on Water
22nd–24th March 2022, Szarvas, Hungary

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Editorial correspondence:
Szent István Campus of the Hungarian University of Agriculture and Life Sciences
Páter Károly utca 1.
H2100 Gödöllő, Hungary
Phone: (+36 28) 522067
Fax: (+3628) 410-804
web: https://journal.uni-mate.hu/index.php/columella/index
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Evapotranspiration of a Hungarian rice variety, 'SZV Tünde' in large weighing lysimeter

Mihály JANCSÓ[1] – Árpád SZÉKELY[1] – Tímea SZALÓKI[1] – Csaba LANTOS[2] – Noémi Júlia VALKOVSZKI[1] – Csaba BOZÁN[1] – János PAUK[2]

1: Hungarian University of Agriculture and Life Sciences, Institute of Environmental Sciences, Research Center for Irrigation and Water Management, Szarvas, Hungary, e-mail: Jancso.Mihaly@uni-mate.hu, 0000-0003-1934-9686

2: Cereal Research Non-Profit Ltd., Szeged, Hungary

Abstract: Aerobic rice production is an alternative growing method to reduce water consumption of rice and thus increase the water productivity of the system without a significant reduction of yield and quality. Evapotranspiration (ETc) of a Hungarian rice variety, 'SZV Tünde' under aerobic conditions was measured in large weighing lysimeter during the growing season in 2020. In our experiment, 506.7 g/m^2 grain yield and a total above-ground biomass of 1140.4 g/m^2 were produced with the application of 315.6 mm of irrigation. Water use-efficiency (WUE) based on the water input and the grain yield was 0.65 g/L. Total ETc for the whole season was measured as 648.3 mm. However, ETc values were ranged 2.04-3.86 mm/day, 3.57-7.90 mm/day and 0.90-4.26 mm/day at the initial, mid and end stages, respectively. Crop coefficients for the different periods of the season were calculated as Kc_{ini}=0.82, Kc_{mid}=1.40 and Kc_{end}=0.77. Negative effects of drought can seriously damage rice crop; therefore irrigation scheduling has significant role in successful aerobic rice cultivation. Reliable estimation of evapotranspiration rate in different crop developmental stages can promote this goal.

Keywords: evapotranspiration, crop coefficient, aerobic rice, water-use efficiency

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Introduction

Traditional rice production needs high amount of irrigation water (Tabbal et al., 2002). Water requirement is ranging from 5500 m^3/ha to 11000 m^3/ha during the growing season depending on soil and tillage method (de Avila et al., 2015; Pimentel et al., 2004). The efficiency of water use (WUE) is depending on the yield and the amount of irrigation water (Borrell et al., 1997). In case of alternative irrigation conditions, higher water productivity can be achieved (Ibadzade et al., 2020) but without the proper drought tolerant rice varieties, production can be also significantly reduced (Hassen et al., 2017; Bouman et al., 2002). Alternate wetting and drying (AWD) is a low-cost innovation that enables farmers to adapt to increasingly water scarcity conditions and increase overall farm production efficiency (Enriquez et al., 2021).

Aerobic rice system is a relative new production system in which rice is grown under non-puddled, non-flooded, and non-saturated soil conditions with an intensive production technology (Prasad, 2011). Aerobic rice varieties are developed in the last decades that have drought tolerance as well as high yielding ability (Bouman et al., 2006; Nie et al., 2011).

In Hungary, aerobic rice research and breeding was started in 1984 and a new water-saving rice growing method (Sanoryza) was patented in 1992 (Simonné Kiss, 2001). In the recent years, new released varieties were developed such as 'Janka' and 'Ábel' (Jancsó et al., 2017).

Selection for drought tolerance, especially under the temperate climate is very complex, because plants are usually exposed to multiple stressors (drought, salinity, low temperature, mechanical damage, etc.) (Courtois et al., 2012; Sulmon et al., 2015; Székely et al., 2021, 2022). Therefore, new biotechnology based methods i.e. *in vitro* androgenesis culture (Lantos et al., 2005), and traditional pedigree breeding are integrated to promote the effective selection of new high yielding and abiotic stress tolerant genotypes for temperate aerobic rice cultivation in Hungary (Jancsó et al., 2017; Pauk et al., 2009).

Besides varietal development, improvement of aerobic cultivation technology is also necessary for an economically feasible cultivation. One of the most important factors is the irrigation requirement of different varieties in different developmental stages (Luo, 2010). Evapotranspiration (ET) is the simultaneous occurrence of evaporation and transpiration which are significant forms of water losses on agricultural lands and due to the increasing water scarcity in many regions, correct evaluation of ET is very important (Rana & Katerji, 2000). Weather parameters, crop characteristics, management and environmental aspects are factors affecting ET (Allen et al., 1998).

The Penman-Monteith method is widely used for the estimation of the standard reference crop evapotranspiration rate, i.e., ETo. Different crops have different ET rates and the specific crop evapotranspiration (ETc) depends on genotype, growth stage, crop canopy, population density, climatic conditions, irrigation and other crop management practices (Irmak, Djaman, & Sharma, 2015). The difference in ET between the cropped and the reference grass surface can be combined into a single crop coefficient (Kc). Experimentally determined ratios of ETc/ETo, called crop coefficients (Kc) (Allen et al., 1998) what is necessary to calculate ETc and thus to determine water requirements for irrigation scheduling.

The goals of this study were to determine the actual crop evapotranspiration (ETc), the single crop coefficients (Kc) and the water-use efficiency (WUE) for different growth stages of a new high yielding Hungarian rice variety under aerobic growing conditions in a large weighing lysimeter.

Materials and Methods

Experimental area and the weighing lysimeters

The experiment was carried out at the Lysimeter Station (46°51′44.7″N 20°31′35.5″E, 81 m elevation above sea level) of the Hungarian University of Agriculture and Life Sciences, Institute of Environmental Sciences, Research Center for Irrigation and Water Management in Szarvas, Hungary in 2020 (Jancsó et al., 2019, 2021). For the measurement of crop evapotranspiration, one large precision weighing lysimeter was used for one growing season of rice from May to October. The weighing lysimeter (Type S 6048, Metrisystems Ltd., Hungary) has the surface area of 2.7 m^2 and a soil profile depth of 110 cm. The soil profile was constructed in 2018. The physical soil texture is clay loam. Basic soil parameters are presented in Table 1. The bottom layer of the lysimeter was filled with fine gravel (10 cm) to drain and measure percolation water. The automatic data logging (EMX100 connected to a MS Windows PC) was set to 1 hour to measure increasing (precipitation, irrigation) and decreasing (evapotranspiration, percolation water) changes of lysimeter weight during the experimental period. The

Table 1: Chemical characteristics of soil in the weighing lysimeter at the beginning of the experiment

pH (H_2O)	Liquid limit (cm^3)*	Total soluble salts (wt%)	Carbonate (wt%)	Organic matter (wt%)	NO_2-NO_3 (KCl) mg/kg	P_2O_5 (AL) mg/kg	K_2O (AL) mg/kg
7.34	42	0.045	2.57	2.16	14.9	362.2	365.2

* liquid limit according to Arany (Kassai & Sisák, 2018)

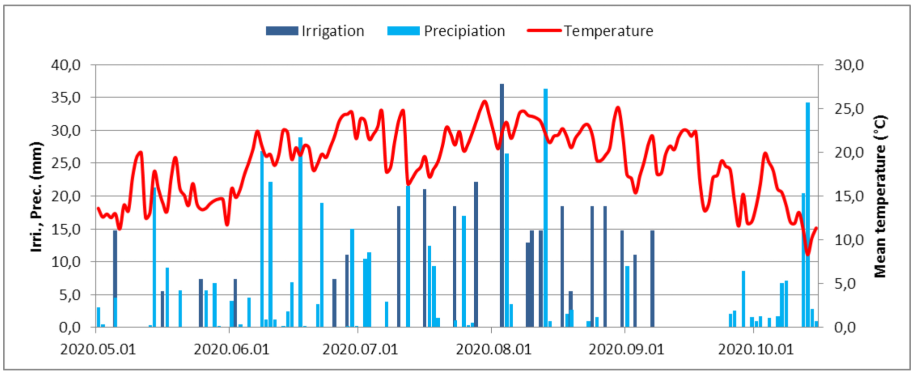

Figure 1: Data of daily mean temperature, precipitation and irrigation during the growing season of aerobic rice in 2020 (Szarvas, Hungary)

display resolution of the load cells is 100 grams, with an accuracy of 0.05%. ETc of the aerobic rice was calculated on the basis of hourly weight changes in MS Excel. Effects of management activities (e.g. manual weeding) were removed manually from the dataset.

Weather conditions and ETo calculation

Basic weather parameters are shown on Figure 1 and Table 2. Meteorological data were collected by an automatic weather station (Agromet Solar, Boreas Ltd., Hungary) next to the lysimeter. The natural precipitation was 460.9 mm during the growing season. For the calculation of daily ETo values, daily mean temperature (°C) at 2 m, daily average relative air humidity (RH%), daily average wind speed (m/s) at 2 m and daily solar radiation (MJ/m^2/day) were used. The frequency of measurements was set to 10 minutes. Site specific reference evapotranspiration (ETo) was calculated with ETo Calculator 64bit, version 3.2 based on Penman-Monteith equation (Raes, 2012). ETo and ETc data were calculated for 5-day averages to remove daily fluctuations and identify specific values for different plant development stages. Crop growth-stage-specific coefficients were determined for the initial (Kc_{ini}), mid-season (Kc_{mid}) and the end-season (Kc_{end}) stages as it was described by Allen et al. (1998).

Plant material and agronomic management

A new rice variety ('SZV Tünde') of the Hungarian University of Agriculture and Life Sciences, Research Center for Irrigation and Water Management was used for the experiment. The variety belongs to the group of temperate japonica genotypes. Basic characteristics of the variety are shown in Table 3. 'SZV Tünde' is a high yielding (>7 t/ha), medium height (80 cm), mid-

Table 2: Ten-day average of relative air humidity, wind speed and solar radiation during the growing season of aerobic rice in 2020 (Szarvas, Hungary)

Month	Decade	RH* %	Wind speed m/s	Solar radiation $MJ/m^2/day$
May	1	70.1	2.0	22.4
	2	70.8	1.9	19.3
	3	69.6	2.7	21.6
June	1	76.3	1.6	20.2
	2	86.5	1.6	18.6
	3	78.6	1.2	20.9
July	1	74.0	1.4	23.7
	2	76.9	1.8	21.8
	3	78.8	1.2	21.6
August	1	71.9	2.0	23.7
	2	76.9	1.4	21.2
	3	67.5	1.5	22.0
September	1	72.8	1.4	19.8
	2	66.2	1.9	18.8
	3	78.6	1.4	13.0
October	1	84.0	2.3	12.0

* relative humidity at 2 meters (Kassai & Sisák, 2018)

Table 3: Basic characteristics of the Hungarian rice variety 'SZV Tünde', which was used for the measurement of evapotranspiration

Name	Released year	Duration* days	Plant height cm	TKW** g	L/W ratio ***	Blast resistance	Amylose
SZV TÜNDE	2021	135-140	80	30-31	2.3	1	20-21

* based on the calculation after direct dry sowing
** thousand kernel weight of paddy seeds
*** ratio of grain length and width on cargo seeds

late duration and blast resistant genotype in Hungary. Blast resistance was evaluated on a 1–9 scoring system on leaves (Raboin et al., 2016).

Management of the plants in the lysimeter was set according to the standard aerobic rice production practice. Fertilizer (COMPLEX 15/15/15 +7SO_3+Zn, Borealis L.A.T. Ltd., Austria) was applied at a rate of 60 kg/ha of N, 60 kg/ha of P_2O_5 and 60 kg/ha of K_2O before sowing. The forecrop was sunflower. Date of sowing was 5th of May, 2020. The row spaces were 25 cm. Manual weed control was used upon necessity. Irrigation was performed as hand watering with sprinklers. During the growing season, 315.6 mm of irrigation water was applied in 21 times from the sowing to 7th of September. Harvest was done after fully ripening on the 9th of October, 2020. Total above-ground biomass and yield were measured with a Sartorius PMA7500 scale (Sartorius AG., Germany). Threshing was done by a Wintersteiger LD350 threshing machine (Wintersteiger AG., Austria). Moisture content of the straw and the seeds was measured by a Kern MLS 50-3 electronic moisture analyser (Kern&Sohn GmbH., Germany). Results of the biomass and the yield were calculated and presented by 14 m/m% moisture content.

Results and discussion

Evapotranspiration of aerobic rice

Evapotranspiration of a Hungarian rice variety, 'SZV Tünde' under aerobic conditions was measured in large weighing lysimeter during the growing season in 2020. The biomass production and grain yield were 1140.4 g/m^2 and 506.7 g/m^2, respectively. Water use-efficiency (WUE) based on the water input and the grain yield was 0.65 g/L, which is a low value according to (Tabbal et al., 2002). However, 315.6 mm of irrigation was also low compared to the average water need of rice cultivation described by de Avila et al. (2015) and Pimentel et al. (2004).

Figure 2 shows five-day average ETc values. Growing season was divided into three periods based on the development of rice. Initial stage was set until 25th of June (52 DAS). ETc values were ranged in that period between 2.04-3.86 mm/day. Mid-stage with the highest biomass development was set until 5th of September (124 DAS) with the 5-day average ETc of 3.57-7.90 mm/day. The highest ETc values were measured during the flowering period in mid-August. Relative high ETc values were achieved because of the non-limiting conditions and high frequency of irrigations. At the last period of the season, ETc was between 0.90-4.26 mm/day. Total ETc for the whole season was measured as 648.3 mm. This result agrees with the previously presented data of Tabbal, who described 600–700 mm ET modern short-duration variety of 100-day crop growth duration in the dry season (Tabbal et al., 2002).

Crop coefficients in different developmental stages

Calculation of crop coefficients (Kc) for different phenological stages is based on the method of (Allen et al., 1998). To calculate Kc, site specific reference evapotranspiration (ETo) was determined. Five-day average ETo values are shown in Figure 3.

Crop coefficient for the initial developmental stage of aerobic rice was calculated as Kc_{ini} between 0.57-1.19. The average Kc_{ini} value was 0.82. These results meets with the data of Allen et al. (1998). In the mid-season period, Kc values were higher than it was previously published. Our Kc_{mid} data were 1.11-1.80 with an average value of 1.40. At the end of the growing season, Kc_{end} data were 0.57-0.88. The average Kc_{end} was 0.77.

Conclusion

Aerobic rice growing technology is an efficient method to increase water use-efficiency of rice. However, appropriate rice varieties need to be developed. In case of the utilization of high yielding and drought tolerant rice genotypes, better water use-efficiency can be achieved. In our experiment, 5.07 t/ha grain yield was produced with the application of 315.6 mm of irrigation. Negative effects of drought can seriously damage rice crop; therefore irrigation scheduling is an important task for the successful aerobic rice cultivation. Water requirement can be estimated with the better understanding of evapotranspiration in different crop phenological stages and of its relationship with the site specific reference evapotranspiration.

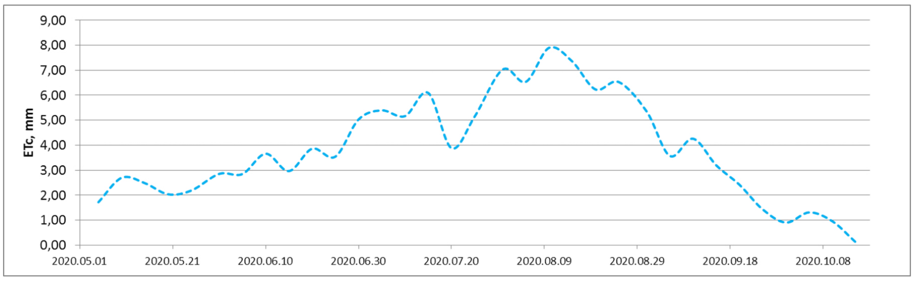

Figure 2: Five-day average crop evapotranspiration (ETc) of aerobic rice measured in large weighing lysimeter in 2020 (Szarvas, Hungary)

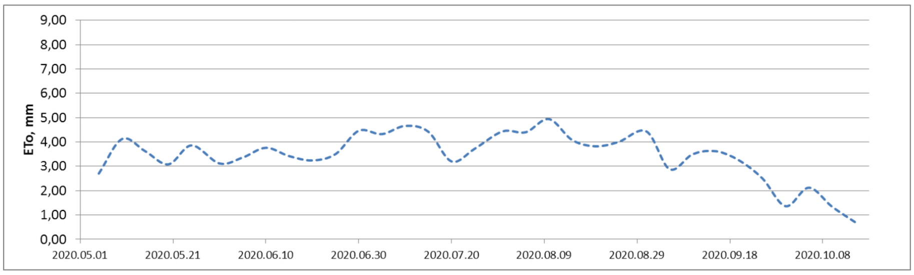

Figure 3: Five-day average site specific reference evapotranspiration (ETo) based on the meteorological data of the MATE ÖVKI Lysimeter Station (Szarvas, Hungary)

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Characteristics of Groundwater Level in the Szarvas-Békésszentandrás Oxbow Subbasin

Béla GOMBOS[1] – Ildikó SZALÓKINÉ ZIMA[1] – Erzsébet CSENGERI[1]

1: Hungarian University of Agriculture and Life Sciences, Institute of Environmental Sciences, Department of Irrigation and Land Improvement H-5540 Szarvas, Petőfi u. 9., Hungary, e-mail: Gombos.Bela@uni-mate.hu, 0000-0001-6072-5394

Abstract: The shallow groundwater has a direct and indirect effect on natural vegetation and agricultural production. The decline in groundwater level (GWL) can have negative impacts. In many areas in Hungary decreasing GWL trends in the last decades were found by earlier studies. In our research we studied the characteristics of groundwater level focusing on our study area, the subbasin of Szarvas-Békésszentandrás Oxbow. We analysed 20 years daily data of groundwater level of eight monitoring wells. Annual course and long term tendencies of groundwater level were examined. In average of 16 years the GWL reaches its maximum in April and its deepest level in autumn (September, October and November depending on the station). Four typical groups of groundwater level courses could be distinguished based on the average depth and seasonal variations of GWL. The year to year GWL variability is larger in January and April compared to July and especially to October. The trends of the middle months of the seasons are almost the same in significance and slope compared to the trends based on yearly mean time series. The differences in trends can be found between stations rather than between the months used for calculations. The larger part of the subbasin can be characterised by decreasing trend in groundwater levels (2002-2020). The change exceeds 1 m at station Szarvas 2832 (144 cm) and Szarvas 2778 (122 cm). However, there is a station with no significant trend, GWL at Csabacsűd 2779 station shows relative stability in yearly average, which is valid for some areas in the eastern part of the subbasin.

Keywords: groundwater level, trend, long-term, annual course

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Introduction

The shallow groundwater has a direct and indirect effect on natural vegetation and agricultural production. High levels of groundwater increases the risk of inland excess water. In case of optimal level the groundwater can significantly contribute to the water supply of plants. This optimal level depends on the crop species, soil type and meteorological conditions. The decline in the groundwater level can result in loss of this positive effects. Such a phenomenon can be observed in many regions caused by the climate change. In our study we focus on these questions related to our research area, Szarvas-Békésszentandrás Oxbow Subbasin.

In the lysimeter groundwater experiments, the optimum level was at 1 m depth for field crops (wheat, maize, sugar beet, alfalfa) and higher (0.5 m) for grasses, where the average yield reached values of irrigated treatments. In deeper-rooted plants, the effect of decreasing groundwater level occurs more slowly, as they are able to absorb water from deeper groundwater (Szalóki, 1994). From the groundwater, the water enters the upper layers of the soil mainly through capillary water lifting (Pálfai, 1996).

High groundwater levels can help or cause the formation of inland excess water (Rétháti, 1983). Rising groundwater levels can bring harmful salts to the soil surface, which can cause secondary salinization. If the upward water movement can be changed to a downward one by some technical solution (e.g. drainage), then the salinity in the given place can be kept at the leaching stage or in equilibrium even at a higher than critical groundwater level (Molnár & Winter, 1983).

The change of groundwater level is influenced by meteorological factors (precipitation, temperature, evaporation) and human activity (water extraction, irrigation, sewerage) ((Li et al., 2020; Yan et al., 2021)). Near watercourses, groundwater level follows the water level of the surface water (river) ((Stelczer, 2000)). An increase in groundwater levels may occur as a result of irrigation and leakage from irrigation channels (Molnár & Winter, 1983).

Groundwater levels change periodically throughout the year. Annual and daily fluctuations in the vertical movement of the groundwater level are observed (Li et al., 2020). The general seasonal course in water level in Hungary has a spring maximum and an autumn minimum (Réthási, 1983). Nyizsalovszki and Szabó (2003) showed two minimum in the groundwater level in Tokaj-Hegyalja during the year, a smaller minimum at the end of summer (August-September) due to lack of precipitation, evaporation loss, water uptake by plants, and then as an organic continuation, a stronger minimum late autumn-early winter minimum, that occurred during November-December. It was caused by low rainfall during the measurement period. The maximum values occurred in the spring (March-April). There was a strong correlation between the amount of precipitation and the fluctuation of the groundwater.

In the studies of Kovács and Turai (2004) the result for the Mátra-Bükkalja area the groundwater level basically depends on precipitation conditions. It was also found that the extraction of mining water and the changes of confined aquifers have no influence on the groundwater level. However, according to other Hungarian studies the intensive water withdrawals from the confined aquafer reduces the amount of shallow groundwater (Pálfai, 2010). In another study of Mátraalja-Bükkalja area the groundwater level reached its maximum values in April-May during the year (Kovács, 2014). There was no direct correlation between the monthly precipitation and the groundwater level depth in the given month. The maximum groundwater level of each well occurred only 0.6–1.2 years after the occurrence of precipitation maxima, depending on the depth of the average groundwater level in the wells. The time shift is longer if the groundwater level is deeper (1.5-3 m water depth: 0.7-0.9 years, 3-4 m water depth: 1.0-1.4 years).

In areas with different climatic conditions Abliz et al. (2016) also found seasonal fluctuations in groundwater level in Northwest China, with the shallowest groundwater levels in spring, sinking during summer and autumn, due to evapotranspiration and extensive agricultural water consumption. Hao et al. (2017) observed a continuous decline in groundwater levels in China as a result of long-term water extraction.

In Hungary between the Danube and the Tisza rivers, in the north-western observation wells (Ócsa, Ladánybene), the groundwater level decreased significantly between 1940 and 2008. The measurements showed a decrease in the groundwater level in the southern part of the Danube-Tisza area (around Rém) and in the area of Ásotthalom, too, regarding the long-term series data. Annual fluctuations can be detected in the water regime of the Öregcsertó observation well in the floodplain of the Danube, but it does not

Table 1: Average air temperature (T, °C) and precipitation (P, mm) in Szarvas, 1981-2010

	1	2	3	4	5	6	7	8	9	10	11	12	year
T	-1.0	0.5	5.6	11.5	16.8	19.8	21.9	21.4	16.6	11.2	5.0	0.3	10.8
P	29	30	28	42	51	61	58	51	48	32	41	45	515

Table 2: Groundwater monitoring stations metadata

Monitoring well	soil surface elevation	first data	daily data from	data for every 4 hours from	last data for the study
Békésszentandrás (4035)	82.82 m	2002.01.	2014.11.	2014.11.	2021.01.
Csabacsűd (2779)	84.79 m	2002.01.	2004.01.	2006.01.	2021.08.
Kardos ((4602)	85.43 m	2004.11.	2004.12.	2010.06.	2021.11.
Öcsöd (3858)	84.21 m	2002.01.	2004.11.	2005.11.	2021.12.
Szarvas (2778)	83.19 m	2002.01.	2003.12.	2005.12.	2021.12.
Szarvas (2832)	82.02 m	2002.01.	2017.11.	2017.11.	2021.06.
Szarvas (2833)	81.87 m	2003.07.	2010.05.	2010.05.	2021.12.
Szarvas (2835)	84.00 m	2002.01.	2004.01.	2004.03.	2021.12.

show a trend-like change (Szalai, 2011).

In our research the characteristics of the groundwater level (especially the average seasonal course and long term tendencies) was examined in the subbasin area of the Szarvas-Békésszentandrás Oxbow using time series of 8 monitoring wells (2002-2021).

Materials and Methods

The study area of our research, the Szarvas-Békésszentandrás Oxbow Subbasin is located in the middle part of the Hungarian Great Plain. The area is almost totally flat. The elevation above sea level is typically between 82 m (near river, oxbow) and 86 m (at loess areas in the eastern part). The 8 groundwater monitoring wells which data were used in the research are located within a distance of 15 km from town Szarvas (Figure 1).

The climate is continental with average air temperature of 10.8°C and yearly average precipitation of 515 mm. Annual course of precipitation shows a slight maximum from May to July and minimum from January to March (Table 1).

The groundwater level data of 8 monitoring wells were provided by Körös Region Water Directorate. Most data series start in year 2002 and finish in 2020 or 2021. There were changes in the frequency of measurements during this time period. In the first years manual measurements of the groundwater level were carried out weekly. After automatization data were get daily, later in every 4 hours (six times a day). The monitoring stations represent different types of topography and location related to the oxbow (Table 2.).

Before the statistical examination the monthly average groundwater levels were calculated for each well for the whole period using software Excel. Parallel, the check of missing data was performed.

The average annual groundwater level course of each wells was calculated. It was important to do it based on the same time interval for all of the 8 wells (2005-2020) not to get misleading results. Using the data and graphs it was possible to describe the main char-

Figure 1: Location of the monitoring wells in the study area

Table 3: Average groundwater depth and its annual amplitude (using monthly average data, 2005-2020)

well groups	average (cm)	amplitude (cm)
A	257	62
B	288	72
C	360	100
D	400	51

acteristics of groundwater level in the study area and identify groups of wells with distinguishable patterns.

The main aim was to find long term trends of groundwater level. The trend analysis was based on 5 time series data set (annual, and middle months of the seasons: January, April, July and October) for groundwater level of 4 monitoring wells. The criteria for choosing this 4 wells were: they represent different groundwater characteristics, their data sets have no interruptions over the period 2002-2020.

The analysis was based on the nonparametric Mann-Kendall test for the significance of trend and the nonparametric Sen's method for the magnitude of the trend. These methods are commonly used in analysing climate time series and groundwater level time series, too. Practically, the MAKESENS Excel Macro developed by the Finnish Meteorological Institute was used in our research (Salmi et al., 2002).

Results and discussion

In average of 16 years the groundwater level (GWL) reaches its maximum in April. It is in accordance with the results of previous studies made in Hungary. The groundwater reaches its deepest level in autumn, but there are differences in months. Both September, October and November can be the month when the GWL reaches its minimum. That is in average, but there were years with maxi-

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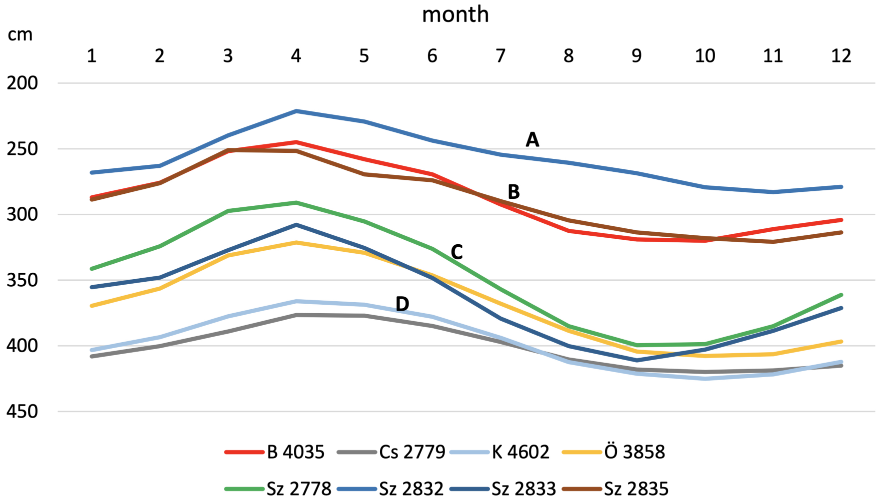

Figure 2: Average annual course (2005-2020) of groundwater level of the monitoring wells. A, B, C, D: groups of groundwater level course

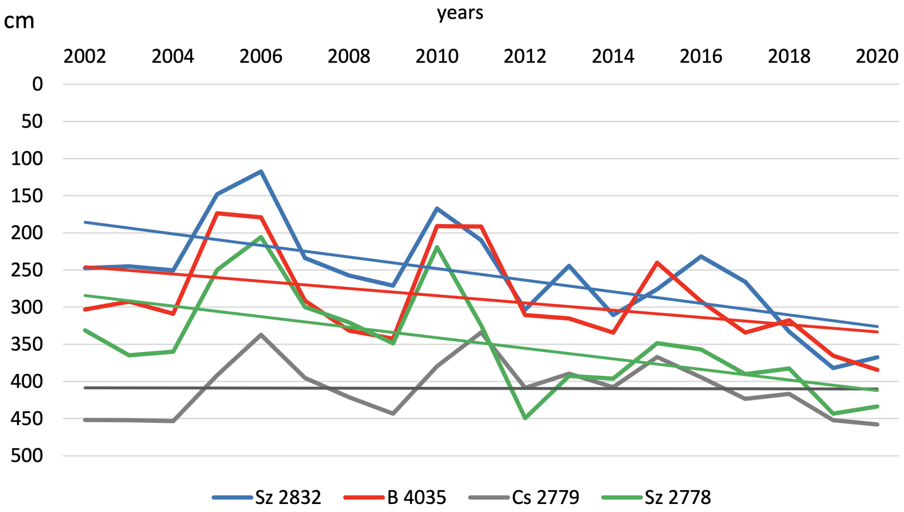

Figure 3: Course of the yearly average groundwater level at 4 monitoring stations (2002-2020)

mal GWL in January, February, March, April or in December, and with minimal GWL in any month from July to February (Figure 2). According to the graphs showing 16-year-average, 4 typical groups of groundwater level courses can be distinguished:

A Highest groundwater level, small annual variation. Szarvas 2832 (Sz 2832) is the only well with this characteristics. It can be clearly explained by the effect of the nearby oxbow (70 m distance).

B Relatively high groundwater level in winter and spring, medium annual variation. Békésszentandrás 4035 (B 4035) is located at a low terrain (only stations near to the oxbow have

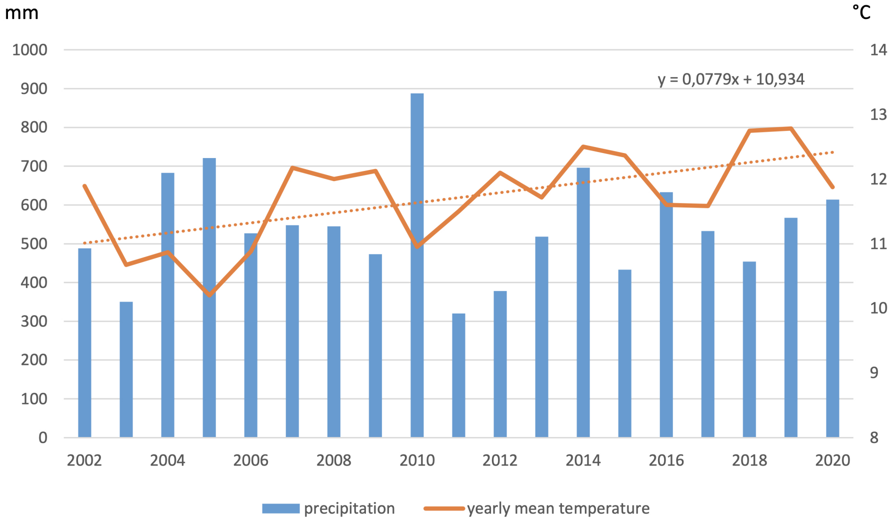

Figure 4: Course of the yearly sum of precipitation (mm) and the yearly mean air temperature in Szarvas (2002-2020)

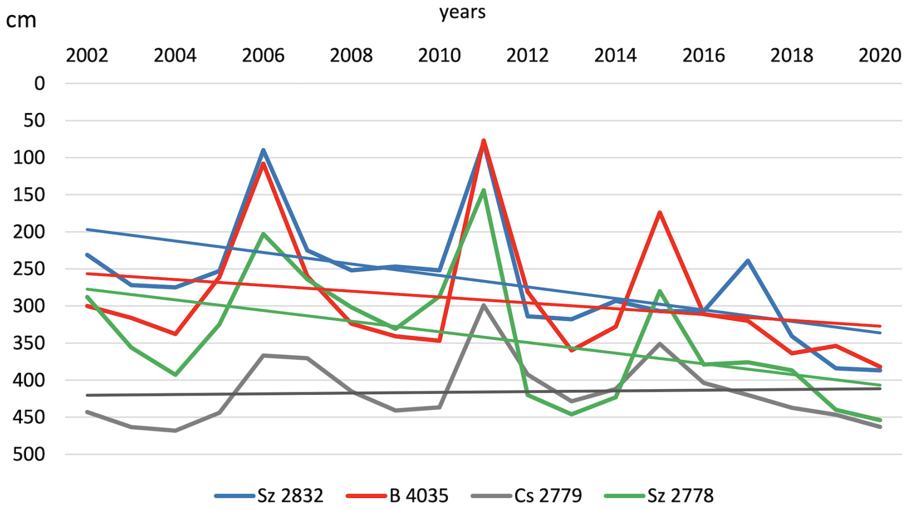

Figure 5: Course of the January mean groundwater level at 4 monitoring stations (2002-2020)

lower elevation above sea level), while Szarvas 2835 (Sz 2835) has a higher elevation, but with a local depression in the topography (about 1 m compared to the surrounding).

C Medium groundwater level, large annual variation. Monitoring stations Öcsöd 3858 (Ö 3858), Szarvas 2778 (Sz 2778) represent the medium level terrains in our study area.

D Deepest groundwater level, small annual variation. Csabacsűd 2779 (Cs 2779) and Kardos 4602 (K 4602) represent the loess areas in the eastern part of the study area with elevation about 85-86 m above sea level.

The expressions such as low, medium, high GWL and others describing seasonal varia-

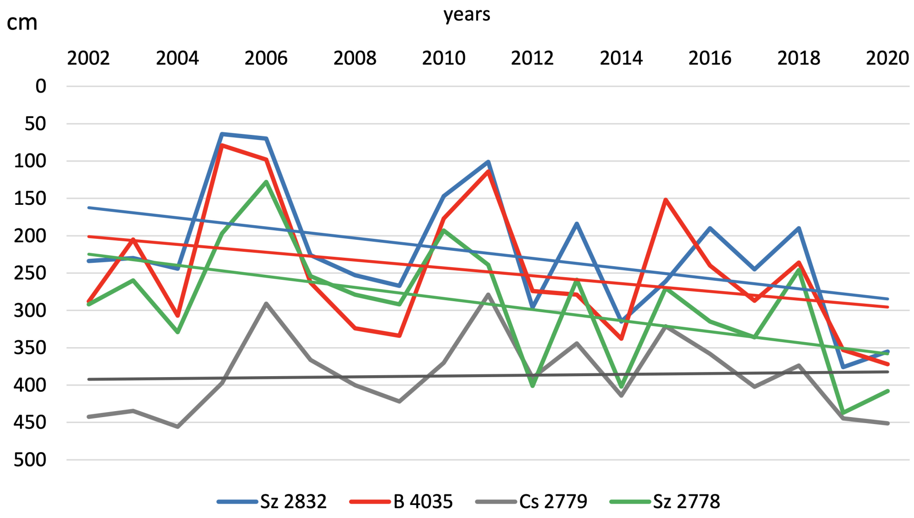

Figure 6: Course of the April mean groundwater level at 4 monitoring stations (2002-2020)

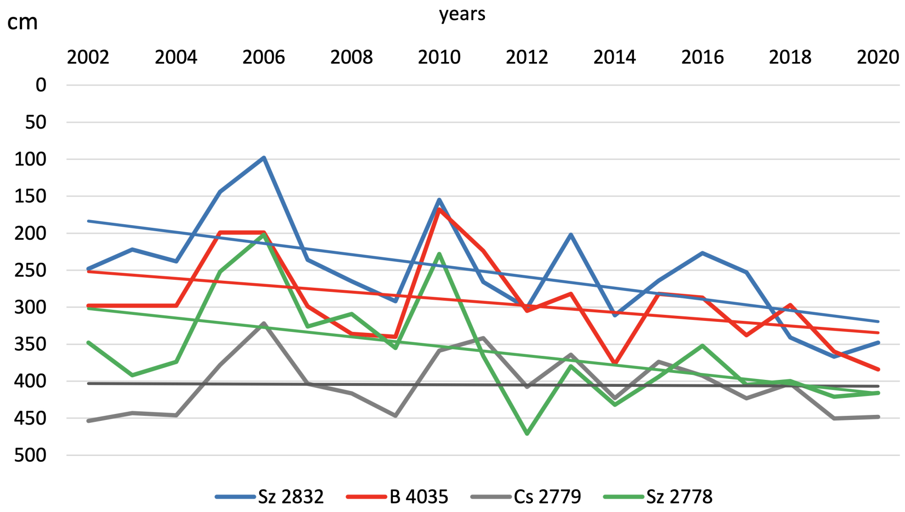

Figure 7: Course of the July mean groundwater level at 4 monitoring stations (2002-2020)

tion are only valid in the context of our research. Near to the oxbow the average GWL is about 2.5 m, while at higher elevated areas it is 4.0 m. The annual amplitude calculated from the average monthly values is small near the oxbow (0.6 m) and at the higher elevated loess areas (0.5 m) with the deepest GWL. It has to be noted that a larger average amplitude is get in case the yearly amplitudes are calculated first and just averaging after that (Table 3).

The long term trends of GWL were studied based on time series of yearly average GWL and the GWL values of January, April, July and October. The trends of yearly average values show the decrease of groundwater level in case of Szarvas 2832, Szarvas 2778 and Békésszentandrás 4035 monitoring wells (Figure 3). These decreasing trends are significant at p= 5% or 1% level (Table 4), with the largest rate of 7.6 cm/year (Q, the Sen's estimator, the groundwater level

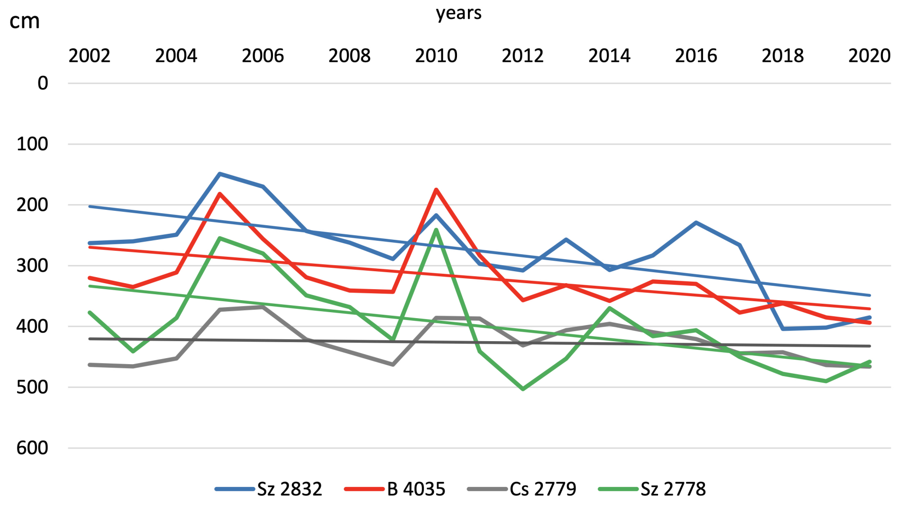

Figure 8: Course of the October mean groundwater level at 4 monitoring stations (2002-2020)

Table 4: Parameters of the linear trend analysis based on data sets (yearly average, January, April, July and October) for groundwater level at 4 monitoring stations (2002-2020)

	Sz 2832			B 4035			Cs 2779			Sz 2778		
	R^2	Q	sign.	R^2	Q	sign.	R^2	Q	sign.	R^2	Q	sign.
year	0.42	-7.6	**	0.18	-4.4	*	0.00	-0.3	-	0.34	-6.4	*
Jan	0.30	-7.3	**	0.07	-4.0	*	0.00	+0.4	-	0.23	-6.9	*
Apr	0.20	-6.8	*	0.11	-5.0	-	0.00	+1.0	-	0.27	-7.2	*
July	0.37	-7.5	**	0.19	-4.2	*	0.00	-0.3	-	0.26	-6.2	*
Oct	0.46	-7.5	*	0.28	-4.3	**	0.01	-1.9	-	0.29	-6.9	*

Mann-Kendall test ** trend at $\alpha = 0.01$ level of significance, * trend at $\alpha = 0.05$ level of significance, – no significant trend, Q, the Sen's estimator, R^2: coefficient of determination calculated by Excel to linear trend.

change per year) in case of the well near the oxbow (Sz 2832). The GWL at Station Cs 2779 (deepest groundwater level, small annual variation) shows no significant trend in groundwater level during the 2002-2020 period.

The decreasing GWL at 3 stations can not be explained by the changes in yearly precipitation sums. The precipitation has no decreasing trend during this period (Figure 4). However, the yearly average air temperature is increasing (significant, 0.78°C/10 years increase). This can be a cause of the groundwater level sink through the indirect effect of temperature on evapotranspiration.

The year to year GWL variability is larger in January and April compared to July and especially to October. The trends of the middle months of the seasons (January, April, July, October) are almost the same in significance and slope compared to the trends based on yearly mean time series (Figures 5-8.). The differences in trends can be found between stations rather than between the months used for calculations.

It can be concluded that in the study period

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(2002-2020) there was a decline in groundwater levels in the Szarvas-Békésszentandrás Oxbow Subbasin in most monitoring wells. The change exceeds 1 m at station Szarvas 2832 (144 cm) and Szarvas 2778 (122 cm). That has an agricultural importance because the recent level of groundwater can much less contribute to the water supply of arable crops than the earlier values. However, there is a station with no significant trend, GWL at Csabacsűd 2779 station shows relative stability at around 4 meter depth in yearly average, which is valid for some areas in the eastern part of the subbasin.

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MAGYAR AGRÁR- ÉS ÉLETTUDOMÁNYI EGYETEM

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Effect of irrigation and water quality on the physiological status of sugar beet and fodder beet using SPAD-502 chlorophyll meter

Ágnes KUN[1] – Ildikó KOLOZSVÁRI[1] – Mihály JANCSÓ[1] – Norbert TÚRI[1] – Csaba BOZÁN[1]

1: Research Center for Irrigation and Water Management, Institute of Environmental Sciences, Hungarian University of Agriculture and Life Sciences, H-5540 Szarvas, Anna-liget u. 35., e-mail: Kun.Agnes@uni-mate.hu

Abstract: In Hungary, irrigation determines the success of water-intensive beet cultivation. Taking into account the guidelines of the circular economy, we investigated the effect of irrigation with pre-treated nutrient-rich effluent from an intensive catfish-farm on the growth stages of sugar beet and fodder beet. In the two-year-experiment (2020, 2021), two sugar beet (‘Helenika’, ‘Grandiosa’) and two fodder beet (‘Rózsaszínű Beta’, ‘Beta Vöröshenger’) cultivars were grown. In addition to the effluent water of the fish farm, the water of the Körös oxbow lake and a mixed water type (1:3 effluent and Körös water, added gypsum) were used for irrigation (sprinkler irrigation methods, 4 replications). The experiment was performed in 64 lysimeter vessels/units (1 m^2) in Szarvas. During the research we sought answers to the following questions: (1) whether the onset and length of sugar growth stage and accumulation stage differ depending on water quality, (2) which beet variety has the highest relative chlorophyll content, (3) whether irrigation water quality affected the relative chlorophyll content of beet cultivars. SPAD values measured with the SPAD-502 chlorophyll meter were used to estimate the relative chlorophyll content of beet leaves. According to our results, in the case of sugar beet, the shifts of the phenological phases due to irrigation were well observed based on the SPAD values. Based on the SPAD values, the quality of the irrigation water had no verifiable effect on the chlorophyll content of the beets.

Keywords: relative chlorophyll content, sugar growth stage, accumulation stage, maximum canopy cover, canopy senescence

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Introduction

An early trace of sugar beet cultivation can be found in Hungary: in 1790, the Hungarian Lutheran pastor Sámuel Tessedik brought from Germany the seeds of the burgundy beet, the ancestor of sugar beet (Rombay, 1914). In 2021, there was sugar beet cultivation in Hungary on an area of 12 173 ha (KSH, 2022). At the national level, the average yield (2019) was 53 t/ha, which corresponds to the Central and Eastern European average. However, it lags far behind the Western European average (61,1–95 t ha^{-1}). Although sugar and fodder beets are currently grown in small areas, crop production has a long history and excellent soil conditions for it in Hungary. The most common limiting factor of the beet production is drought stress, as it is a water-intensive plant and the nitrogen supply because excessive N application results decreased sugar concentration due to increased levels of impurities in the beet (Akeson et al., 1979). Leaf chlorophyll content measurement is a good criterion for estimating nitrogen status of the plant (Ghasemi et al., 2017; Moghaddam et al., 2011). The SPAD chlorophyll meters give immediate results and have been used successfully for determining N status of

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crops. Aim of our study was to determine the nitrogen status of the sugar and fodder beets under different water quality irrigation using SPAD measurements, in order to examine the different growing periods, the effects of water quality on the plants and to compare 2 fodder and 2 sugar beet cultivars based on SPAD values.

Materials and Methods

Study Site and Climatic Conditions

The experiment was carried out at the Lysimeter Research Station (46°51′49″ N 20°31′39″ E Szarvas, Hungary) of the Hungarian University of Agriculture and Life Sciences (MATE), Institute of Environmental Sciences (IES), Research Center for Irrigation and Water Management (ÖVKI). Sixty-four non-weighing lysimeters (1 m^3) were used to determine the effect of effluent water irrigation on the development of beet cultivars. The lysimeters were 1 m deep and 1 m^2 in surface. Eight plants were sown into each vessel. The soil of the lysimeter is not stratified disturbed soil, where the soil properties in lysimeters where clay loam texture, 0.03% total salinity, 2.1% total carbonate content, and 1.31% total organic carbon content. At the bottom of all lysimeters, a 10 cm layer of fine gravel was placed for the collection of leachate water.

The climate of Hungary is influenced by continental and oceanic effects, the specific area of the experimental site is described as warm dry climate region. The meteorological data during the two years experiment (2020–2021) were collected by an automatic weather station maintained by the MATE ÖVKI in Szarvas. Its distance to the Lysimeter Research Station is 600 m. The year of 2021 was dry, the total precipitation was only 433.9 mm while in the year of 2020, 611.6 mm was measured. The annual average temperature was 12.1 °C in 2020 and 11.6 °C in 2021 (Figure 1).

Plant material

Both fodder beet varieties are on the National List of Varieties according to National Food Chain Safety Office in Hungary (NÉBIH, 2022). The fodder beet ‘Beta Vöröshenger’ was added to the list on 25 May 1977. The fodder beet ‘Rózsaszínű Beta’ was added to the list on 31 January 1944. University of West Hungary bred both varieties. ‘Grandiosa’ was added to our national list on 9 March 2016, the variety belongs to KWS Saat SE, Germany. ‘Helenika’ was also bred by KWS Saat SE and was added to the list in 2014, however it was cancelled in last year (25/3/2021).

Experimental Design for Effluent Water Irrigation

Two different water types and their combinations were applied for the irrigation experiment of the beet varieties. Untreated effluent water from a local intensive African catfish farm was used directly collected from the outflow of fish rearing tanks. The flow-through system of the fish tanks is supported by a geothermal well from stratified aquifer. This system has the main role of temperature and water quality maintenance since the African catfish are fed high protein diet and need warm water (above 16 °C) to grow. The daily amount of effluent water from the farm exceeds 1000 m^3. That effluent water (EW) contains large amount of metabolites as fish feces, organic materials and rarely chemicals or antibiotics depending on the fish rearing technology (Tóth et al., 2020). Because of the geothermal origin, the effluent water also carrying high content of total salinity including high percent sodium and high concentration of hydrogen-carbonate (Table 1). As an irrigated control treatment, freshwater was applied from the local oxbow lake of the River Körös (KW) (46°51′38.6″ N 20°31′28.0″ E, Szarvas, Hungary). Diluted effluent water with gypsum (DW) was ap-

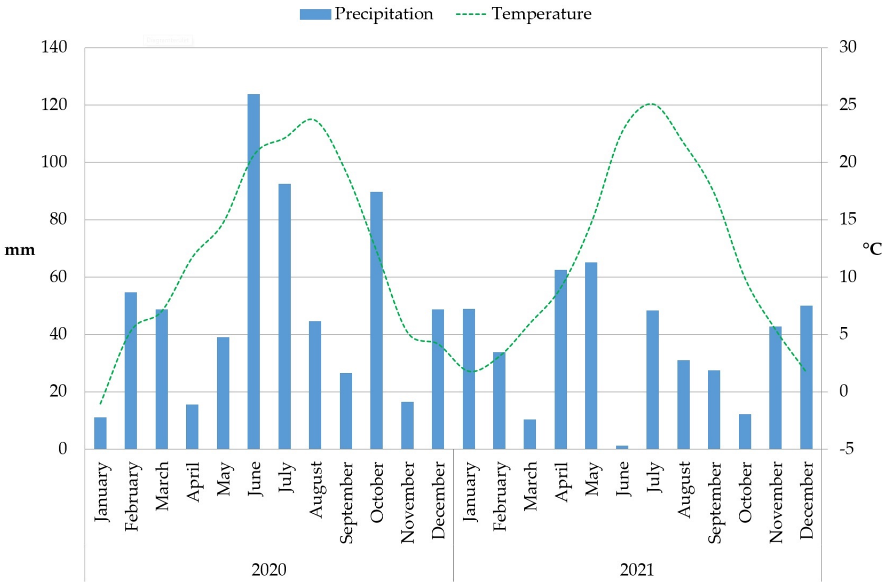

Figure 1: Precipitation and monthly mean temperature of experimental years (2020, 2021)

Table 1: Average major quality parameters of irrigation water used under experiment according to Kolozsvári et al. (2021)

Irrigation waters	EC (μS cm^{-1})	NH4-N (mg l^{-1})	N (mg l^{-1})	P (mg l^{-1})	K (mg l^{-1})	Na (mg l^{-1})	SAR
EW	1306.7	21.9	29	3.9	7.2	273.5	11.9
KW	388.3	0.4	1.2	0.2	4.3	31.3	1.2
DW	1073.0	10.3	13.3	1.7	5.4	132.3	3.5

plied with 1:3 rate of EW and KW + 0,312 kg m^{-3} gypsum. Additionally, a non-irrigated control (C) treatment was also applied with four replications.

The weather in the experimental years differed in 2020 and 2021. There was approximately 200 mm more precipitation in the vegetation period in 2020 than in 2021 (Table 2). To determine the amount of irrigation water, the water demand of sugar beet described earlier was taken into account.

Determination of Phenological Paramteres and Statistical Analyses

SPAD values (Konica Minolta SPAD-502) were measured on a weekly basis during the growing seasons (Table 3). Measurements were performed in 32 replicates per treatment (4 vessels per treatment × 8 plants/vessel). One measurement data is the average of the values measured on the plant at 3 points. (In the first experimental year (2020), leaf senescence was so intense that the measurement had to be stopped in August.)

Statistical analyses were implemented by IBM SPSS Statistics 25.0 software. Applying one-way analysis of variance (ANOVA), we examined the effect of irrigation water quality on the phenological properties of beets per treatment and plant part. The differences were determined significant, where the Tukey's or Dunnett post hoc test were considered significant at $p \leq 0.05$.

Table 2: Precipitation and water amount in the vegetation period of beet. Average water demand of 10 days period according to Posch (1997)

10 days period	Average water demand of beet in the period (mm)	Precipitation in the period (mm)		Irrigation water amount in the period (mm)	
		2020	2021	2020	2021
21-30 April	12	10.6	2.3	10	0
1-10 May	14	7.4	10.0	10	0
11-20 May	17	13.5	52.7	10	0
21-31 May	22	18.0	7.4	4	0
1-10 June	27	56.3	0.0	10	27
11-20 June	35	63.0	0.7	0	35
21-30 June	43	58.2	0.5	0	43
1-10 July	53	32.0	30.5	20	20
11-20 July	56	40.0	16.8	16	60
21-30 July	65	18.5	1.0	46	0
1-10 August	60	27.7	6.7	30	52
11-20 August	53	6.7	0.2	46	53
21-31 August	52	3.7	24.2	48	22
1-20 Sept.	47	0.0	3.9	47	43
Total	556	356	157	297	355

Table 3: Dates of SPAD measurements

Year 1		Year 2	
Day after sowing	Date	Day after sowing	Date
62	17/6/2020	67	14/6/2021
70	25/6/2020	75	22/6/2021
75	30/6/2020	88	5/7/2021
84	9/7/2020	99	16/7/2021
91	16/7/2020	105	22/7/2021
97	22/7/200	113	30/7/2021
106	31/7/2020	120	6/8/2021
117	11/8/2020	139	25/8/2021
		147	2/9/2021
		154	9/9/2021

Results

Effect of irrigation on chlorophyll content of sugar and fodder beet

The SPAD of leaves is presented in Figure 2 and Figure 3. In 2020, chlorophyll content was measured from 17 June till 11 August, this period was from 62nd till 117th days after sowing. The minimum SPAD values were 33.4 and 31.6 and the maximum

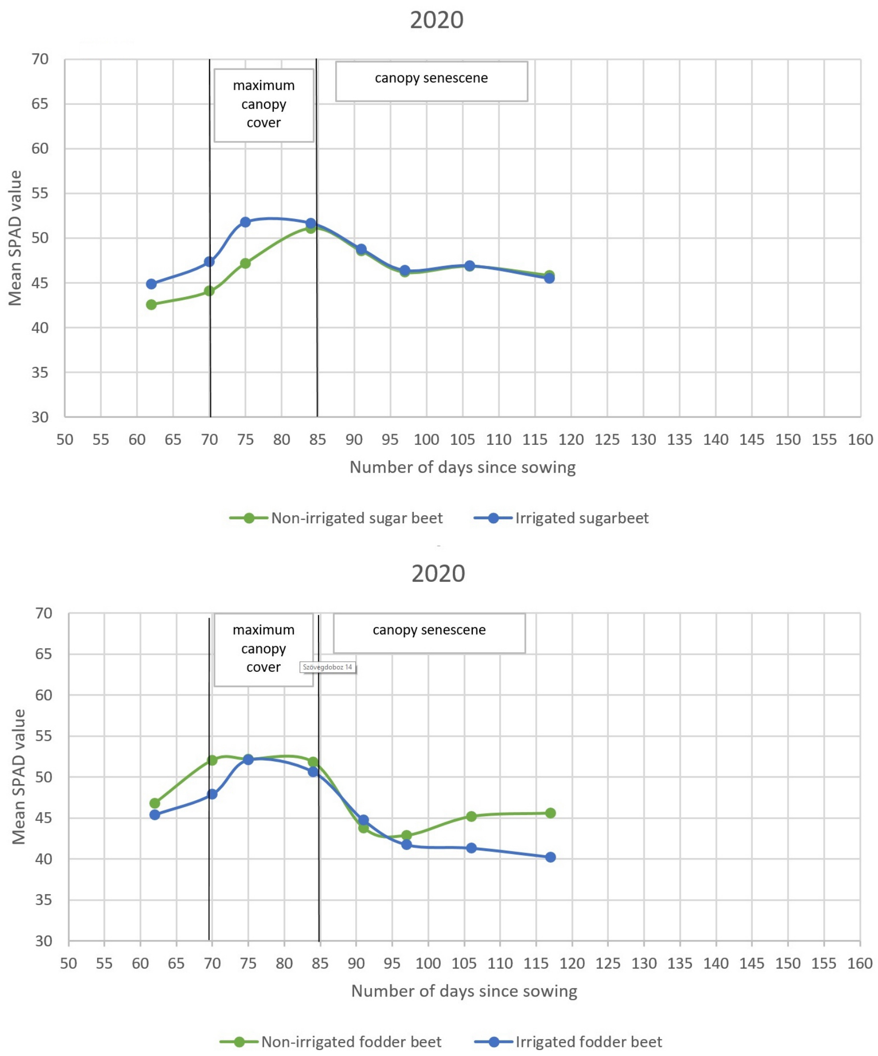

Figure 2: Mean SPAD values in irrigated and non-irrigated beet production in 2020

values were 60.6 and 60.7 for sugar beet and fodder beet, respectively, in the analysed period. The mean value of sugar beet (47.62 ± 4.5) were significantly (Independent T-test, $p < 0.001$) higher than fodder beet (45.49 ± 5.5). Before the 85th day after sowing, the non-irrigated sugar beet has significantly (ANOVA Dunnett *post hoc* test) lower SPAD values (mean 44.62 ± 3.4) than in irrigated treatments (mean 47.94 ± 4.3). After that date, similar chlorophyll content was measured for irrigated (mean SPAD value 46.91 ± 4.7) and non-irrigated sugar beet (mean SPAD value 46.90 ± 3.7). In contrast to sugar beet, between 31 July and 11 August significant differences (ANOVA Dunnett *post hoc* test) were detected between control treatment (mean SPAD value 45.4 ± 4.1) and irrigated treatment (mean SPAD value 40.80 ± 4.3).

In 2021, chlorophyll content was measured from June till 9 September, this period was from 67th till 154th days after sowing. The minimum SPAD values were 30.0 and 30.2 and the maximum values were 77.1 and 74.9 for sugar beet and fodder beet, respectively, in the analysed period. The maximum SPAD values were higher in 2021 than in 2020. There was significant difference between SPAD values in irrigated and non-

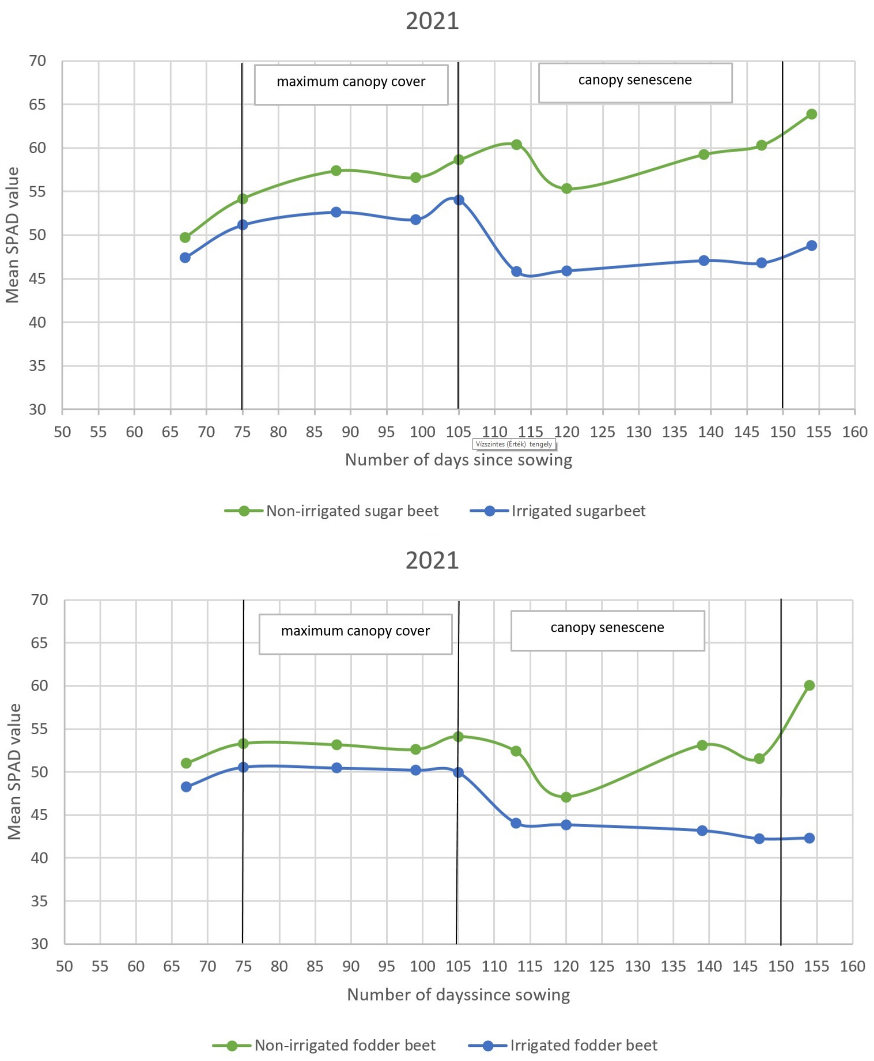

Figure 3: Mean SPAD values in irrigated and non-irrigated beet production in 2021

irrigated treatments over the entire period in the case of both beets. The mean SPAD value of non-irrigated sugar beet and fodder beet (57.5 ± 6.7, 52.8 ± 6.5, respectively) were higher (ANOVA, Dunnett test) than irrigated ones (49.2 ± 5.9, 46.5 ± 6.3, respectively).

Effect of irrigation water quality on chlorophyll content of sugar and fodder beet

When examining growth phases separately, it is generally typical in all treatments and in case of all beet cultivars (Table 4) that in the rapid growth stage of leaf cluster (46.35 ± 3.5) and in the sugar accumulation stage (44.74 ± 5.1) the mean SPAD value is lower than in sugar growth stage (51.3 ± 3.1) in 2020. However, the irrigation water quality has different impact on chlorophyll content in each phases and cultivars. In case of fodder beet 'Rózsaszínű Beta', in each phases the highest mean SPAD value was measured in non-irrigated treatment, which means difference was significant compared to irrigated treatments. Comparing water quality, in the DW treatment the mean SPAD value were higher than treatment KW (significant differences in sugar accumulation stage. The mean SPAD differences were significant only between KW and EW treatment in sugar growth stage (Table 4).

Table 4: Mean SPAD value of beet cultivars in 2020

2020 SPAD (mean±std.dev)		’Rózsaszínű Beta’ (fodder beet)	’Beta Vöröshenger’ (fodder beet)	’Grandiosa’ (sugar beet)	’Helenika’ (sugar beet)
Rapid growth stage of leaf cluster	C	49.6±3.4^{c}	49.0±3.1^{c}	44.5±2.7^{ab}	42.2±2.4^{a}
	DW	47.5±3.1^{b}	47.0±3.1^{b}	43.6±1.8^{a}	47.5±4.3^{b}
	KW	47.3±2.8^{ab}	47.8±3.1^{bc}	45.4±2.4^{b}	48.6±3.3^{b}
	EW	45.7±2.6^{a}	44.7±2.3^{a}	43.9±1.7^{a}	47.7±2.6^{b}
Sugar growth stage	C	53.2±3.1^{c}	50.9±2.5^{ab}	50.2±3.9^{ab}	48.9±2.9^{a}
	DW	51.6±3.3^{ab}	52.2±3.1^{c}	50.4±2.3^{ab}	53.8±2.7^{c}
	KW	50.3±1.9^{a}	50.0±2.4^{a}	49.3±2.1^{a}	51.3±2.4^{b}
	EW	52.0±2.9^{b}	51.2±2.2^{ab}	51.4±3.0^{b}	54.3±2.2^{c}
Sugar accumulation stage	C	45.2±4.4^{c}	43.5±4.6^{b}	45.8±4.0^{b}	48.0±2.9^{a}
	DW	43.0±4.8^{b}	42.5±4.8^{ab}	45.9±4.3^{b}	49.7±3.9^{b}
	KW	41.2±4.4^{a}	42.1±4.9^{ab}	44.0±3.2^{a}	48.9±4.2^{ab}
	EW	41.7±4.4^{ab}	41.6±4.3^{a}	44.0±3.8^{a}	49.2±4.6^{ab}

^{a,b,c} indices means the result of Tukey’s *post hoc* test of ANOVA.

Table 5: Mean SPAD value of beet cultivars in 2021

2020 SPAD (mean±std.dev)		’Rózsaszínű Beta’ (fodder beet)	’Beta Vöröshenger’ (fodder beet)	’Grandiosa’ (sugar beet)	’Helenika’ (sugar beet)
Rapid growth stage of leaf cluster	C	50.8±5.2	51.1±4.5^{b}	48.1±6.3	50.6±4.5
	DW	50.0±5.9	46.9±3.7^{a}	46.7±5.2	48.5±4.9
	KW	49.1±5.2	49.1±4.5^{ab}	46.6±4.6	48.6±4.8
	EW	48.1±4.8	46.9±4.6^{a}	46.0±3.3	48.2±4.2
Sugar growth stage	C	53.4±5.8^{b}	53.0±5.9^{b}	55.6±5.5^{b}	58.4±5.1^{b}
	DW	50.5±6.4^{a}	47.8±6.0^{a}	50.0±5.9^{a}	52.6±5.5^{a}
	KW	49.5±6.2^{a}	48.7±6.3^{a}	49.6±5.2^{a}	52.6±5.3^{a}
	EW	49.8±6.2^{a}	48.4±6.2^{a}	49.8±6.6^{a}	51.9±6.2^{a}
Sugar accumulation stage	C	50.9±6.4^{b}	50.3±6.4^{b}	58.9±7.4^{b}	58.0±5.7^{b}
	DW	43.7±5.3^{a}	43.1±4.1^{a}	45.3±4.6^{a}	47.0±4.8^{a}
	KW	43.2±5.1^{a}	42.7±5.5^{a}	46.3±6.4^{a}	48.6±4.6^{a}
	EW	43.4±4.6^{a}	42.4±4.5^{a}	45.7±5.0^{a}	47.0±4.9^{a}

^{a,b,c} indices means the result of Tukey’s *post hoc* test of ANOVA.

In case of fodder beet ‘Beta Vöröshenger’, only in the sugar growth stage the highest mean SPAD value was not measured in the non-irrigated treatments. In the rapid growth stage of leaf cluster, the mean SPAD value was significantly lower in treatment EW, than in treatment KW and DW, this is also true for sugar accumulation stage, but the difference cannot be statistically justified. In the sugar growth stage, irrigation with used water (treatment DW and EW) resulted in a higher chlorophyll content (Table 4).

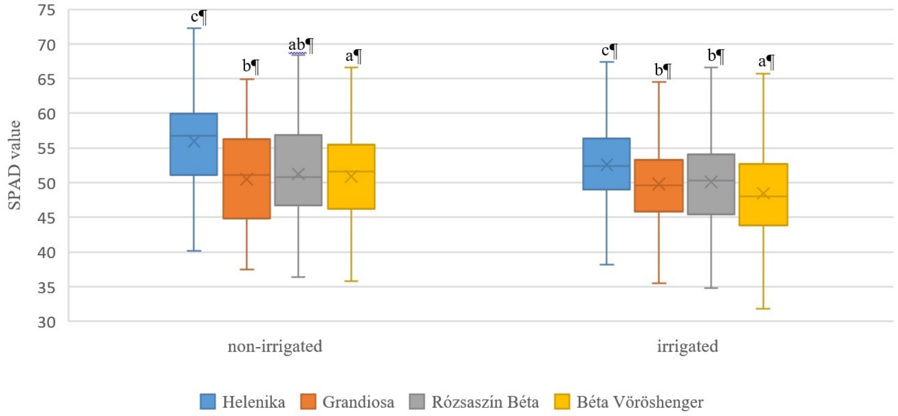

Figure 4: SPAD values of different beet cultivars in sugar growth stage in 2021 (^{a,b,c} indices means the result of Tukey's *post hoc* test of ANOVA.)

In case of sugar beet 'Grandiosa', only in sugar accumulation stage was significantly difference between irrigated and non-irrigated treatments (Table 4). Water quality did not have a clear effect in all growth phases, the highest SPAD value was in the first phase in the treatment KW, in the second phase in the treatment EW and in the third phase in the treatment DW.

In case of sugar beet 'Helenika', the lowest mean SPAD value was measured in non-irrigated treatment in each phase (Table 4). Significant differences in mean SPAD values were measured between the irrigated treatments only in sugar growth stage, when the irrigation of the used waters (treatment DW and EW) resulted in a higher SPAD value compared to the Körös River irrigation water.

In 2021, when examining growth phases separately, in the rapid growth stage of leaf cluster (48.45 ± 4.9) and in the sugar accumulation stage (46.45 ± 6.8) the mean SPAD value is lower than in sugar growth stage (50.97 ± 6.5) in 2020, however, it is not true in all treatments and in case of all beet cultivars (Table 5). For all sugar beet cultivars, it can be demonstrated that in the second and third phases, significantly higher SPAD values were measured in the non-irrigated treatments than in the irrigated ones (Figure 2, Table 5). Unlike 2020, significant differences in mean SPAD value were not measured between irrigation treatments in case of any beet cultivars in 2021. In the rapid growth stage of leaf cluster, the chlorophyll content of the fodder beet 'Beta Vöröshenger' was higher in treatment KW than in treatments irrigated with reused waters (Table 5).

Effect of irrigation on chlorophyll content of each beet cultivars

As water quality did not have a significant effect on the SPAD value of any variety in the sugar growth phase of 2021, we examined the differences between the SPAD values of the varieties in this period. In both irrigated and non-irrigated treatment, sugar beet 'Helenika' had significantly higher chlorophyll content (mean SPAD value 52.5 ± 5.5 and 58.38 ± 5.1, respectively) than other cultivars (Figure 4). The highest SPAD values were measured also in case of sugar beet of 'Helenika'. The fodder beet 'Beta Vöröshenger' had the lowest mean SPAD values in both treatments (48.28 ± 6.2 and 52.82 ± 5.5). However, the lowest SPAD values were measured in case of 'Rózsaszínű Beta' in both treatments. There were no significant differences between mean SPAD value of fodder beet ‘Rózsaszínű Beta’ and sugar beet ‘Grandiosa’ nor in irrigated and non-irrigated treatment. Each beet cultivars had lower SPAD value in irrigated treatment during this period.

Discussion

According to Zhang et al. (2021), SPAD value in sugar growth stage was relatively higher than in the rapid growth stage of leaf cluster and the sugar accumulation stage. Based on their results and the number of days after sowing in our experiment, developmental stages can be distinguished in both years using SPAD values. According to Sims and Gamon (2002) and Salehi et al. (2016), chlorophyll content declines rapidly when plants are experiencing stress and during leaf senescence. In 2020, between days 85-90 after sowing SPAD values started to decrease in case of both fodder and sugar beets (Figure 2). In 2021, the SPAD value began to decline 15 days later than in 2020 (Figure 3). However, we observed that in 2021, the leaf senescence period started at least 10 days earlier in the irrigated treatments than the non-irrigated treatment in case of sugar beet. In 2020, the sugar growth period began earlier in the irrigated treatments of sugar beet by at least 10 days (Figure 2 and Figure 3). Our result is consistent with J. T. Tsialtas and Maslaris (2012), according to their SPAD readings increased till early July, decrease till early September and then increase toward the end of the season showing maximum at the end of October. Wang et al. (2021) also measured maximum chlorophyll content at harvest time, however, in our experiments SPAD measurements did not occur throughout all leaf senescence period and harvest time because of leaf diseases it was not feasible.

Both irrigation and water quality significantly affect the SPAD values of beets cultivar, but in a different way in the experimental years (Table -5). In 2020, in the rapid growth leaf stage the SPAD values were higher in the irrigated sugar beets than in non-irrigated ones. According to Wang et al. (2021) chlorophyll content was higher in irrigated treatments than in rain-fed treatments in sugar beet. In contrast, in 2021 SPAD values were lower in irrigated treatment throughout the analyses periods in case of all beet cultivars. According to Széles (2008) as a result of irrigation, the leaf area increases and the nitrogen concentration is diluted which caused higher SPAD values in the corn experiment.

Irrigation water quality had significant effect on SPAD values only in rapid growth stage of leaf cluster in case of sugar beet ‘Grandiosa’ in 2020. We hypothesized that the nitrogen content of the water caused the higher chlorophyll content, several researchers found that a strong correlation could be described between the N content of the soil or fertilizers and the the chlorophyll a, b and total content, petiole NO3-N of the sugar beet (Ghasemi et al., 2017; J. Tsialtas & Maslaris, 2008). In contrast, J. T. Tsialtas and Maslaris (2012) did not found correlation between SPAD value and soil total N, NO_3-N, root alpha-amino-nitrogen and petiole NO_3-N. In conclusion, based only on SPAD value analyses, the effluent water had no clear effect on the chlorophyll content of beets in the years and cultivars studied in this experiment. Among the varieties, ‘Helenika’ sugar beet had the highest chlorophyll content in both irrigated and non-irrigated treatments. Islam et al. (2020) compared 11 varieties of sugar beet in their research, according to their results ‘Helenika’ (and ‘Recoddina’) had significantly higher chlorophyll a, b and total content than other 9 varieties. According to them, ‘Helenika’ – and six other cultivars – were found best fitted to the given drought condition (Islam et al., 2020).

Conclusion

In the case of sugar beet, the shifts of the phenological phases due to irrigation were well observed based on the SPAD values. Based on the SPAD values, the quality of the irrigation water had no verifiable effect on the chlorophyll content of the beets. The differences between the varieties could be described with great certainty in one vegetation period in 2021 where "Helenika" differed from the other studied varieties. In the continuation of the research, we plan to investigate the relationship between SPAD values and other plant (yield, sugar content, alpha-amino nitrogen content, etc.) and soil (nutrient supply, salinity) parameters.

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Correlation of secondary salinization and soil conditioning in vegetable production under irrigation with saline water

Arzu RIVERA-GARCÍA[1,2] – Géza TUBA[2] – Györgyi KOVÁCS[2] – Lúcia SINKA[1,2] – József ZSEMBELI[1]

1: Kálmán Kerpely Doctoral School, University of Debrecen, 4032 Debrecen, Böszörményi út 138., Hungary, e-mail: arzu89@agr.unideb.hu 0000-0002-3074-6132
2: Research Institute of Karcag, Hungarian University of Agriculture and Life Sciences, 5300 Karcag, Kisújszállási út 166. Hungary

Abstract: Secondary salinization is a main problem around the world due to climate change and intrusion of salts in the soil by improper irrigation. Our aim was to study the soil salinization process by simulating vegetable production under irrigation with saline water (total soluble salt content 700 mg L^{-1}). We tested 6 different technologies of soil conditioner application and 3 vegetable crops with different sensitivity to salinity in a small plot experiment set up on a meadow chernozem soil. During the irrigation season in 2020, we regularly measured the electric conductivity (EC_a) and the soil moisture content (v/v%) in the topsoil (0.1 m) and analysed these parameters with Pearson's bivariate correlation (PCC) method. As our hypothesis, we expected that there is correlation among EC_a, soil moisture content, soil conditioning, and providing the possibility to quantify the secondary salinization process. We found that all the 4 biosynthetic soil conditioners technologies minimized the harmful effect of saline irrigation. In the case of the not salt tolerant (NT) peas, the PCC correlation was higher to compost application and control expressing more intense salinization. NT beans showed a weaker correlation with lower PCCs, which must be due to its higher root activity leading to intensive leaching resulting in a lower degree of salinization. In the case of chilli with low salt tolerance (LT), micro dosing of soil conditioners was not effective in mitigating the harmful effect of secondary salinization, only full doses decreased the PCC. The salt tolerance of the investigated vegetable crops was also manifested in the yields. We found that PCC is a suitable statistical method to understand and quantify the process of secondary salinization.

Keywords: electric conductivity, soil moisture content, soil conditioners, salt tolerance, secondary salinization
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Introduction

Nowadays, soil salinity constitutes one of the major abiotic constraints in global food production and particularly critical in semi-arid and arid regions (Minhas et al., 2020). In regions with the scarcity of good quality water, it is common to practice irrigation with saline groundwater for agriculture. Salinity has a big effect on plant nutrient availability reducing phosphate availability, competitive uptake, and transport or partitioning within the plant and yield performance (Grattan & Grieve, 1998). However, in Hungary's semi-arid regions like Jász-Nagykun-Szolnok (JNS) County with extreme climatic conditions, irrigation water requirement for horticulture increased due to climate change. The water used for irrigation is usually saline in this region. Particularly in Karcag, the irrigation water coming from subsurface water bodies (aquifers) have been monitored and proved not to be suitable for irrigation (Zsembeli et al., 2013, 2015). In such a case,

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the salt concentration (net accumulation of salts) of a horticultural system is increasing and is considered to have a risk of salinization to land and water resources (Rhoades et al., 1997).

In general, salt composition of the soil solution influences the composition of cation exchange and affects the soil structure and its hydraulic properties (Bower, 1959). The main effect of salinity is the reduction of the transport of Ca^{2+} and mobility to the growing parts of the plant, not only reducing Ca^{2+} availability, but affecting the quality of both the vegetative and the reproductive organs. Salinity, in general, directly affects nutrient uptake, such as Na^+ reduce K^+ uptake or Cl^- reduce NO^{3-} uptake. Apparently, there is antagonism between Cl^- and NO^{3-} (Martinez et al., 1987; Wang et al., 2003). Also, salinity can cause a combination of complex interactions that affects plant metabolism, susceptibility to injury or internal nutrient requirement (Grattan & Grieve, 1998). Salinity is one of the most injurious abiotic stresses for plants that alters different morphological and physiological traits of plants to an abnormal state. The severity of salinity is a complex process and the response is also mediated by environmental interactions with the plant-soil system such as relative humidity, temperature, radiation, genetic background etc. (Sadras et al., 2020; Shannon et al., 1994).

Controlling or reducing salinity levels in the soil depends on the practices of water application including the amount of water, frequency and method of irrigation, drainage, and soil cultivation (Dudley et al., 2008; Pereira et al., 2014; Reeve & Fireman, 1967). Management of saline water for irrigation is often based on application of excess water designed to maintain minimum root zone salinity (Smedema & Shiati, 2002; Burt & Isbell, 2005; Ben-Gal et al., 2008). Nevertheless, in Karcag, the water quality is a limiting factor for leaching purposes (Juhasz et al., 1997). In the MATE Research Institute of Karcag, several studies are carried out focussing on the problem of secondary salinization involving soil conditioner applications for large- and small-scale production and lysimeter experiments. The main concern is the increase of water use efficiency while maintaining sufficient levels of production (Gadissa & Chemeda, 2009; Zsembeli et al., 2021).

According to our previous soil analyses and soil conditioner experiments carried out in Karcag, we categorized soil conditioners into different groups (Kovács et al., 2013; Monori et al., 2009; Szűcs et al., 2014a, 2014b, 2015; Tuba et al., 2020b, 2020a; Zsembeli, Sinka, et al., 2019; Zsembeli, Rivera-García, et al., 2019). The first group includes the natural organic materials (like composts). The organic amendments have the typical use to increase infiltration, retention of water. They are often negatively viewed as waste products with undesirable features such as odour, excessive nitrogen and phosphorus content, incorporating heavy metals, pathogens, toxins and other contaminants, which are potentially transportable to surface or ground waters by runoff or leaching (Bergström, 1990).

The second group of soil amendments are the biosynthetic soil conditioners, which are made mainly by biotechnology companies. These soil amendments use three main sources: clay minerals, trace elements, microorganisms and algae sulphated polysaccharides (Balusson, 2018). Specific organisms are used like renewable raw materials. RHIZO-VAM is a water-soluble soil inoculum that contains in-vitro produced spores and infective propagules of arbuscular mycorrhizal fungus *Rhizoglomus intraradices* in mixture with other natural products, like mycorrhizal helper bacteria, Ca-modulating products and extract of algae stimulates the exchange between the soil and the plant and promotes the growth of the root system. Other strategies that improve plant tolerance against salt stress are the application of plant growth-promoting rhizobacteria (PGPR), plant fungi associations, and organic and inorganic amendments (Kumar et al., 2021; Mekonnen & Kibret, 2021; Nemenyi et al., 2021). These technologies are focused on different areas like plant care, soil life activation, crop nutrition, plant health optimization and improving of soil fertility (Muhammad et al., 2020).

The aim of this recent study was to simulate vegetable production involving irrigation with saline water characteristic to the region of Karcag and soil reclamation by the application of soil conditioners with the purpose of the mitigation of the harmful effect of secondary salinization. In order to understand the salinization process better, a new approach was introduced to reveal the correlation among the electric conductivity (EC_a) and the moisture content (v/v%) of the soil and the PCC value calculated for these regularly measured parameters.

Materials and Methods

The experiment was set up in the Irrigation Experimental Garden (IEG) of the MATE Research Institute of Karcag (RIK) in 2020. IEG is dedicated to carry out experiments to study the process of secondary salinization by simulating the vegetable production and irrigation being typical in the hobby gardens located at Karcag, but also characteristic to the Middle-Tisza region of Hungary (Rivera Garcia et al., 2020). The experiment was settled on a meadow chernozem soil, which is basically salt effected only in the deeper layers. We applied two biosynthetic and one organic soil amendments in order to study their potential secondary salinization mitigating effect, as the treatments of the experiment. All of the indicator crops were vegetable species with various salt tolerance, all are typically grown in the region. The amendments used as treatments and the relevant indicator crops with their salt tolerance degree are listed in Table 1.

The amendments were applied and distributed on 18 small plots of 3×3 m each in May, 2020, prior to sowing or planting of the indicator crops. The small plots were arranged in 3 blocks, each block represented one indicator crop (beans, peas, chili) and was irrigated as the given indicator crop needed it. The blocks consisted of 6 small plots. Within the blocks, 5 plots were dedicated to each amendment (2 plots for Neosol, 2 plots for Physiomax, 1 plot for Terrasol) and there was one untreated control plot. In the case of the biosynthetic amendments (soil conditioners) on the 2 dedicated plots, standard dose and micro-dose were applied. Standard dose represented the full dose of the soil conditioner recommended by the producer of each product. Micro-dose means the application of a reduced amount of soil conditioners. This new technique was developed on the same principle as micro-irrigation: small doses of soil conditioners are placed only close to the roots, not distributed on the whole soil surface. This way, the physical and chemical properties of the soil of the space directly surrounds the roots are reclaimed with lower doses of soil conditioners (Rivera Garcia et al., 2020). It is important to mention that each crop has particular growth stages and water demand, therefore each treatment-crop combination created a certain situation where secondary salinization interacted with the amendments and could cause a different respond in the variables.

We induced secondary salinization by irrigation of vegetable crops with saline water (total soluble salt content 600 mg/L) to understand the salinity process taking place in the upper (0-30 cm) layer of the soil. In order to test the different soil conditioners in the upper layer, we measured the EC_a (mS cm^{-1}) and the moisture content of the soil (v/v%) once week in three repetitions during the

Table 1: The amendments and indicator crops used in the irrigation experiment (Karcag, 2020)

Amendment type	Amendment name and dose	Components	Crops	Degree of tolerance to salinity (Rasool et al., 2012)
Biosynthetic	Neosol (micro-dose: 120 kg/ha, standard dose: 200 kg/ha)	Algae sulphated polysaccharides and trace elements (CaO, Ca, MgO, Mg). (Balusson, 2018, Szűcs et al. 2014b;2015)	chili peas beans	LT NT NT
	Physiomax (Micro-dose: 180 kg/ha, standard dose: 300 kg/ha)	Mineral CO_3 and sulphates as biostimulants (Zsembeli, Sinka, et al., 2019) (Zsembeli, Rivera-García, et al., 2019)	chili peas beans	LT NT NT
Organic	Terrasol biocompost (10 t/ha)	sheep manure 96% + zeolite 2% + mineral phosphate 2% + bacterial culture EM 1) (Monori et al. 2009; Kovács, 2013; Tuba et al. 2020b)	chili peas beans	LT NT NT

LT: low salt tolerance, NT: no salt tolerance

Figure 1: SMT-100 soil moisture probe (left) and the EC-tester (right) Source: I1, I2

Table 2: Salt inputs in the irrigation experiment (Karcag, 2020)

Crop	Number of irrigation events	Irrigation input [mm = L m^2]	Average salt concentration of the irrigation water [mg L^{-1}]	Salt mass input [g m^{-2}]
Beans	9	85	691	58.8
Peas	8	74	691	50.9
Chili	16	253	691	147.7

growing season (15th May – 25th September 2020). Former field studies and lysimeter experiments with soil conditioners carried out at RIK proved that compost (Terrasol) and biosynthetic soil conditioners (Physiomax, Neosol and Explorer) are suitable to mitigate the harmful impact of secondary salinization (Monori et al., 2009; Rivera Garcia et al., 2020; Szűcs et al., 2014b; Zsembeli, Rivera-García, et al., 2019). Nevertheless, in all these investigations, full doses of the applied amendments were studied. We wanted to complete and extend our former findings with the micro-dose application of the two investigated biosynthetic amendments revealing if it is also suitable for the mitigation of the harmful effect of secondary salinization. During the irrigation period, we regularly measured the soil moisture content (v/v%) with an SMT 100 sensor (Figure 1) by Umwelt-Geräte-Technik GmbH, while the EC_a of the upper 10 cm soil layer with a mobile HI 98331 EC-tester by Hanna Instruments.

In order to control the irrigation inputs, we monitored the precipitation data recorded at the meteorological station of RIK. To complete the irrigation schedule, we used sprinkle irrigation to maintain the crop water demand of all the experiments above wilting point, and we monitored the moisture content and maintained above 16% in order to create a suitable environment for the root zone, adopted from Sinka et al. (2019). The salt content of the water we used for irrigation was regularly measured over the irrigation period and was found to be around 700 mg L^{-1}, which is higher than the upper threshold (500 mg L-$^{-1}$) determined in the regulation as the maximum salt content of waters allowed to use for irrigation in Hungary (Zsembeli, Sinka, et al., 2019). Each crop was irrigated as indicated in Table 2 showing the irrigation and salt inputs during the period from May to September 2020. The different input of irrigation (number of irrigation events) depended on the water demand and the salt tolerance of the indicator crop species.

In order to determine the direct effect of soil conditioning on the investigated crops, their yields were measured and expressed in kg m^{-2}. The yield data were derived from the results of several harvest days according to the continuous ripening of the fruits of the crops.

We also investigated the influences of the tested soil amendments on the variables of soil moisture content and EC_a with a statistical analysis. We calculated the means of the two measured variables and calculated the PCC values with the software of Windows Office Excel 2016. PCC is the covariance, a measure of the joint variability of two variables divided by the product of their standard deviations, a measure of the amount of variation or dispersion of a set of values. This statistical analysis gives information about the magnitude of the correlation, as well as the direction of the relationship (Giacomini Sari et al., 2017). In the case of our study, PCC was calculated for the correlation between EC_a and the actual volumetric soil moisture content (Θ). In other words, irrigation with salty water induces higher salt input and soil moisture content, which represents the interaction of electrolyte solution and salts binding to the clay particles. The PCC value close to 1 represents a positive correlation showing the probability of salt accumulation (higher EC_a), hence the risk of secondary salinization is high. In contrast, PCC value tending to 0 shows no significant increase in EC_a even under irrigation with saline water due to the more intensive leaching down to the deeper soil layers and/or the influence of the plant on the salt content of the soil.

Results and discussion

The yields of the three indicator crops irrigated with saline water under soil conditioning are presented in Figure 2. It is obvious that the yields of the investigated vegetable crops cannot be compared to one another, partly because of the differences of their genetic potential, and partly because of the differences in their vegetation periods. Never-

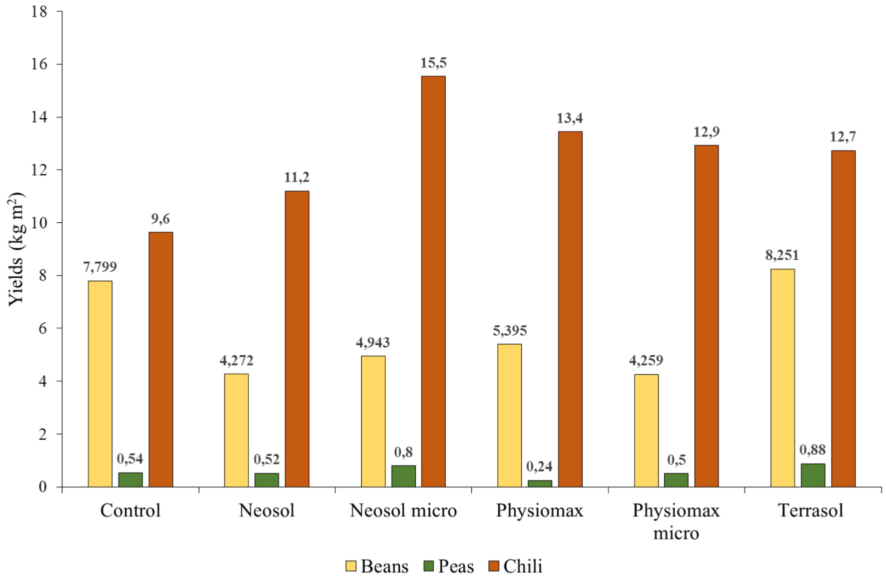

Figure 2: Yields of the indicator crops in terms of the different soil conditioning treatments

theless, the longer the vegetation period, the higher the water demand, hence the salt affection due to the irrigation with saline water. This correlation was manifested in the degree of the differences occurred among the treatments. For peas with the shortest vegetation period, the differences in the yields could not lead to the conclusion that they were due to the treatments as the yields were extremely low. For chili, which had the vegetation period until the first frost in autumn, the yield differences were expressive. Beans were in the middle in terms of the length of the vegetation period and the differences in yields as well.

The micro-dose application of Neosol and the Terrasol treatment showed positive effect on the yield of peas. Bean yields were unexpected as the second highest yield was found for the untreated control, while Terrasol was proven to be the best in this case as well. The differences in the yields of beans treated with the two soil conditioners were not significant, though micro-dosing was better for Neosol, while standard dose application of Physiomax was more favourable. In the case of chili with the longest vegetation period, all the treatments showed a yield increasing effect compared to the untreated control. We could reveal a difference between the standard dose and the micro-dose applications of Neosol (with the favour of the latter one), while this was not valid for Physiomax. The compost treatment had also positive effect on the yield of chili, just like in the cases of the other two vegetable crops.

The differences in crops yields are also related to the physiological strategies from each type of plant. Root system architecture and expansion is mostly regulated by water and nutrient uptake efficiency. According to Robin et al. (2016), under salinity stress in particular, both root hair length and density of root hairs per unit surface area decreased 25% to 40%. Liu et al. (2020) suggested that in the development of crops with large root systems could be considered as another tool to cope with soil salinization.

In order to quantify and evaluate the joint effect of soil moisture content and ECa, we differentiated 2 types of salt tolerance of the indicator crops: with no salt tolerance (NT), and low salt tolerance (LT). The PCC values determined by the ECa and moisture content of the 0–0.1 m soil layer in the function of soil conditioning are illustrated in Figures 3-

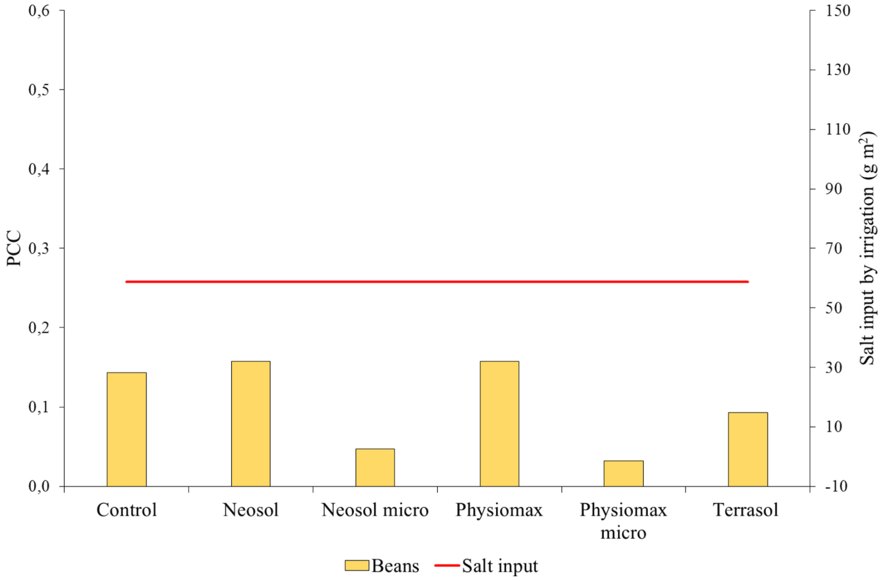

Figure 3: Pearson's correlation coefficients determined by EC_a and moisture content of the 0-0.1 m soil layer in the function of soil conditioning for beans

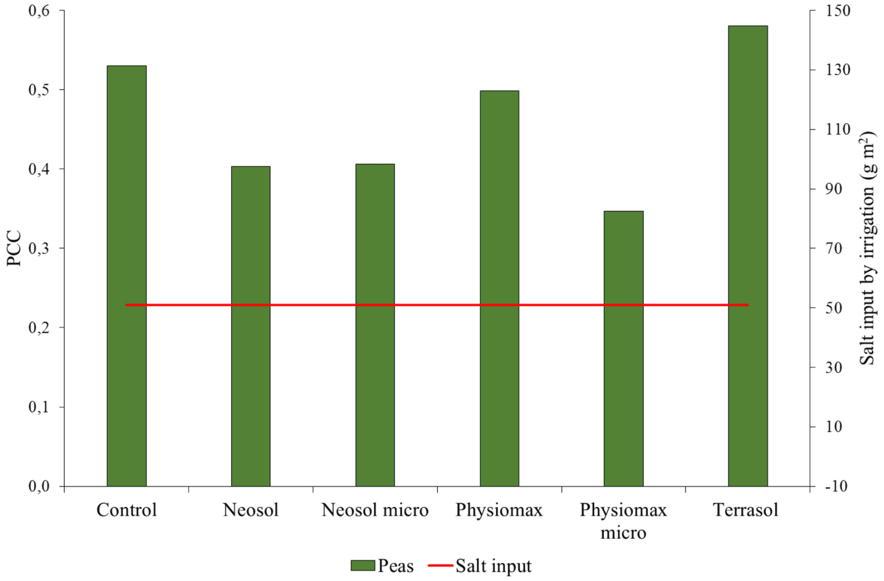

Figure 4: Pearson's correlation coefficients determined by EC_a and moisture content of the 0-0.1 m soil layer in the function of soil conditioning for peas

5.

We did not expect a big difference in the correlation between beans and peas as NT crops, but in beans, we observed that salt affected soils increase mineral availability by root exudation and protonation like a strategy under salt stress (Figures 3-4). Beans has a symbiotic association with bacteria, which fix nitrogen, which helps to reduce pH and causing changes in the root zone and it affects the correlation between soil moisture content and ECa in the top layer. Meanwhile peas cannot cope salinity as beans, but the compost addition increased yield by 60% comparing with the control (Figure 2). In addition, Terrasol compost can mitigate

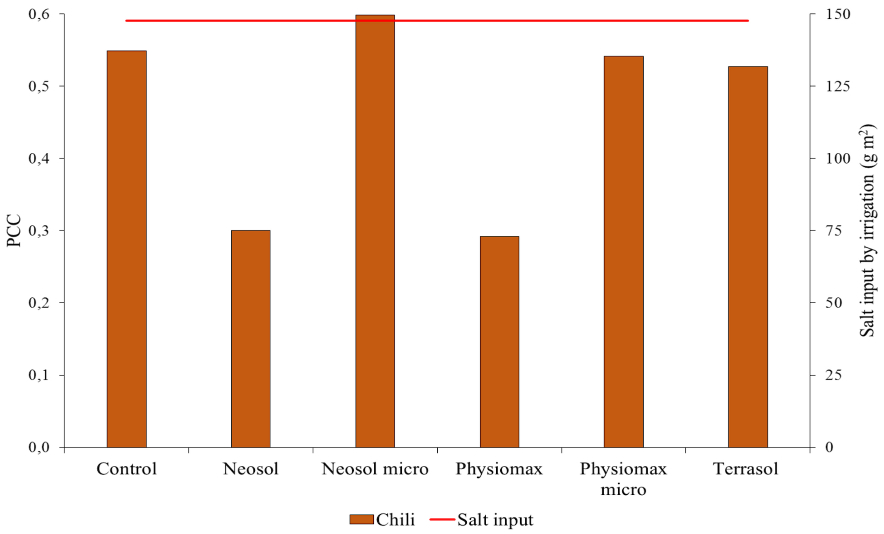

Figure 5: Pearson's correlation coefficients determined by ECa and moisture content of the 0-0.1 m soil layer in the function of soil conditioning for chili

the extent of secondary salinization and is commonly used to increase crop productivity, quality, and can improve soil structure, enhance soil fertility, increase soil microbe abundances and activity, and improve the water holding capacity of the soil (Zsembeli et al., 2015). However, in the soil, Physiomax in micro doses had better performance in both crops. In our previous lysimeter experiments with the micro-doses of Physiomax, we found that it improved the effect of leaching in the same meadow chernozem soil and helped the microbiological activity (Rivera Garcia et al., 2020; Zsembeli, Rivera-García, et al., 2019).

Chili is a LT crop and also was tested at different salt inputs and with soil conditioners (Figure 5). Sinka et al. (2019) experienced (in a previous lysimeter experiment on sweet corn) an effective improvement as a result of Neosol application in salts leaching to the deeper soil layers. One particular patent inside Neosol is the Enzyme Catalyser for Organic Substrate (ECO), which is a part of soil enzyme assays emerging as technological tools for various applications in environmental and ecosystem management (Balusson, 2018).

We identified that Terrasol biocompost is beneficial to mitigate the effect of secondary salinization in a certain salinity input range (500–1,000 g L of salt concentration of irrigation water) due to the enormous number of organic compounds in various states of decomposition creates a high content of proteins like lignin. The high content of proteins can be adsorbed by clay minerals and rendered resistant to decomposition creating a higher PCC value. This means that organic colloids supress the harmful effect of salinization under non-tolerant crops under salty water irrigation in clay soils (Foth & Turk, 1972; Kumari et al., 2020).

Biosynthetic soil conditioners interact in different ways in the soil than other amendments. Physiomax is a product that boosts the biological process in the root zone by inoculation of microorganism that can protect the root from the harmful effects of soil solution. In a former study, we found that Physiomax effected the PCC value and the yield of chili (Rivera Garcia et al., 2020). In the case of Neosol, algae proteins and clay minerals are able to leach salts and improve plant nutrition (Balusson, 2018), which is in harmony with our recent results. Comparing micro-dose application to full dose application of the investigated soil conditioners, we could establish different effects. Micro-dose application resulted in lower (better) PCC value in the following treatment/crop combinations: Neosol/bean, Physiomax/bean, and Physiomax/pea, while no difference was found for Neosol/pea. Higher PCC values were determined for Neosol/chili and Physiomax/chili.

Conclusion

Based on our results, we could identify that irrigation with saline water creates a positive correlation between soil moisture content and the salts in the upper soil layer (ECa). The correlation depended on the irrigation and the salt content coming from an aquifer (well) water and the amount of clay soil particles in the soil. The proportional positive correlation was increased by adding higher amount of salts getting down to the root zone. We expected a different correlation due to soil conditioners and biotic interactions in the soil (Foth & Turk, 1972). For example, plant growth depends on the climate conditions, irrigation and salt tolerance of the crop. In our case, the investigated meadow chernozem soil contains clayey material that cannot be easily washed. The salt particles dissolved from the irrigation water can easily attach to the soil particles due to the dissociation of anions in the soil solution. Consequently, the soil water and the salts are less available to plants roots (Hewitt & Smith, 1975).

Salinity is an abiotic risk that can cause damage in vegetable crops. In Karcag, water is a limiting factor for normal leaching techniques. Therefore, the need of amendments has been required, but the amount and kind of amendments must best ascertained by soil tests and experimentation. Irrigation with saline water resulted in a positive correlation between ECa and soil moisture content in the investigated meadow chernozem soil. This correlation is useful to monitor the soil health and risk of salt affected conditions. PCC value involves and expresses a favourable condition generated by the higher soil moisture content due to irrigation, and at the same time, it also involves and expresses the unfavourable process of salt affection induced by irrigation with saline water. We found that the harmful effect of salinity in the soil can be managed in the upper layer with plants that can cope salinity with their root architecture supported by soil conditioners or compost. We differentiated the soil conditioners depending on their application doses. We determined that micro-doses of biosynthetic conditioners can be as effective as standard (full) doses with the considerable advantage of much lower application costs. We intend to continue this research by monitoring salt mass balance to understand vertical salt movement.

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A narrative review on the use of camera traps and machine learning in wildlife research

Hanna BIJL[1] – Miklós HELTAI[1]

1: Institute for Wildlife Management and Nature Conservation, Department of Wildlife Biology and Management, Hungarian University of Agriculture and Life Sciences, H-2100, Páter Károly u. 1., Gödöllő, Hungary, e-mail: hanna_bijl@live.nl

Abstract: Camera trapping has become an important tool in wildlife research in the past few decades. However, one of its main limiting factors is the processing of data, which is labour-intensive and time-consuming. Consequently, to aid this process, the use of machine learning has increased. A summary is provided on the use of both camera traps and machine learning and the main challenges that come with it by performing a general literature review. Remote cameras can be used in a variety of field applications, including investigating species distribution, disease transmission and vaccination, population estimation, nest predation, animal activity patterns, wildlife crossings, and diet analysis. Camera trapping has many benefits, including being less invasive, allowing for consistent monitoring and simultaneous observation (especially of secretive or aggressive animals even in dangerous or remote areas), providing photo/video evidence, reducing observer bias, and being cost effective. The main issues are that they are subject to their environment, dependent on human placements, can disrupt animal behaviour, need maintenance and repair, have limitations on photographic data, and are sensitive to theft and vandalism. When it comes to machine learning, the main aim is to identify species in camera (trap) images, although emerging technologies can provide individual recognition as well. The downsides include the large amount of annotated data, computer power, and programming and machine learning expertise needed. Nonetheless, camera trapping and machine learning can greatly assist ecologists and conservationists in wildlife research, even more so as technology further develops.

Keywords: camera trapping, wildlife research, conservation, machine learning, artificial intelligence

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Introduction

Camera trapping has become a new scientific tool in wildlife conservation since the early 1990s and are increasingly being used to study and monitor animal behaviour and ecology (O'Connell et al., 2011; Rovero et al., 2013; Rovero & Zimmermann, 2016). Consequently, the demand for trail cameras in wildlife research and management continues to increase as this method meets the accrescent needs and specialisations in this field (Parker et al., 2020). Moreover, the number of scientific publications that used camera trapping has exponentially increased since the early 1990s; from less than 50 studies per year between 1991-2004 to more than 200 studies per year since 2012 (Rovero & Zimmermann, 2016). According to Delisle et al. (2021), annual publications on camera trapping increased 81-fold since 1994 but are decelerating since 2017. However, to use camera traps, whether for research or recreational purposes, all images and videos need to be classified and analysed manually when no software assistance is available. This traditional method of data analysis poses a large limitation which can result in the reduction of sampling intensity (e.g., the number of camera traps that are used), limiting the geographical extent and the duration of studies (Tabak et al., 2019). Consequently, machine learning, which is the ability of a computer to perform prediction tasks by learning from data based on an algorithm, is becoming an increasingly popular tool in wildlife conservation (Tuia et al., 2022). Therefore, machine learning can be a potential solution as it greatly reduces the time and effort needed to analyse all data, because it automatically discerns images from camera traps. Moreover, the synthesis and evaluation of international experiences are particularly important in domestic research in wildlife biology and conservation biology. The reason for this is that although camera traps are used for individual observations, collecting information, proving the presence of certain species or detecting certain behaviours, we are not aware of any large-scale projects with a large number of elements and a uniform methodology. Therefore, in this study, we undertook a literature review on camera trapping studies and the use of machine learning as a solution to analyse images or video data without time-consuming manual work and thus, providing a summary of international camera trapping application methods and current data evaluation practices.

Materials and Methods

A general literature review was conducted on the use of camera traps and the use of machine learning in camera trapping by using Web of Science as the main search engine. The review is made up of two sections: camera trapping in different field applications and the use of machine learning for processing data from camera traps. For each part, separate data collection was carried out. For the first section, the uses of trail cameras are based on Parker et al. (2020). Then, to specify the findings, further data collection was done by using the search engine with the keywords "*camera trap*" followed by the field application in question, namely *"species occupancy and distribution", "disease transmission", "population estimation", "nest predation", "activity patters", "crossing", "diet analysis"; e.g.*, camera trap activity patterns. For the second part, the keywords were "*machine learning*" AND "*camera trapping*". As there were limited results for this data collection, no further specification was needed. Keywords were looked for in the title and abstract, and publications from all years were used and from all continents. Due to the high number of results in the data collection for the first section, papers were selected based on novelty and relevance to the scope of this study. For the second section, publications within the found papers were used as well. This resulted in 1,890 papers found and 52 processed for the first section and 60 papers found and 24 processed for the second section. Overall, the list of scientific documents is not exhaustive and does not include all studies related to camera trapping and machine learning. However, we believe that the list of publications is sufficient to give a clear and concise overview of current practices of camera trapping and machine learning and the main issues with data analysis and processing.

Results

Field applications

Camera traps are an effective and common tool to collect data on different aspects of wildlife research but can be also used in hunting. In fact, manufacturers of trail cameras mainly serve the needs of North American hunters (Meek & Pittet, 2012). However, camera trapping (mainly in research) can help determine the occu pancy of certain species, analyse behaviour, investigate conservation threats, and even aid communication with policymakers and the public (McCallum, 2013). Based on Parker et al.

Table 1: Summary of the results of 10 papers on the use of camera traps in species occupancy and distribution

Main objective	Target species	Number of cameras	Main results	Source
Biodiversity monitoring to compare species richness and occupancy	Medium to large-sized mammals and pheasants	94 stations	23 mammal and 7 pheasant species; alpine/subalpine zone and dry-hot valleys have the highest richness	Li et al. (2018)
Examining distribution patterns and occupancy trends	Ground-dwelling rainforest birds	18-30 stations with two cameras per station	4083 detections of 28 bird species; occupancy in protected area complex and annual trends in occupancy at three surveyed sites for five commonly observed species	Murphy et al. (2018)
Determining the factors that affect occupancy patters	African forest elephant (*Loxodonta cyclotis*)	87 cameras	Key factors were the distance to the nearest research or ecotourism areas, the distance to the periphery and the rate of poaching index of the installation site	Kely et al. (2021)
Establishing the first range-wide baseline of occurrence	Crested black macaque (*Macaca nigra*)	111 cameras	Species occupancy of 0.66 and highest inside protected areas and closed canopy forests	Johnson et al. (2020)
Comparing two occupancy-based sampling methods	Sun bear (*Helarctos malayanus*)	60 cameras	Camera traps are a more appropriate tool to study sun bears in tropical forests	Bisi et al. (2019)
Better understanding the distribution and habitat relationship	Mohave ground squirrel (*Xerospermophilus mohavensis*)	24 cameras	Site occupancy was positively related to the length of ephemeral stream channels within a site	Kotschwar Logan (2016)
Gathering information on the ecology and distribution of muntjacs	Large-antlered muntjac (*Muntiacus vuquangensis*), northern red muntjac (*Muntiacus vaginalis*), dark muntjac species complex (*Muntiacus rooseveltorum/ truongsonensis*)	134 stations with two cameras per station	Large-antlered muntjac and northern red muntjac were widespread; dark muntjac was restricted to a single high elevation area	Alexiou et al. (2022)
Obtaining baseline data on the current distribution and abundance	Florida Key deer (*Odocoileus virginianus clavium*)	30 stations (two stations per island complex)	Abundance was well below estimated carrying capacities on all outer islands, with larger natural populations occurring closest to Big Pine Key	Watts et al. (2008)
Information on abundance and distribution	Brown hyaena (*Hyaena brunnea*)	6 cameras	Population density of 2.8/100 km2, occupancy at 1.0 and model-averaged detection probability at 0.1	Thorn et al. (2009)
Comparing scat detection dogs, cameras, and hair snares for detecting carnivores	Black bear (*Ursus americanus*), fisher (*Martes pennanti*), and bobcat (*Lynx rufus*)	74 cameras	Scat detection dogs yielded the highest raw detection rate and probability of detection for each of the target species, as well as the greatest number of unique detections	Long et al. (2007)

Table 2: Summary of the results of 6 papers on the use of camera traps in disease transmission and vaccination

Main objective	Target species	Number of cameras	Main results	Source
Estimating rates of interaction between wild and farmed deer	White-tailed deer (*Odocoileus virginianus*)	18 cameras	Little direct contact between wild and captive deer through fences	VerCauteren et al. (2007)
Monitoring carcasses of fallow deer to study the role of ungulates as disease reservoirs	Wild boar (*Sus scrofa*), red deer (*Cervus elaphus*), fallow deer (*Dama dama*)	Not specified	All carcasses were consumed by wild boar	Gortázar et al. (2008)
Identify mammalian and avian scavengers that are potentially exposed to CWD from consumption of deer carcasses	Scavengers	Not specified	Infected deer carcasses or gut piles can serve as potential sources of CWD prions to a variety of scavengers	Jennelle et al. (2009)
Determining vaccine bait contact	Raccoon (*Procyon lotor*)	7 cameras	Detected raccoon movement in all culverts; half of the bait contacts in the culverts were by raccoons	Wolf et al. (2003)
Comparing species-specific visitation and removal rates of baits with and without raccoon repellent	No specific target species	40 cameras	Cumulative bait removal rates after four nights ranged from 93% to 98%	Campbell and Long (2007)
Conducting a synthesis on banded civet habitat preferences with a focus on factors relevant to the species conservation and the risk of zoonotic disease transmission to humans	Banded civet (*Hemigalus derbyanus*)	5 cameras within a sampling area (49 areas in total)	Low likelihood of overlap with humans in degraded habitats, and therefore, a low risk of zoonotic disease transmission from the banded civet in the wild	Dunn et al. (2022)

(2020), the following field applications are explained in more detail.

Species occupancy and distribution

Camera trapping is an efficient way to monitor animal populations remotely and provide real-time observations (Parker et al., 2020). One of the most used applications is the occupancy and distribution of species, in particular rare, endangered, or elusive species (Alexiou et al., 2022; Bisi et al., 2019; Johnson et al., 2020; Kely et al., 2021; Li et al., 2018; Kotschwar Logan, 2016; Murphy et al., 2018; Parker et al., 2020) (Table 1). Traditionally, these were done by visual or auditory surveys, track counts, scat analysis, detection dogs, driven counts, and trapping (Parker et al., 2020). Moreover, camera traps can be used for remote areas as well, like the monitoring of Florida key deer on outer islands that were difficult to visit (Watts et al., 2018). Moreover, camera trapping with the help of baits can increase encounter rates and detection probability (Thorn et al., 2009). Therefore, when properly used, camera traps can be an effective tool, however, in some cases, other methods like the use of detection dogs can be more effective depending on the

Table 3: Summary of the results of 12 papers on the use of camera traps in population estimation

Main objective	Target species	Number of cameras	Main results	Source
Determining if infrared-triggered cameras could be used for population estimation of freeranging antlered white-tailed deer	White-tailed deer (*Odocoileus virginianus*)	49 stations	Population and sex-ratio estimates differed among camera-station densities, but infrared-triggered cameras are useful tools to census deer in forested environments	Jacobson et al. (1997)
Comparing data from infrared-triggered cameras and replicated helicopter counts to estimate pre-hunt population size and sex and age ratio	White-tailed deer (*Odocoileus virginianus*)	31 stations	Both techniques resulted in a reasonable population estimate for the area indicating the camera technique may be a viable option for counting deer	Koerth et al. (1997)
Investigating the utility of time-lapse photography to provide population estimates and lamb:ewe ratios	Bighorn sheep (*Ovis canadensis*)	Not specified	Failed to reject the null hypothesis that population estimates and lamb:ewe ratios from time-lapse and direct observation sampling were the same	Jaeger et al. (1991)
Developing cost-effective and quantitative methods for estimating population parameters based on mark-sight techniques using automatic camera systems	Feral hogs (*Sus scrofa*)	54 stations	Obtained sufficient sightings for reliable estimates	Sweitzer et al. (2000)
Estimating population size using camera sightings	Grizzly bear (*Ursus arctos horribilis*)	5-8 cameras per 100 km^2	Sighting rates varied considerably (18-178 camera-nights/sighting), but were generally highest during spring when attractants were more effective	Mace et al. (1994)
Estimating density	American black bear (*Ursus americanus*)	8 stations	Bear densities of 0.18 (0.09-0.32) and 1.33 (0.54-3.29) bears/km^2 on the two sites	Matthews et al. (2008)
Estimating density	Red fox (*Vulpes vulpes*)	22-30 stations	Estimated density ranged from 0.91 ± 0.12 foxes/km^2 to 0.74 ± 0.02 foxes/km^2	Sarmento et al. (2009)
Estimating density	Tiger (*Panthera tigris*)	20 cameras	Estimated population size and standard error of 29 (9.65) and a density of 6.94 (3.23) tigers/100 km^2	Karanth and Nichols (1998)
Estimating density	Bobcat (*Lynx rufus*)	10 units	Abundance estimation of 15 individuals from 56 bobcat photographs	Heilbrun et al. (2006)
Estimating density	Ocelot (*Leopardus pardalis*)	7-19 stations with two cameras per station	Densities of 25.82–25.88 per 100 km^2 in the broadleaf versus 2.31–3.80 per 100 km^2 in the pineforest	Dillon and Kelly (2007)

Table 3: continued. Summary of the results of 12 papers on the use of camera traps in population estimation

Main objective	Target species	Number of cameras	Main results	Source
Estimating density	Bobcat (*Lynx rufus*)	0.5-8 cameras/ km^2	Estimated density of 0.27 bobcats per km^2 overall in an area in the northern Sacramento River Valley and 0.35/km^2 in a steep and rocky canyon within the area; at a third site in the Coast Range, the estimate was 0.39/km^2	Larrucea et al. (2007)
Estimating relative abundance	Not specified	60 cameras	19 large and medium-sized mammal species were recorded; spotted deer was the most frequently captured species which represented high relative abundance and the rusty spotted cats were represented by a relatively low abundance	N. C. Palei et al. (2021)

specific case (Long et al., 2007).

Disease transmission and vaccination

Camera traps can aid in vaccine intake by monitoring visitation rates to the baits or individual bait consumption (Parker et al., 2020). Additionally, intra- or interspecies disease transmission can be studied by gaining knowledge on direct or indirect individual contact, such as nuzzling, faecal-oral contact, and site visitation (Parker et al., 2020). This way, camera trapping can cover knowledge gaps and therefore, aid in disease mitigation strategies and vaccine delivery methods, with lower costs and higher effectiveness (Parker et al., 2020). Several studies observed disease transmission and the intake of vaccines (Table 2). For example, VerCauteren et al. (2007) looked at possible transmission routes for bovine tuberculosis and chronic wasting disease by providing moment-of-contact pictures between wild and farmed cervids. Gortázar et al. (2008) and Jennelle et al. (2009) monitored cervid carcasses for possible ways of bovine tuberculosis and chronic wasting disease (CWD) transmission from carrion consumed by scavengers. Dunn et al. (2022) gained information on intermediator species for the SARS-CoV-1 outbreak through camera trapping. Moreover, Wolf et al. (2003) and Campbell and Long (2007) monitored baits containing vaccines for rabies by using trail cameras. Overall, using camera traps to monitor the access and behaviour of wildlife towards vaccines is not a sole data collection effort, but is rather part of a larger disease monitoring programme (Parker et al., 2020).

Population estimation

One of the most common ways to use camera trapping is in estimating population abundances. There are many (traditional) methods to estimate population size, including driven counts, strip counts, line transects, removal methods, and capture-mark-recapture strategy (Parker et al., 2020). The use of camera traps is based on the mark-recapture tech-

Table 4: Summary of the results of 10 papers on the use of camera traps in nest predation

Main objective	Target species	Number of cameras	Main results	Source
Assessing whether restricted-area culling of foxes was associated with local reduction in an index of predation risk	Red fox (*Vulpes vulpes*)	Not specified	Restricted area culling of red foxes was not associated with local reductions in predation risk, nor lower probability of a fox sighting, even for the plots with the largest hunting bags	Kämmerle et al. (2019)
Assessing conditioned food aversion (CFA) as a method to reduce nest predation	Red-legged partridge (*Alectoris rufa*)	1 camera per nest (3-4 nests in each territory)	CFA reduced ground nest predation by foxes and had a positive effect on the partridge population despite the compensatory predation	Tobajas et al. (2020)
Describe black grouse nest predators and potential predation risk	Black grouse (*Lyrurus tetrix*)	1 camera per nest (50 nests in total)	56% of nests were predated; stone marten was the main potential nest predator in both study areas, followed by common raven and red fox	Cukor et al. (2021)
Identifying duck nest predators on real and artificial nests	Boreal ducks	15 cameras	8 species of duck nest predators that ate or removed eggs from nests: American black bear, short-tailed or least weasel, Canada lynx, coyote, American marten, red squirrel, common raven, and red-tailed hawk	Dyson et al. (2020)
Highlighting the impact of a semi-feral cat on a threatened seabird	Australian Fairy Terns (*Sternula nereis nereis*) and feral cat (*Felis catus*)	2 cameras (+ human observations)	Significant predator-induced mortality, alteration of natural behaviour of nesting birds, and complete reproductive failure of 111 nests due to predation by a single, desexed, semi-feral cat	Greenwell et al. (2019)
Monitoring interspecies interactions	Harpy eagle (*Harpia harpyja*)	9 cameras	Mammals at high risk of predation that visited the nest did not avoid daylight hours	Aguiar-Silva et al. (2017)
Investigating nest visitation rates to examine their effect on breeding success	Hooded vulture (*Necrosyrtes monachus*)	Not specified	Observations of 33 species recorded at 12 nests	Thompson et al. (2017)
Assessing predation on nests	Loggerhead sea turtle (*Caretta caretta*)	12-30 traps	Yellow-spotted goannas appeared at nests more frequently than lace monitors did	Lei and Booth (2017)

Table 4: continued. Summary of the results of 10 papers on the use of camera traps in nest predation

Main objective	Target species	Number of cameras	Main results	Source
Investigating nesting biology	Nile crocodile (*Crocodylus niloticus*)	2-3 cameras per nest (in total 26 cameras)	Of 19 monitored nests, 37% were raided by predators; all females returned to their nests following first predation, and on average returned three times between predator raids before nest abandonment; water monitors and marsh mongoose were the main egg predators	Combrink et al. (2016)
Quantifying the impact of mongoose predation on iguana nests, and to assess the utility of a trap-removal program designed to mitigate mongoose impacts	Jamaican rock iguana (*Cyclura collei*) and small Asian mongoose (*Herpestes auropunctatus*)	8 cameras	Catastrophic levels of nest loss (at or near 100%) can be ameliorated or even eliminated by removal trapping of the mongoose	van Veen and Wilson (2017)

nique by using Petersen estimators (Sweitzer et al., 2000). During the "capture", the animals in the pictures are "marked" based on their physical characteristics (e.g., unique antlers, pelage, or other visible features) and then "recaptured" whenever they appear in new pictures. Camera trapping for estimating abundance has been used for a long time, for example, for white-tailed deer (Jacobson et al., 1997; Koerth et al., 1997), bighorn sheep (Jaeger et al., 1991), feral hogs (Sweitzer et al., 2000), bears (Mace et al., 1994; Matthews et al., 2008), red fox (Sarmento et al., 2009), various feline species (Dillon & Kelly, 2007; Heilbrun et al., 2006; Karanth & Nichols, 1998; Larrucea et al., 2007), and even for censusing complete areas (N. C. Palei et al., 2021) (Table 3). Even though the use of remote cameras for population estimates are encouraging, several factors need to be considered. Such as the use of baited stations to maximise captures, which violates the assumption of equal catchability, and therefore, affects the accuracy and precision of the estimate (White et al., 1982). Other factors include camera placement, sample size, survey duration and timing, which are to overcome demographic and geographic closure of highly mobile and wide-ranging species (Parker et al., 2020).

Nest predation

The identification of nest predators is usually done by using physical evidence, such as eggshell fragments or animal signs like hair, scat, or tracks (Lariviére, 1999). However, these can be subjective and time-consuming and fail to report predation by multiple predators (Leimgruber et al., 1994). Moreover, human presence in order to collect these evidences can disrupt nesting patterns or deter certain predators (Parker et al., 2020), conflicting with the very aim of the investigation. Therefore, camera traps are a preferred method by many researchers to provide information on predation events, predator identification, and timing of predation (Cutler & Swann, 1999). This method is not only used for monitoring birds' nests, such as ground nesting birds (Cukor et al., 2021; Kämmerle et al., 2019; Tobajas et al., 2020), ducks (Dyson et al., 2020), seabirds (Greenwell et al., 2019), birds of prey (Aguiar-Silva et al., 2017; Thompson et al., 2017) but also for reptiles' nests, such as turtles (Lei & Booth, 2017), crocodiles (Combrink et al., 2016), and iguanas (van Veen & Wilson, 2017) (Table 4).

Animal activity patterns

Investigating diel or seasonal activity patterns of wildlife species is essential to better understand their ecology. Additionally, activity data allows us to understand interspecific and intraspecific interactions as well as predator-prey relationships (Hernández et al., 2015; N. C. Palei et al., 2021; Foster et al., 2013; Tang et al., 2019) (Table 5). Often radiotags are used as they provide relatively large datasets that can be used remotely and in real time (Millspaugh & Marzluff, 2001). However, this method is occasionally invasive, expensive, labour intensive and often not feasible when it comes to elusive species (Lashley et al., 2018). On the other hand, camera trapping is a non-invasive method that can be used to study activity patterns due to time stamps on the images. For instance, assessing the activity patterns of deer species can result in more efficient culling programs (Ikeda et al., 2015; Soria-Díaz & Monroy-Vilchis, 2015). Another strategy which has the same idea as radiotags, is attaching a camera to the animal itself. For example, Brockman et al. (2017) used neck-mounted cameras on brown bears to determine kill rates of moose and caribou in south-central Alaska. The results showed higher kill rates than previous estimates via other methods and gives insight to the diet of the species as well. Moreover, monitoring activity patterns can also aid in reducing damage to wildlife; e.g., Christiansen et al. (2014) combined thermal monitoring with unmanned aerial vehicles, to inform landowners and managers about wildlife in their area and therefore, reduce wildlife injury and mortality during agricultural activities. Furthermore, camera traps are not only used on land; there is a novel type of remote camera that can be used under water by using stereo cameras, which greatly increases the information that can be extracted from underwater systems and marine animals (Williams et al., 2014).

Wildlife crossings

Roadways can have a negative effect on wildlife movement patterns, like its dispersal, migration, and corridor connectivity (Jackson, 2000), sometimes resulting in wildlife-vehicle collisions. Therefore, to provide safe alternative movement corridors, wildlife-crossing structures can be constructed (Ng et al., 2004). To ensure proper function, these structures must be strictly monitored on how the crossings are accepted and used by wildlife (Braden et al., 2008). In this case, camera traps are often the preferred method for data collection. Examples of this can be seen in Mexico (González-Gallina et al., 2018), India (Chakraborty et al., 2021), China (Wang et al., 2017), and Canada (Pomezanski & Bennett, 2018) (Table 6).

Diet analysis

There are direct (observation) and indirect (scat or stomach analysis, prey remains) methods for analysing wildlife diets (Lanszki, 2012). Trail cameras offer an alternative to direct observation by monitoring multiple areas simultaneously (Parker et al., 2020). This is especially the case with nesting raptors, where they found that the trail-camera system provided the largest number of prey items and is probably the least biased method (García-Salgado et al., 2015) (Table 7). However, the downside is that a lot of prey items remain unidentified to species level and it underestimates small prey, more-

Table 5: Summary of the results of 8 papers on the use of camera traps in animal activity patterns

Main objective	Target species	Number of cameras	Main results	Source
Comparing daily activity patterns and the relationship with prey	Jaguar (*Panthera onca*) and puma (*Puma concolor*)	34-119 stations with two cameras per station	Both cats showed intensive nocturnal and crepuscular activity; only in one region a pattern of concentrated diurnal activity for both species was observed; little temporal segregation; significant overlap between the activity patterns of the predators and their main prey species	Foster et al. (2013)
Exhibiting activity patterns by spotted and melanistic colour morphs	Guiña (*Leopardus guigna*)	127 stations	Guiñas are mainly active at night; melanistic guiñas were more nocturnal than the more common spotted cats; spotted guiñas were more active on cloudy and moonless nights	Hernández et al. (2015)
Detecting population size and activity patterns	Eurasian lynx (*Lynx lynx*)	50 cameras	20 lynx identified; daily activity rhythms overlapped with those of different prey in different seasons; yearly activity pattern was influenced by its main prey's biology	Tang et al. (2019)
Investigating activity pattern in relation to prey	Leopard (*Panthera pardus*)	211 cameras	Cathemeral activity pattern and positive co-occurrence pattern and significant spatial and temporal overlap with its main prey, the wild pig	H. S. Palei et al. (2021)
Investigating activity patterns in central Mexico	White-tailed deer (*Odocoileus virginianus*)	10 cameras	Mostly diurnal with activity peaking between 16:00-18:00h and 10:00-12:00h; the peak activity at night was between 0:00-2:00h with low or no crepuscular activity	Soria-Díaz and Monroy-Vilchis (2015)
Investigating seasonal variation of activity patterns	Sika deer (*Cervus nippon*)	12 cameras	Deer activity at dawn, dusk and night showed clear seasonal patterns, with peaks in September, while the activity pattern during the day was constant in all seasons; activity at dawn and dusk tended to be higher than that at day during Jul–Oct and Jul–Nov	Ikeda et al. (2015)
Estimating kill rates by individual bears	Brown bear (*Ursus arctos*)	17 cameras	Kill rates considerably greater than previous estimates; median handling times were 40 min for caribou calves and 60 min for moose calves	Brockman et al. (2017)

Table 5: continued. Summary of the results of 8 papers on the use of camera traps in animal activity patterns

Main objective	Target species	Number of cameras	Main results	Source
Assessing the suitability of thermal imaging in combination with digital image processing to automatically detect a chicken and a rabbit in a grassland habitat	Domestic rabbit (*Oryctolagus cuniculus domesticus*) and a domestic chicken (*Gallus domesticus*)	1 camera	The study animals were detected with a high precision, although the most dense grass cover reduced the detection rate; thermal imaging and digital imaging processing may be an important tool for the improvement of wildlife-friendly farming practices in the future	Christiansen et al. (2014)

over, cameras can alter the birds' behaviour which is an aspect that must be controlled (García-Salgado et al., 2015). Although using cameras for diet analysis has mainly been done for raptor species, it has also been used for bats (Pereira et al., 2017), although these studies are usually in combination with other diet analysis methods.

Data management and machine learning

Difficulties of manual data processing

Camera trapping can be used in a variety of applications and provides many benefits. However, one of its main limiting factors is the processing of data. Sometimes millions of images need to be visually reviewed one by one in order to extract information (Tabak et al., 2019). Newey et al. (2015) showed that one camera typically captures around 2,000–10,000 images per month of deployment, which only increases the more cameras are used. Although this greatly varies per habitat and species activity, it displays the amount of effort it would take to process these images. Consequently, one of the problems they experienced was falling behind in cataloguing images due to a lack of in-built tools to facilitate image and data management (Newey et al., 2015). An additional problem might be the asynchrony between camera trap units, which makes it difficult to compare images from different cameras but mainly hinders the linking of imagery to corresponding (time-stamped) meteorological data (Newey et al., 2015), if this is one of the objectives of the study. This results in manually extracting weather variables from the meteorological data and linking them with the appropriate images and then augmenting by visual assessment of weather from images, which is a long process that took around 14 hours for every 1,000 images (Newey et al., 2015). Therefore, processing imagery manually can cause latency and is time-consuming and costly, moreover, these limitations will only increase as camera trapping becomes more complex (Duggan et al., 2021).

Machine learning models

Although models can be individually made, this requires a lot of annotated data, computer power, and programming and machine learning expertise (Carl et al., 2020). Therefore, there are several pre-trained, open-source example models available for object detection and classification of camera (trap) images for certain datasets. The most common object detectors include Faster R-CNN (region convolutional neural network (Ren et

Table 6: Summary of the results of 4 papers on the use of camera traps in wildlife crossings

Main objective	Target species	Number of cameras	Main results	Source
Describing differential use of available crossing structures	Mammals	28 cameras	24 jaguar crossings; at least 18 other mammal species including five of the target priority species (protected by Mexican law) were documented; wildlife underpasses show higher diversity values compared to culverts because they allow bigger species to cross	González-Gallina et al. (2018)
Assessing corridor's functionality	Not specified	5 cameras	39 mammal and avian species were identified; elephants used the corridor patch most frequently, followed by hog deer, while hog badgers were most rarely recorded	Chakraborty et al. (2021)
Determining what species uses wildlife crossing structures to cross the highway, the frequency, and time of crossings	Not specified	8 cameras	A total of 13 medium and large-sized wildlife species crossed the highway; one third of species were Chinese national protective species, and almost all species that were present within 500 m from the highway used bridges and culverts to cross this highway	Wang et al. (2017)
Characterising the seasonal and daily usage patterns of species using crossing structures	Not specified	2 cameras	Of the 1178 mammal crossing events, 74% were by small mammals and 26% were by larger mammals; large mammal crossings took place consistently, while small mammal crossings were particularly frequent during September and October	Pomezanski and Bennett (2018)

al., 2017)), R-FCN (region-based fully convolutional network (Dai et al., 2016)), SSD (single shot multibox detector (Liu et al., 2016)), FPN (future pyramid network (Lin, Dollár, et al., 2017)), RetinaNet (Lin, Goyal, et al., 2017), and YOLO9000 (you only look once (Redmon & Farhadi, 2017)). According to a summary of object detectors by Hui (n.d.), one of the best models is the combination of Faster R-CNN and Inception-ResNet V2, which results in a high average precision. Moreover, by using bounding boxes, it is easier to identify the region of interest which surrounds the animal (Carl et al., 2020), because models without these are problematic (Miao et al., 2019). This means that when using images of the same camera trap, the background stays the same and when a specific animal frequently visits this area, false results are given when a new animal appears (Carl et al., 2020). Hence, bounding boxes can aid in detecting the animal and classifying the animal(s) within the boxes (Carl et al., 2020). See Figure 1 for examples of the use of Faster-RCNN+InceptionResNet V2.

Species identification accuracy

The main aim of object detectors in machine learning in wildlife research is to detect and

Table 7: Summary of the results of 2 papers on the use of camera traps in diet analysis

Main objective	Target species	Number of cameras	Main results	Source
Evaluating the usefulness of commercially available trail-cameras for analysing diet	Northern goshawks (*Accipiter gentilis*)	1 camera per nest (80 nests)	Cameras registered the greatest number of prey items and were probably the least biased method for estimating diet composition	García-Salgado et al. (2015)
Providing evidence on the consumption of leaves	Seba's short-tailed bat (*Carollia perspicillata*)	1 camera	Consumption of the whole leaf (juices and fibers), which was never recorded in Neotropical bats	Pereira et al. (2017)

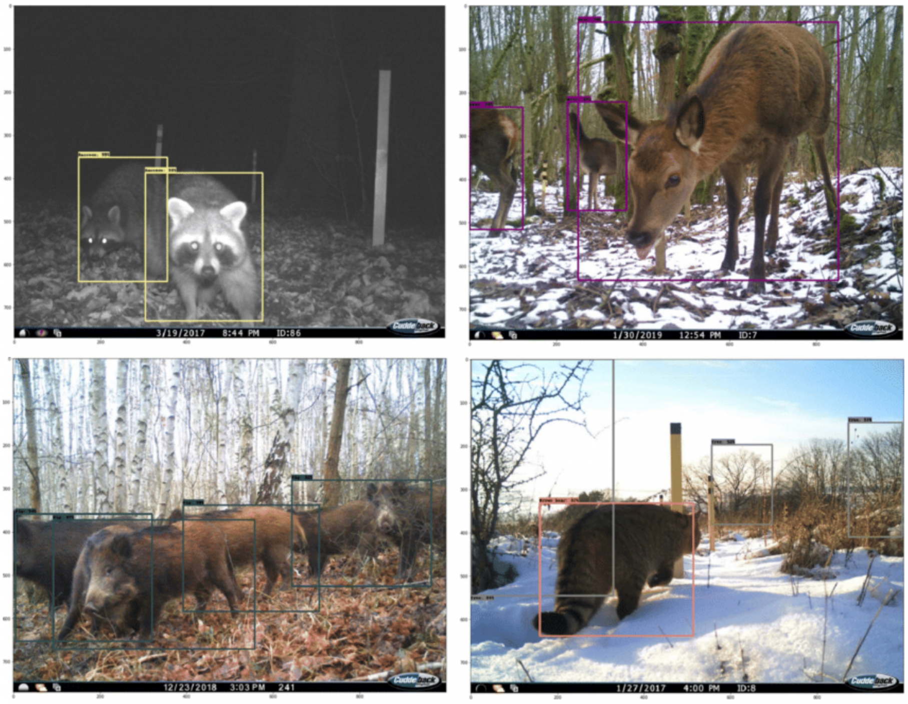

Figure 1: Detection and classification of wildlife species using Faster-RCNN+InceptionResNet V2 network - examples of correct classification (upper images) and none detection (two hidden wild boars) and incorrect classification ("brown bear" instead of "cat") (lower images) (Carl et al., 2020).

classify animal species in camera trap images. Depending on the model(s) used and the training process beforehand, there are different rates of accuracy. Norouzzadeh et al. (2018) used deep learning models to automatically identify the species, their numbers, the presence of young animals, and even the behaviour of the animals in the Serengeti in Africa with an accuracy of 93.8%. Miao et al. (2019) utilised the same dataset to analyse the usability to classify and cluster 20 wildlife species with 87.5% accuracy. Banupriya et al. (2020) used machine learning to test the applicability to classify elephants and cheetahs with an accuracy of 79%. Carl et al. (2020) looked at ten different European wildlife species and found a classification accuracy of 71% for the correct name of the species as mammals and 93% for the correct species or higher taxonomic ranks. The highest accuracy rate was achieved by Tabak et al. (2019) with 98% by using CNNs with the ResNet-18 architecture and 3.37 million images. Kutugata et al. (2021) came close with an overall accuracy of 97% with 120,000 images. Moreover, Bilodeau et al. (2022) represent the first successful method for underwater camera trap deployment and machine learning classification of fish; they achieved 92.5% accuracy with over 100,000 images.

Furthermore, machine learning can be used not only for identifying objects in images, but also for identifying empty images (false positives) and deleting these, which is one of the most acknowledged problems in camera trapping, along with false negatives (Newey et al., 2015). False triggers like wind or lose shrubs as well as camera settings and animal behaviour specific to a camera site will add noise to the dataset (Newey et al., 2015). Wei et al. (2020) compared a freely available software Zilong with a CNN-based R package MLWIC (Machine Learning for Wildlife Image Classification) and found that Zilong performed better than MLWIC in identifying empty images; Zilong identified 87% of animal images and 85% of empty images correctly, whereas MLWIC identified correctly 65% and 69%, respectively. However, Tabak et al. (2020) found that MLWIC2 performed with 97.3% accuracy in their empty-animal model. In this case, the high accuracy rate can be attributed to the high number of training images (three million).

Taking it a step further, there are emerging technologies to identify not only the species but also individuals for species that lack consistent or unique body markings. Clapham et al. (2020) used object detection, landmark detection, a similarity comparison network, and a support vector machine-based classifier to identify brown bear individuals. They achieved facial detection with an average precision of 0.98 and an individual classification accuracy of 83.9% based on 4674 images with an 80-20% split for training and testing, respectively (Clapham et al., 2020). de Silva et al. (2022) similarly looked at individual identification, but in wild Asian elephants by using five different types of CNN models. The highest level of accuracy was achieved by using an Xception model which was specifically trained on the ears of the elephants and reached an accuracy of 89.02% for matching the top candidate and 99.27% for including the right individual in the top five (de Silva et al., 2022). Sforzi and Lapini (2022) propose new criteria to evaluate European wildcats from domestic cats from camera trap observations; however, be it either human or computer, specific expertise on the identification of the species in question is needed. To further increase accuracy, another method is combining both artificial intelligence and humans as a way to increase data processing efficiency, for example, where machine learning is used as an additional vote to citizen science (Adam et al., 2021; Green et al., 2020; Willi et al., 2019).

Discussion

Since the invention of the camera traps in the late 1860s by George Shiras III and the rediscovery by Seydack in 1984, the use of remote cameras has significantly increased since then (Rovero & Zimmermann, 2016). Camera trapping has many benefits, including being less invasive, allowing for consistent monitoring and simultaneous observation (especially of secretive or aggressive animals even in dangerous or remote areas), providing photo/video evidence, reducing observer bias, and declining costs (Parker et al., 2020). Additionally, the effectiveness of camera systems is dependent on their technology, i.e., battery life, data storage capacity, and picture/video quality (Parker et al., 2020). Consequently, the better the technology, the more opportunities this tool can provide, whereas the worse the technology, the harder it is to apply. Moreover, the usefulness largely depends on the quality of the study design and the capabilities of the operator (Parker et al., 2020). The opportunities for camera traps are in areas or situations where humans would cause disturbance to wildlife, extended observational periods are required, monitoring takes place in dangerous and/or remote areas, permanent and provable data is needed, or just different capabilities from the human eye are needed (Parker et al., 2020). Also, Dubois and Harshaw (2013) found that the general public is more supportive of less invasive data collection techniques, including camera trapping, than other techniques where animal handling or killing is needed. On the other hand, the negatives of camera traps are that they are subject to their environment, dependent on human placements, can disrupt animal behaviour, need maintenance and repair, limitations of photographic data, and the sensitivity to theft and vandalism (Parker et al., 2020). For example, Meek et al. (2019) found that the theft of camera traps is a global issue with a maximum financial loss of USD 1.48 million between 2000 and 2015. Also, according to Newey et al. (2015), one of the main issues with camera trapping is data management; e.g., large number of images, highly variable proportion of false positives/negatives, even between locations, time periods of cameras, and the lack of tools to simultaneously log or match external data sources to the images. Therefore, machine learning could partially solve these issues and reduce the burden of manual classification (Table 8).

However, to use machine learning models, advanced computational skills are needed, which quickly make them inaccessible to biologists (Tabak et al., 2020). Machine learning also never has a 100% accuracy level and largely depends on the information that is provided during the training process. van Horn et al. (2015) support this by mentioning that learning algorithms are robust to annotation errors and training data corruption. However, Gomez Villa et al. (2017) emphasise that if a training set has sufficient samples, then the results show robustness to data corruption, which can be achieved with the help of citizens. Consequently, object recognition problems can be reduced. This is further supported by Norouzzadeh et al. (2018), who show that deep learning technology can save 98.2% of manual labour with an accuracy level of 96.6%, and that this time (over 17,000 hours) could be redirected to other scientific purposes. Lastly, Tuia et al. (2022) highlight the importance of interdisciplinary thinking, as processing big ecological data requires complex analytical techniques that no single conservationists or biologist can carry out on their own. Overall, camera trapping along with the use of machine learning can greatly assist ecologists and conservationist in wildlife research, even more so as technology further develops.

We encourage wildlife biologists to utilise (open-source) software and machine learning algorithms and cooperate with computer programmers to optimise the use of available modern technology in wildlife research, especially when analysing camera trap data. Moreover, the use of such data management solutions should be user-friendly, accessible, and preferably open-source (Steenweg et al., 2017). This could also aid in increasing the transparency and repeatability of projects (Young et al., 2018), and provide a standardised solution (Scotson et al., 2017). Whether the project is big or small, the understanding of ecological systems and closing knowledge gaps should be at the forefront and consume

Table 8: SWOT analysis of the use of machine learning algorithms for trail camera data analysis

Strengths	Opportunities
• Decreases human labour • Decreases the amount of human error • Saves money as no human employment is needed	• Robustness to data corruption • Can be paired with citizen science • Can process big data
Weaknesses	Threats
• High number of training images are needed for high accuracy • Advanced computational skills are needed • Individual models need to be made first according to the given datase • Data annotation during training is time-consuming	• Unbalanced dataset with uncommon species can cause issues • Errors in image objectification (false positives/negatives) • Very few open-source algorithms

most of the time instead of generating big data (Nichols et al., 2011; Steenweg et al., 2017; Young et al., 2018)).

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MAGYAR AGRÁR- ÉS ÉLETTUDOMÁNYI EGYETEM

Columella

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Influence of agricultural effluent irrigation on common purslane (*Portulaca oleracea* L.) and garden basil (*Ocimum basilicum* L.): preliminary results

Noémi Júlia VALKOVSZKI[1] – Mihály JANCSÓ[1] – Árpád SZÉKELY[1] – Tímea SZALÓKI[1] – Ildikó KOLOZSVÁRI[1] – Ágnes KUN[1]

1: Hungarian University of Agriculture and Life Sciences, Institute of Environmental Sciences, Research Center for Irrigation and Water Management, Szarvas, Hungary, e-mail: Valkovszki.Noemi.Julia@uni-mate.hu

Abstract: The agricultural costs can be reduced with waste water application. The effect of water quality was tested on several parameters of purslane and basil. Four treatments were applied (Irr0: non-irrigated control; Irr1: effluent water from an intensive African catfish farm; Irr2: diluted effluent water with gypsum; Irr3: Körös-oxbow lake water as irrigated control). Completely random sampling was used, ten plants were measured per treatment. The purslane developed the most shoots by Irr0 (8.70 number plant^{-1}); and the treatment of Irr3 decreased it significantly (4.80 number plant^{-1}). Regarding the fresh root weight, significant difference was found between the Irr0's maximum value (7.83 g plant^{-1}) and the Irr3's minimum one (3.87 g plant^{-1}). For biomass Irr0 treatment resulted in the maximum yield (413 g plant^{-1}); there were not significant differences among the treatments. Very strong positive correlation was noted between the fresh root weight and the biomass ($p = 0.01$; Pearson's $r = 0.84$). Based on our result purslane does not require high amount of water. For basil the benefical effects of Irr3 irrigation were detected; there were significant differences among the treatments. The highest values of the parameters were in Irr3: plant height (47.96 cm), root length (23.22 cm), biomass (164 g plant^{-1}, fresh floral shoot tip (85.56 g plant^{-1}), fresh stem (78.44 g plant^{-1}) and fresh root weight (9.38 g plant^{-1}). At basil very strong positive correlation was evinced between the biomass, and fresh root weight ($p = 0.01$; Pearson's $r = 0.87$). The significantly more yield was achieved by irrigation on basil. Irrigation with undiluted effluent water (Irr1: biomass: 124.50 g/plant) is similarly effective to increase yield, as in Irr3.

Keywords: herbs, irrigation, salinity, yield, waste water

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Introduction

Around the world the raw matter production as cost-effectivly as possible is the one of the most important factors during the growing season of herbs. Due to climate change weather extremities are more frequent nowadays, the precipitation does not fall in the right time and it occurs in unpredictable amount; as a result the irrigation contributes to an increasingly bigger part of the production costs nowadays.

In the future, the solution can be preferably herbs such as purslane (*Portulaca oleracea* L.) that do not require irrigation or irrigation with effluent water from agricultural sector can be applied in case of plants with high water requirement such as basil (*Ocimum basilicum* L.).

Portulaca oleracea L. is a herbaceous succulent annual plant with a cosmopolitan distribution belongs to the Portulacaceae family, is commonly known as purslane in English. It is consumed extensively as a

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potherb in many Mediterranean and tropical Asian countries and added in soups, salads and has been used as folk medicine. Diverse compounds have been isolated from *Portulaca oleracea*, such as flavonoids, alkaloids, polysaccharides, fatty acids, terpenoids, sterols, proteins vitamins and minerals. *Portulaca oleracea* possesses a wide spectrum of pharmacological properties such as neuroprotective, antimicrobial, antidiabetic, antioxidant, anti-inflammatory, antiulcerogenic, and anticancer activities (Zhou et al., 2015). The purslane is an alternative source of omega-3 fatty acids (Petropoulos et al., 2015).

Basil wellknown as sweet or garden basil, a member of the Lamiaceae family, is cultivated throughout the Mediterranean region (Abbas, 2010). Its fresh, dried leaves and floral shoot tip are used as carminative, galactogogue, stomachic and antispasmodic medicinal plant in traditional medicine (Sajjadi 2006). The potential uses of *O. basilicum* essential oil has been investigated, especially as antimicrobial and antioxidant. The chemical composition of basil essential oil has been studied in several studies. The main effective compounds of *O. basilicum* are methyl chavicol, linalool, methyl cinnamate, methyleugenol, eugenol and geraniol (Sajjadi, 2006). One of the most important positive effects of using wastewater is the reduction in agricultural cost. This type of water is usable throughout the year and has no access restrictions (Jiménez, 2006; Khater et al., 2015).

The use of fish farm effluent in plant production has been reported for the cultivation of several species, such as tomato (Castro et al., 2006; Jchappell et al., 2008; Khater et al., 2015), basil, marigold (Hundley et al., 2013), lettuce (da Rocha et al., 2017), legumes (Silva et al., 2018), potato, soybean, onion (Abdelraouf, 2019), rice (Ibadzade et al., 2020), and willow (Kolozsvári et al., 2021). The combination of fish farming and agriculture can reduce the need for irrigation (McMurtry et al., 1997). The use of saline water for irrigation on various crops, such as quinola and ocra, has already been implemented (Azeem et al., 2020; del Carmen Rodríguez-Hernández et al., 2021).

In some cases, the effluent waters from fish farming can contain high saline level due to its origin (Kolozsvári et al., 2021). Significant salt tolerance had been already published on *Melissa officinalis*, *Echinacea purpurea*, *Thymus vulgaris* and *Matricaria chamomilla* (Bistgani et al., 2019; Omer et al., 2014; Ozturk et al., 2004; Sabra et al., 2012). Utilization of wastewater and compost increased the basil yield and nutrient content (Marofi et al., 2015). Alam et al. (2015) investigated the effect of salinity (0, 8, 16, 24 and 32 $d\mathrm{Sm}^{-1}$) on 13 purslane genotypes: salinity stress caused significant reduction in all measured parameters (biomass production, physiological parameters, and stem-root anatomical changes) and the highest salinity level showed more detrimental effects compared to the control.

According to Kafi and Rahimi (2011) salinity caused a reduction in purslane root and shoot growth (volume, area, diameter, total and main length and root dry weight). According to He et al. (2021) plants grown with 100 mM NaCl had the highest productivity and the fastest leaf growth followed by those with 0, 200 and 300 mM NaCl. Purslane grown with 300 mM NaCl had the lowest specific leaf area, highest leaf dry matter content and the lowest water content.

The purslane can cumulatively remove considerable amounts of salt from the soil in practice to cultivate as an intercrop in orchards. In this regard, 6.5 $d\mathrm{Sm}^{-1}$ can be concluded as the threshold salinity level for the purslane managed to be intercropped (Kiliç et al., 2008). In the short vegetation period of *Portulaca oleracea* can be grown high fresh weight yields of about 70 t ha^{-1} (Kiliç et al., 2008). As for results of Bekmirzaev et al. (2021), *P. oleracea* is resistant to salinity, is able to remove sodium ions (400–500 kg ha^{-1} NaCl), and can be grown in saline soil. Inhibitory effects of salinity on biomass production of the shoot and the root, and area of individual leaves were apparent already under cultivation with 25 mM NaCl. Elevation of salinity from 1 to 100 mM NaCl induced 63% and 61% reductions in fresh and dry herb biomass production, respectively (Bernstein et al., 2010). The results reveal that salinity caused significant decreases in growth of basil (Heidari, 2012). Significant decreases in yields were resulted in by increasing salinity levels from 0.4 to 8.0 $d\mathrm{Sm}^{-1}$. However, basil could able to survive at high salt stress (Caliskan et al., 2017). The increase in salinity was detrimental to all evaluated variables in both cultivars, but the cultivar 'Roxo' was more tolerant than the cultivar 'Verde'. Both cultivars are tolerant to irrigation water salinity of up to 1.5 $d\mathrm{Sm}^{-1}$ (Maia et al., 2017). The salt tolerance decreased in the respective order of basil $\approx$ sage > thyme > oregano (Tanaka et al., 2018).

Omeir et al. (2019) published that irrigation with effluent water of fish farm significantly increased the fresh and dry weight of shoot and root, leaf number, and stem height both in purslane and basil, too. In the fish farm treatment, the fresh weight of shoots increased 203% and 250% compared to river water irrigation, in basil and purslane, respectively. The using of effluent water of fish farm in irrigation may satisfy water requirement.

Our aim was to prove the suitability of the effluent water irrigation to grow common purslane and garden basil.

Materials and Methods

The experiment was carried out at the MATE IES ÖVKI Lysimeter Station in Szarvas, Hungary in 2021. The soil of the experimental field was charaterized by low humus content, slightly alkaline, clay loam (Filep, 1999). Nitrogen supply is poor, phosphorus supply is excessive and the potassium content of the soil is high (Hoppe, 2009; Kádár, 1992; MéM NAK, 1979) (Table 1.).

The season was drier and warmer than the 30-year average (1981–2010). June was very dry, because only 1.2 mm was the natural precipitation. The irrigation was carried out seven times from May to August. Overall, the total amount of irrigation was 105 mm (Table 2.).

Effect of water quality was tested on several parameters of purslane and basil. Four treatments were applied. (Irr0: non-irrigated control; Irr1: Effluent water from an intensive African catfish farm; Irr2: Diluted effluent water with gypsum: 1/3 effluent water+2/3 Körös-oxbow water+ 0,312 kg m^{-3} gypsum; Irr3: Körös-oxbow lake water as irrigated control). The effluent water has higher macro nutrient content than water of Körös oxbow. The Na- content of Irr1 was ten times higher than to Irr3 (Table 3.).

Completely random sampling was used, ten plants were measured per treatment. In case of purslane four plant properties - plant diameter (cm), number of offshoots (number plant^{-1}), shoot length (cm), root length (cm)- and two yield parameters - fresh root weight (g plant^{-1}) and biomass weight (g plant^{-1}) - were studied. On basil five plant properties - plant height (cm), plant diameter (cm), number of offshoots (number plant^{-1}), root length (cm), and SPAD value - and six characterising features of yield - weight of biomass, floral shoot tip, dry herba, fresh stem, fresh root, dry root (g plant^{-1}) - were examined.

SPAD values were measured with Konica Minolta SPAD-502 chlorophyll meter from an average of 6 replicates per stem. The SPAD value was determined on the third mature leaf pair under the floral part. The weight of fresh biomass, fresh floral shoot

Table 1: Characteristics of the soil of experimental field (Szarvas, 2021)

Soil depth	pH (KCl)	Soil texture	Total carbonate content (% w w^{-1})	Humus (% w w^{-1})	Nitrite + Nitrate-N (KCl) (mg kg^{-1})	P_2O_5 (AL) (mg kg^{-1})	K_2O (AL) (mg kg^{-1})	Na (AL) (mg kg^{-1})
0-30 (cm)	7.21	clay loam	1.14	2.20	3.64	2230.00	609.00	77.60

Table 2: The comparison of monthly precipitation and temperature data between the study period and reference period (1981-2021)

Season	Precipitation (mm) 2021	Precipitation (mm) 1981-2010	Average Temperature (°C) 2021	Average Temperature (°C) 1981-2010	Irrigation (mm) 2021)
January	48.90	29.10	1.76	-1.04	0.00
February	33.90	29.93	3.10	0.54	0.00
March	10.30	27.83	5.98	5.59	0.00
April	62.50	42.03	9.08	11.47	0.00
May	65.10	50.57	14.75	16.80	15.00
June	1.20	61.27	22.74	19.84	75.00
July	48.30	57.53	25.15	21.91	15.00
Sum or Average	270.20	298.26	11.79	10.73	105.00
Season of May–July	114.60	169.37	20.90	19.50	105.00

tip, fresh stem parts were measured with CAS 25 type scales and the fresh root, the dry root and dried herba of basil weight were measured with CAS MWP-1500. The leaves, floral shoot tips and roots were dried in the ÖVKI Laboratory for Environmental Analytics in Szarvas in a Memmert UFP 800 oven at 40 °C.

Basil seedling was planted on May 17, 2021. In 40 cm row space and 15 cm planting distance. Harvest was done on July 8, 2021.On purslane plant number setting was done on June 8, 2021 from natural weed flora of the Lysimeter Station in 40 cm row space and 40 cm planting distance. Harvesting was in July 16, 2021.

To the evaluation of the results MS Excel 2012 and IBM SPSS 22 softwares were used. The outliers were excluded from further analysis. The variances ($p = 0.05$) of parameters in the four irrigation treatments were compared with one-way analysis of variance (ANOVA). Tukey test was applied at Post Hoc test. The relationships were determined between the plant properties by Pearson's correlation ($p = 0.01$).

Results

Results of purslane

Regarding the plant diameter there were not significant differences among the treatments; the highest diameter was detected in the diluted effluent water plus gypsum treatment (Irr2) (75.1 ± 11.06 cm). Significant differences were found only in case of the number of offshoots between Irr0 (8.7 number

Table 3: Characteristics of effluent water from intensive fish farming (Irr1) and Körös oxbow water (Irr3) (Szarvas, 2021)

Characterstics of irrigation water	Effluent water	Körös oxbow water
Temperature of water (in laboratory)* (°C)	20.00	16.60
pH (in laboratory)	7.88	7.67
Specific electric conductivity (20 °C) (μS/cm)	1380.00	329.00
Total alkalinity (p-alkalinity) (mmol l^{-1})	<0.10	<0.10
Total alkalinity (m-alkalinity) (mmol l^{-1})	16.70	2.79
Carbonate (mg l^{-1})	<6.00	<6.00
Bicarbonate (mg l^{-1})	1 016.00	170.00
Ammonium ion (mg l^{-1})	36.10	0.45
Ammonium-N (mg l^{-1})	28.00	0.35
Nitrite ion (mg l^{-1})	0.26	0.10
Nitrite-N (mg l^{-1})	0.08	0.03
Nitrate ion (mg l^{-1})	<0.44	2.80
Nitrate-N (mg -1)	<0.10	0.63
Total N (mg l^{-1})	40.60	1.69
Orthophosphate ion (mg l^{-1})	4.88	0.17
Orthophosphate -P (mg l^{-1})	1.59	0.06
Total P (mg l^{-1})	3.68	0.07
Chloride (mg l^{-1})	33.50	20.90
Sulphate (mg l^{-1})	62.40	33.50
Total floating matter (mg l^{-1})	80.00	6.00
Natrium (mg l^{-1})	276.00	22.60
Potassium (mg l^{-1})	6.51	3.00
Calcium (mg l^{-1})	18.80	47.10
Magnesium (mg l^{-1})	8.30	8.57

plant^{-1}) and Irr3 (4.8 number plant^{-1}). As for plant diameter, shoot length and root length did not show any differences among the treatments. As for results of shoot length and root length too, the highest values were caused by diluted effluent water plus gypsum (Irr2) treatment, but there were not any significant differences among the treatments (Table 4.). There was a significant difference between the Irr0 (7.83 g plant^{-1}) and Irr3 (3.87 g plant^{-1}) at the fresh root weight. The treatment of Irr0 resulted the maximum yield per plant (413 g plant^{-1}); the minimum was detected at Irr3 (261.5 g plant^{-1}). and no found significant difference among the treatments (Figure 1.). However, very strong positive correlation was calculated between the biomass and fresh root weight ($p = 0.01$; Pearson's $r = 0.84$). Based on our result purslane is not requires high amont of water.

Results of basil

As for the results of plant diameter and number of offshoots we could not prove the ef-

Table 4: Results of effect of irrigation treatments on purslane plant diameter (cm), number of branches (n./plant), shoot length (cm), root length (cm) (Szarvas, 2021)

Properties of purslane plant	Non irrigated control (Irr0)	Effluent water (Irr1)	Diluted effluent water+gypsum (Irr2)	Körös-oxbow water (Irr3)
Plant diameter (cm)	74.9±10.66 a	69.1±8.54 a	75.1±11.06 a	72.6±12.98 a
Number of offshoots (number plant^{-1})	8.7±2.83 b	7±3.13 ab	6.2±0.92 ab	4.8±1.4 a
Shoot length (cm)	38.85±6.16 a	38.6±4.02 a	39.64±5.59 a	37.53±5.37 a
Root length (cm)	20.7±3.91 a	21.8±1.69 a	22.25±3.23 a	18.9±3.54 a

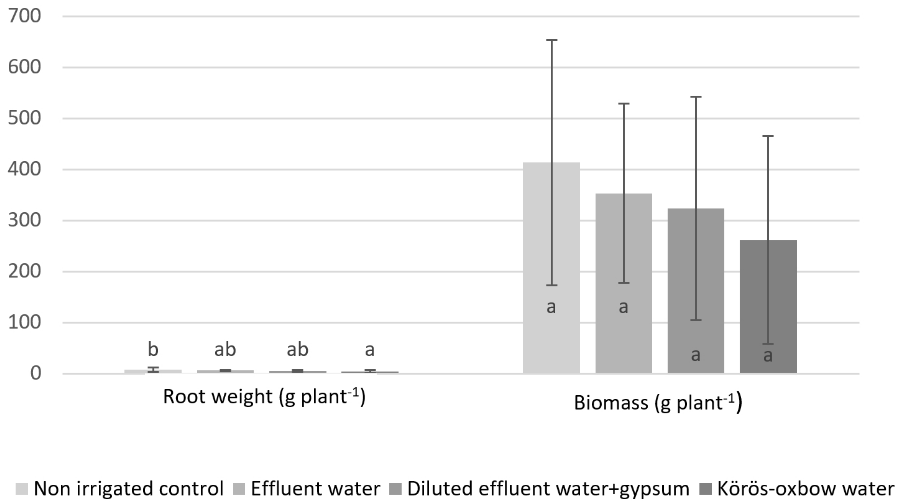

Figure 1: Yield results (biomass and root weight (g plant-1)) of common purslane (Szarvas, 2021)

fectiveness of the irrigation treatments; however, the Körös-oxbow lake water resulted the highest values (plant diameter: 30.05 ± 5.93 cm and number of offshoots: 15.6 ± 2.22 number plant^{-1}). In contrast, we could find significant differences between the Irr0 and Irr3 treatment at the plant height and root length. Although as for SPAD value the minimum (39.68 ± 2.07) was resulted by Irr3 treatment (Table 5.). Regarding the Körös oxbow water treatment (Irr3), in biomass (164 g plant^{-1}), fresh floral shoot tip (85.56 g/plant), fresh stem weight (78.44 g plant^{-1}) and fresh root weight (9.38 g plant^{-1}) the maximum yields were noted. In addition, very strong positive correlate was evinced between the biomass and fresh root weight ($p = 0.01$; Pearson's $r = 0.87$). The significantly more yield was achieved by irrigation on the basil. Based on our results, irrigation with undiluted effluent water from intensive fish farm is similarly effective to increase yield, as Irr3; because there was not significant difference between them (Figure 2.). The results of our experiment indicate that the irrigation help to achieve increased yield.

Table 5: Results of irrigation treatments on basil plant height (cm), plant diameter (cm), number of offshoots (number plant-1), root length (cm) and SPAD value (Szarvas, 2021)

Properties of basil plant	Non irrigated control (Irr0)	Effluent water (Irr1)	Diluted effluent water+gypsum (Irr2)	Körös-oxbow water (Irr3)
Plant height (cm)	41.35±5.32a	44.3±4.64 ab	41.43±6.47 a	47.96±4.43 b
Plant diameter (cm)	29.9±5.1 a	28,77±4.86 a	24.34±4.6 a	30,05±5.93 a
Number of offshoots (number plant^{-1})	14.7±2.21 a	14.6±2.07 a	13.1±3.63 a	15.6±2.22 a
Root length (cm)	18.86±2.5 a	19.55±3.3 ab	19,13±3.54 a	23,22±3.3 b
SPAD value	47.14±4.72 c	41.26±2.81 ab	44.15±1.74 bc	39.68±2.07 a

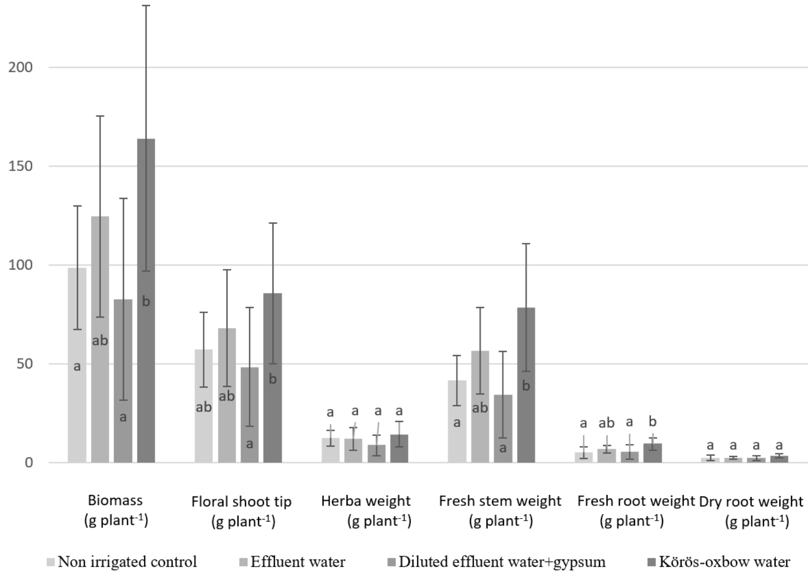

Figure 2: Different yield parameters (biomass, floral shoot tip, herba weight, fresh stem weight, fresh root weight and dry root weight (g plant-1) of garden basil with different irrigation types (Szarvas, 2021)

Discussion

Kafi and Rahimi (2011) published, salinity caused a reduction in purslane root and shoot growth (volume, area, diameter, total and main length and root dry weight). But we could not prove any significant effect of irrigation treatments neither on plant diameter nor on lenght of shoot or root. In our experiment on purslane, we detected that the increasing sodium caused decrasing fresh root weight only between the non-irrigated control treatment (Irr0) and the irrigated control treatment (Irr3). We could not prove significant differences among the irrigation treatments despite the result of Alam et al.

(2015) who published significant reduction of biomass caused by salinity stress, highest salinity level show more detrimental effects compared to the control. However, our results are contradicting to the report of He et al. (2021). Their experiment resulted that the maximum purslane yield was found at the level of 100 mM NaCl (equal to 230 mg Na) in contrast to our results.

Our results of basil is confirm the result of Heidari (2012), because the 22.6 mg l^{-1} (approximately 1 mmol Na) sodium content in Körös oxbow water irrigation (Irr3) increased the biomass yield of basil compared to the control treatment (Irr0) and (Irr2). But 276 mg l^{-1} (12 mM Na) sodium content of effluent water (Irr1) from intensive catfish farm decreased the biomass compared with the control treatment (Irr0), but the difference was not significant (Bernstein et al., 2010). According to Caliskan et al. (2017) the EC 0.4-0.8 dS m^{-1} and as for Maia et al. (2017) to EC 1.5 dS m^{-1} the basil tolerated the sodium. In our experiment EC 329-1380 μS cm^{-1} (Irr3: 0.0329 dS m^{-1} and Irr1:0.138 dS m^{-1}) of the irrigation water was morelower, than which was used by Caliskan et al. (2017) and Maia et al. (2017), so our effluent water can be used for basil irrigation.

Based on our results we can not agree with Omeir et al. (2019) because there were not any significant positive effects of effluent water irrigation neither on purslane nor on basil. We suggest, the application of irrigation to increase the yield of basil. Undiluted effluent water from intensive fishfarming (Irr1: biomass: 124.5 ± 51.01 g $plant^{-1}$) is similarly effective to increase yield of basil, like Irr3 (164 ± 67.2 g $plant^{-1}$); because there was not significant difference between them.

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MAGYAR AGRÁR- ÉS ÉLETTUDOMÁNYI EGYETEM

Columella

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Assessment of some morphological and physiological parameters in lettuce (*Lactuca sativa* L.) cultivated in hydroponic system

Dorin CAMEN[1,2] – Mihaela MOATAR[1] – Adriana CIULCA[1] – Sorina POPESCU[1] – Sorin CIULCA[1]

1: Faculty of Horticulture and Forestry, Banat's University of Agricultural Sciences and Veterinary Medicine, "King Michael I of Romania" from Timisoara, Calea Aradului 119, RO-300645 Timisoara, Romania, e-mail: camendorin@yahoo.com

Abstract: Lettuce is a valuable leaf vegetable for a well-balanced diet, since it is rich in nutrient elements, has low calories and provides dietary antioxidants. Compared to soil-based cultivation, the hydroponic system is an alternative associated with a shortening of growing cycles and a reduction of wasted water amount. The aim of this study was to analyze the growth of lettuce plants under hydroponic and soil cultivation systems, during three phenological growth stages (45; 47 and 49) according to BBCH scale. During the study different morphological and physiological parameters were evaluated: Plant height (PH); Stem diameter (SD); Fresh mass (FM); Dry mass (DM); Leaf area (LA); Chlorophyll content (CC); Transpiration rate (TR). The research was carried out using a complete randomized design with a 2 × 3 factorial arrangement of cultivation system and growth stages. Plants grown in hydroponic system presented higher values of most parameters, except for DM and TR. The cultivation system had the highest effect on PH, SD and LA. The highest variation between growth stages were observed for PH, LA and CC. Finally, we can conclude that lettuce plants cultivated under hydroponic system, presented better growth parameters associated with higher head weight and yield.

Keywords: lettuce, hydroponic, morphological, physiological parameters

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Introduction

Lettuce is one of the most important leafy vegetables worldwide, as it is considered a rich source of vitamins (A, C, E, K), polyphenols, and antioxidant compounds (Senizza et al., 2020), is typically low in calories and packed with fiber (Llorach et al., 2008). Lettuce production during late spring and summer often negatively affects yield and quality of heads. As such, adverse temperatures and long days largely limit warm season production of lettuce. Exposure of lettuce to 13 h of daylight and temperatures above 24 °C caused a premature inflorescence initiation, otherwise known as bolting (Sublett et al., 2018).

Hydroponics is an alternative to conventional soil-based cultivation: both growing environment and inputs of water and nutrients may be controlled; less work is required; growing cycles are shorter; and there is less wasted water (Paulus et al., 2012; de Souza et al., 2019). For short-term crops like lettuce, utilizing Nutrient Film Technique (NFT), which belongs to closed hydroponic systems category, is a frequent choice. However, this system requires repeated monitoring of the flow of the solution (Kaiser & Ernst, 2012). Hydroponics with recirculation (closed system) is the most technically, economically and environmentally efficient system by its

Table 1: Mean of plant height and stem diameter for lettuce under two cultivation systems during three phenophases

		Plant height (mm)		
Cultivation System (CS)		Phenophase (P)		Cultivation system mean
	BBCH45	BBCH47	BBCH49	
Soil	z 62.8±6.0 b	y 120.0±9.9 b	x 197.2±7.0 b	126.7±11.6 B
Hydroponic	z 90.6±4.4 a	y 173.3±10.7 a	x 263.2±12.7 a	175.7±14.9 A
Phenophase mean	76.7±4.9 Z	146.7±9.6 Y	230.2±10.7 X	151.2±3.1
CS − LSD$_{5\%}$ = 14.7 mm (A,B); P- LSD$_{5\%}$ = 17.9 mm; CS × P-LSD$_{5\%}$ = 25.4 mm				
		Stem diameter (mm)		
Cultivation System (CS)		Phenophase (P)		Cultivation system mean
	BBCH45	BBCH47	BBCH49	
Soil	y 10.6±0.4 b	xy 11.9±0.3 b	x 12.9±0.4 b	11.2±0.2 B
Hydroponic	y 14.7±0.7 a	y 15.8±0.8 a	x 18.2±1.5 a	16.2±0.7 A
Phenophase mean	12.7±0.6 Y	13.8±0.7 XY	15.6±0.9 X	13.3±0.1
CS − LSD$_{5\%}$ = 1.2 mm (A,B); P- LSD$_{5\%}$ = 1.5 mm (X,Y); CS × P-LSD$_{5\%}$ = 2.1 mm				

(a, b, for vertical comparisons; x, y, z, for horizontal comparisons). Data represents mean ± SE. Different letters indicate significant differences ($p < 0.05$)

considerable savings in water and fertilizers, and minimal discharge of residual fertilizer solution into the environment (Lazo & Gonzabay, 2020). In hydroponic system, soil preparation and weed control are not require), avoids the need for crop rotation, and reduces pesticide application (Palermo, Paradiso, Pascale, & Fogliano, 2011). Harvesting can be carried out in a complex or simple infrastructure in small spaces and with low costs of production variables, but with a high initial investment. One disadvantage is the easy proliferation of root diseases in a soilless system with recirculation of nutrient solution (Resh, 2013). However, hydroponic systems are particularly sensitive to water pollution due to the lack of any buffer capacity as it is given in soil. Via direct root contact, pollutants may be taken up as shown in numerous studies (Carvalho et al., 2014; Herklotz et al., 2010).

The intensity of light has a major influence on the yield and quality of lettuce. As such, the highest plant biomass was recorded high light intensity treatment, whereas under low light intensity non-marketable and vortex-like plants were produced (Voutsinos et al., 2021). Also, the mineral contents of plants are affected by the amount of received light. Light quality is an important factor in the effective regulation of the growth and quality of lettuce (Li et al., 2021). The combination of red and blue light serves as a highly efficient light source for promoting lettuce growth (Amoozgar et al., 2017; Chen et al., 2016).

Hydroponic production of lettuce uses land and water more efficiently than conventional farming and could become a strategy for sustainably feeding the world's growing population, if the high energy consumption can be overcome through improved efficiency and/or cost-effective of the system (Barbosa et al., 2015). The aim of this study was to an-

Table 2: Mean of plant height and stem diameter for lettuce under two cultivation systems during three phenophases

		Fresh mass (g)		
Cultivation System (CS)		Phenophase (P)		Cultivation system mean
	BBCH45	BBCH47	BBCH49	
Soil	y 196.0±10.1 a	y 249.1±15.6 b	x 317.2±17.2 a	254.1±12.7 B
Hydroponic	y 227.4±12.3 a	x 311.9±20.8 a	x 361.9±23.5 a	300.4±18.2 A
Phenophase mean	211.6±8.6 Y	280.5±15.8 X	339.6±20.5 X	277.2±3.6
CS − LSD$_{5\%}$ = 34.8 g (A,B); P- LSD$_{5\%}$ = 42.6 g (X,Y,Z); CS × P-LSD$_{5\%}$ = 60.2 g				
		Dry mass (g)		
Cultivation System (CS)		Phenophase (P)		Cultivation system mean
	BBCH45	BBCH47	BBCH49	
Soil	y 9.27±0.48 a	xy 11.94±1.39a	x 13.92±1.75 a	11.71±0.82 A
Hydroponic	y 8.67±0.44 a	xy 10.57±0.68a	x 12.82±0.71 a	10.69±0.48 A
Phenophase mean	8.99±0.32 Z	11.20±0.77 Y	13.41±0.93 X	11.20±0.15
CS − LSD$_{5\%}$ = 1.75 g (A,B); P- LSD$_{5\%}$ = 2.14 g (X,Y,Z); CS × P-LSD$_{5\%}$ = 3.03 g				

(a, b, for vertical comparisons; x, y, z, for horizontal comparisons). Data represents mean ± SE. Different letters indicate significant differences ($p < 0.05$)

alyze the growth of lettuce plants (cv. Regina di Maggio) under hydroponic and soil cultivation systems, during three phenological growth stages (45; 47 and 49) according to BBCH scale.

Materials and Methods

The research was carried out using a complete randomized design with a 2 × 3 factorial arrangement of cultivation system (CS) and phenophases (P). Three weeks old seedlings of lettuce plants (cv. Regina di Maggio) were cultivated in pots with soil (1peat:1sand: 1compost) and in hydroponic system using Hoagland nutrient solution. In the greenhouse the temperature ranges between 15-25 °C associated with 60-70% humidity. The light in the greenhouse was based on natural solar radiation.

For each phenophase five plants from different CS were used for analysis and measurements. During the study different morphological and physiological parameters were evaluated: Plant height (PH); Stem diameter (SD); Fresh mass (FM); Dry mass (DM); Leaf area (LA); Chlorophyll content (CC); Transpiration rate (TR). The size of plants was estimated using a digital caliper, and the mass of heads was evaluated with a precision scale. Leaf area was determinate using leaf area meter AM350 and was expressed in cm^2. The chlorophyll content was estimated by means of chlorophyll meter Minolta in SPAD units.

The data for all analyses and determination were statistically processed using ANOVA, and the means were compared using the least significant difference test (Ciulca, 2006). The significance of differences was marked with letters, being considered as significant ($p < 0.05$), the differences between means with different letters.

Table 3: Mean of plant height and stem diameter for lettuce under two cultivation systems during three phenophases

Leaf area (cm^2)

Cultivation System (CS)	Phenophase (P)			Cultivation system mean
	BBCH45	BBCH47	BBCH49	
Soil	z 38.47±2.48 a	y 46.03±4.04 b	x 93.78±5.32 b	59.43±5.32 B
Hydroponic	z 46.54±4.41 a	y 62.20±7.35 a	x 120.45±7.50 a	76.40±7.22 A
Phenophase mean	42.50±2.64 Z	54.11±4.52 Y	107.12±5.51 X	67.91±1.45

CS – LSD$_{5\%}$ = 9.02 cm^2 (A,B); P – LSD$_{5\%}$ = 11.02 cm^2 (X,Y,Z); CS × P – LSD$_{5\%}$ = 15.59 cm^2

Chlorophyll content (SPAD)

Cultivation System (CS)	Phenophase (P)			Cultivation system mean
	BBCH45	BBCH47	BBCH49	
Soil	z 5.16±0.16 a	y 8.17±0.71 b	x 11.34±0.46 b	8.22±0.57 B
Hydroponic	z 7.09±0.36 a	y 10.78±1.94 a	x 13.47±0.38 a	10.44±0.82 A
Phenophase mean	6.12±0.30 Z	9.47±1.05 Y	12.41±0.39 X	9.33±0.16

CS – LSD$_{5\%}$ = 1.20 (A,B); P – LSD$_{5\%}$ = 1.47 (X,Y,Z); CS × P – LSD$_{5\%}$ = 2.08

Transpiration rate (mg H_2O h^{-1} cm^{-2})

Cultivation System (CS)	Phenophase (P)			Cultivation system mean
	BBCH45	BBCH47	BBCH49	
Soil	z 1.92±0.09 a	y 2.04±0.07 a	x 2.16±0.08 a	2.04±0.05 A
Hydroponic	z 1.48±0.04 b	y 1.68±0.06 b	x 1.80±0.07 b	1.65±0.04 B
Phenophase mean	1.70±0.07 Z	1.86±0.06 Y	1.98±0.07 X	1.85±0.01

CS – LSD$_{5\%}$ = 0.06 (A,B); P – LSD$_{5\%}$ = 0.07 (X,Y,Z); CS × P – LSD$_{5\%}$ = 0.10

(a, b, for vertical comparisons; x, y, z, for horizontal comparisons). Data represents mean ± SE. Different letters indicate significant differences ($p < 0.05$)

Results and discussion

The height of plants cultivated in hydroponic system showed significantly higher average values by 38.67%, with increases between 33.47 in BBCH49 and 44.42 in BBCH47. In both cropping systems, a significant increase in plant height of 56.92-91.26% was observed from one phenophase to another (Table 1).

The culture system showed a higher influence on the stem diameter compared to the phenophase or the interaction of the two factors. Thus, in the conditions of hydroponic culture, significantly higher values of this trait were registered by 4.15 mm, on the background of variations from 3.9 mm in BBCH47 to 5.3 mm in BBCH49. Regardless of the culture system, in the first two phenophases the diameter of the stem showed smaller and non-significant variations 0.9-1.3 mm. In the last phenophase the values of this trait were significantly higher by 2.3-3.5 mm compared to the first phenophase.

Under hydroponic system, the plants generally achieved a significantly higher fresh mass by 18.11%. The effect of the culture system on this character was higher in the phenophase BBCH47 where an increase of 25.30% was registered. In BBCH47 and BBCH49, the fresh mass was significantly higher by 32.08-53.51% than in the first phenophase (Table 2). The greater accumulation of biomass observed in plants cultivated on hydroponic system is directly associated

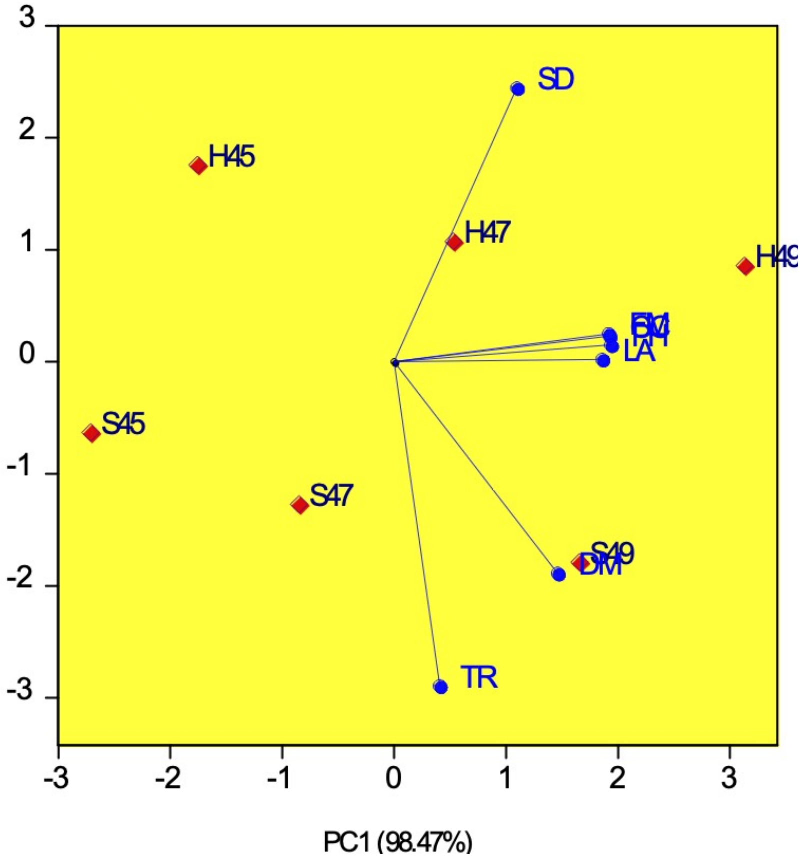

Figure 1: Biplot for morphological and physiological parameters of lettuce under soil and hydroponic systems. S45-Soil BBCH45; S47-Soil BBCH47; S49-Soil BBCH49; H45-Hydroponic BBCH45; H47- Hydroponic BBCH47; H49- Hydroponic BBCH49.

to the availability of nutrients in the nutrient solution, as well as the lower water stress (Rosa et al., 2014).

The culture system showed less influence on dry mass compared to phenophase or the interaction of the two factors. Throughout the study, there are small and insignificant variations of dry mass, against the background of higher values by 0.56-1.73 g in the case of plants grown in soil. Overall, the dry mass of plants recorded significant increases from one phenophase to another, with values ranging from 16.52% between the BBCH47-49 and 24.58% between BBCH45-47.

The leaf area of the plants cultivated in hydroponic system showed significantly higher average values by 28.55%, with increases between 20.98 in BBCH45 and 35.13% in BBCH47. In both culture systems, there is a significant increase in leaf area by 27.32–97.97% from one phenophase to another, more intense in BBCH49 (Table 3).

The phenophase showed a higher influence on the chlorophyll content compared to the culture system or the interaction of the two factors. Thus, under the conditions of hydroponic culture, significantly higher values of this trait were registered by 27%, on the background of variations from 18.78% in BBCH49 to 37.40% in BBCH45. In the last phenophase, the values of this Trait were significantly higher by 31.05% compared to BBCH47. The constant flow of nutrient media to plants in hydroponic systems likely resulted in conditions more favorable than soil cultivation, resulting in plants with significant difference in chlorophyll (Rosa et al., 2014; de Souza et al., 2019).

Under hydroponic conditions, the plants generally achieved a significantly lower transpiration rate by 19%. Regardless of the culture system, a significant intensification of transpiration by 6.45-9.41% from one phenophase to another was observed. In environments with less water availability, there is a decrease in the size of the stomata, so that there is a lower water loss of the plant by transpiration, with the simultaneous increase of its density, contributing to the balance of gas exchange (Batista et al., 2010).

From Figure 1, it can be noticed that plants grown in hydroponic system presented higher values of most parameters, except for dry mass and transpiration rate. Also, based of the position of vectors in the biplot, a strong correlation between leaf area, fresh mass and chlorophyll content was observed.

Conclusion

The cultivation system had the highest effect on plant height, stem diameter and leaf area. The highest variation between phenophases was observed for plant height, leaf area and chlorophyll content. Finally, we can conclude that lettuce plants cultivated under hydroponic system, presented better growth parameters associated with higher head weight and yield. Further studies are needed to analyze the cost-effective and/or efficiency of the two cultivation system of lettuce.

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MAGYAR AGRÁR- ÉS ÉLETTUDOMÁNYI EGYETEM

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Macro-, mesoelement and sodium content of plant parts of energy willows irrigated with effluent water of agricultural origin

Ildikó KOLOZSVÁRI[1,2] – Ágnes KUN[1] – Mihály JANCSÓ[1] – Csaba BOZÁN[1] – Csaba GYURICZA[2]

1: Research Center for Irrigation and Water Management, Institute of Environmental Sciences, Hungarian University of Agriculture and Life Sciences, H-5540 Szarvas, Anna-liget Str. 35., Hungary, e-mail: Kolozsvari.Ildiko@uni-mate.hu
2: Institute of Agronomy, Hungarian University of Agriculture and Life Sciences, H-2100 Gödöllő, Páter Károly Str. 1., Hungary

Abstract: Irrigation with recycled water can be considered as an element of integrated water management, in which the nutrients in the water are used and decomposed by natural processes, while water retention is realized at the local level. The objective of the study was to monitor the changes in nitrogen, phosphorus, potassium, calcium, magnesium and sodium content of the plant parts (leaves, stems, roots) of the energy willow in response to effluent water irrigation of the fish farm. In our study, we used the effluent of an intensive African catfish farm for irrigation. The farm uses thermal water for fish farming, which is characterized by a high sodium content. At the same time, the effluent is rich in organic matter and minerals. The planting of the willow plants in the study area, which is close to 3 ha, took place in the spring of 2014 with a variety candidate 'Naperti'. During the experiment, seven treatments were set up, of which one was non-irrigated, three were irrigated with the water of the Körös oxbow lake and three were irrigated with the effluent water. Three doses of irrigation water (15, 30, 60 mm) were applied to the one-week irrigation intervals with a microspray irrigation system. At the end of the growing season, samples of the plant parts were collected, during which mineral element analysis was performed with special regard to N, P, K, Ca, Mg and Na levels. The results of the study showed a significant difference in macroelements only for nitrogen for all plant parts. However, there was no significant difference in case of the mesoelements. In the case of sodium, compared to the leaf and stem plant samples, the root part accumulated a significant amount of salt, especially in the samples irrigated with 30 mm effluent water, where the Na content reached 521 mg kg^{-1}.

Keywords: effluent water, irrigation, energy willow, mineral content

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Introduction

The growing demand for biomass and renewable energy sources in the European Union can be met in the long term by setting energy efficiency targets in the European Energy Union's strategy and increasing the European share of renewable energy sources (European Environment Agency, 2006). The use of renewable energy sources is becoming less and less avoidable. Nowadays, the production and utilization of bioenergy from biomass has become a strategic issue. Both Europe and the world are facing energy shortages, and energy-based systems are declining, while energy demand is on the rise (depending on social and economic development) worldwide (European Environment Agency, 2013; Popp et al., 2014).

The willows are one of the plants which can be used to produce biomass for energy purposes. Woody stem crops grown

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for energy can generally withstand extreme weather conditions. Mostly 500–600 mm of rainfall are needed for the balanced development of these crops, but they can reach high biomass masses in years with 300–400 mm of rainfall. However, a balanced water supply is particularly important in the year of planting, as the plants are more sensitive to periods of drought during their initial development (Liberacki et al., 2022). Dimitriou and Aronsson (2011) described in their study that the wastewater applied had no negative effect on plant growth. Hangs et al. (2011) noted that moderately saline (ECe $\leq$ 5.0 dS m^{-1}) conditions were still tolerated by energy willows.

Water scarcity and climate change are among the most pressing global challenges of our time. Due to declining freshwater supplies, the use of alternative water sources in agricultural cultivation has become necessary (Gabr et al., 2020). In the integration of aquaculture and crop production, effluent water has been successfully used in irrigation or hydroponic systems in many crops (Castro et al., 2006; McMurtry et al., 1993; Naegel, 1977). The effluents from intensive fish production have a high content of organic matter and macronutrients. They provide an excellent opportunity for nutrient replenishment during crop production (Omeir et al., 2019; Kolozsvári, Kun, Jancsó, Bakti, et al., 2021; Valencia et al., 2001). Several promising studies have been conducted in the field of crop and vegetable productions by using higher salinity effluent water from fish and shrimp farms for irrigation during cultivation (Castro et al., 2006; Guimarães et al., 2016; Simões et al., 2016).

The aim of our thesis was to determine the effect of irrigation with the effluent of intensive fish farming on the macro- and,-mesoelement and sodium contents of the plant parts of the short-rotation energy willows.

Materials and Methods

The experimental area was set up in the field (46°51′06.9″N 20°31′25.0″E Szarvas, Hungary) of the Hungarian University of Agriculture and Life Sciences, Institute of environmental Sciences, Research Center for Irrigation and Water Management in spring of 2014, with an area of 2.7 hectares. The short rotation energy willow (*Salix alba* L.) coppice of Forest Research Institute 'Naperti' candidate variety was used for the experiment. The cuttings were planted in the spring of 2014. Sampling of plant parts (leaf, stem and root) took place in 2014 at the end of the growing season (october). During the examination we applied a non-irrigated treatment (C) and combinations of two different water types and three different irrigation doses for the irrigation of the energy willow clones. The area of a treated plot was 20 × 50 meter (width × length). We used water from the Körös River oxbow lake (K15, K30, K60) and untreated effluent water (E15, E30, E60) from a local intensive African catfish (*Clarias gariepinus*) farm. Irrigation water was sampled three times during the irrigation cycle and the average chemical parameters are presented in Table 1. The effluent water was directly collected from the outflow of fish rearing tanks. The quality of the effluent is characterized by a higher sodium content, as thermal water is used for the production of African catfish (Table 1.). In addition, it is characterized by higher organic matter and nutrient content (Table 1.). The irrigation interval was one week with the doses of 15 mm (K15, E15), 30 mm (K30, E30), and 60 mm (K60, E60). We used microspray irrigation system (in three replications). The plantation was irrigated six time during one irrigation period (June, July, August), with natural rainfall (326 mm).

The mineral content of the plant parts was analyzed at the end of the growing season. All samples were assayed by the Hungar-

Table 1: Mean of plant height and stem diameter for lettuce under two cultivation systems during three phenophases

	EC μS/cm	NH_4-N mg/dm^3	P mg/dm^3	Ca mg/dm^3	K mg/dm^3	Mg mg/dm^3	Na mg/dm^3
Körös River water	399	0.161	0.093	41.2	4.97	9.93	31.9
Effluent water	1 330	21	3.47	20.5	6.8	9.35	273

ian and ISO standard methods according to Kolozsvári, Kun, Jancsó, Bakti, et al. (2021):

Macroelements and sodium:

Kjeldahl-Nitrogen MSZ EN ISO 5983-2:2005: Animal feeding stuffs. Determination of nitrogen content and calculation of crude protein content. Part 2: Block digestion and steam distillation method (ISO 5983-2:2005).

Phosphorus MSZ-08-1783-28:1985: Use of high capacity equipment in plant analyses. Quantitative determination of phosphorus of plant materials by ICP method.

Potassium and Sodium MSZ-08-1783-5:1985: Use of high capacity equipment in plant analyses. Quantitative determination of potassium and sodium contents of plant materials.

Mesoelements:

Calcium MSZ-08-1783-26:1985: Use of high capacity equipment in plant analyses. Quantitative determination of calcium of plant materials by ICP method.

Magnesium MSZ-08-1783-26:1985: Use of high capacity equipment in plant analyses. Quantitative determination of magnesium of plant materials by ICP method.

The statistical analyses were implemented by IBM SPSS Statistics 25.0 software. One-way analysis of variance (ANOVA) was applied. The differences were determined significant, where the Tukey's post hoc test were considered significant at $p \leq 0.1$.

Results

Nitrogen

In the case of nitrogen (Figure 1) it can be stated that the leaf part had the highest N level. In the case of K30 treatment it was 4.47 m/m%, while the lowest value was measured in case of C treatment (0.37 m/m%). Lower levels were observed in the stem and root parts. The N level was between 1.41–0.08 m/m% and 0.88–0.5 m/m% in the stem and the root parts, respectively. Furthermore, it can be considered that the N content of the C and 30 and 60 mm effluent water irrigated plant samples differed from the values measured in the other treatments. In a one-way analysis of variance, we found a significant difference between treatments for all three plant parts. In the case of the leaf part, the K30 treatment ($p = 0.028$) had a significantly higher N level than the other treatments. In the case of the stem and root parts, in both cases the plant samples of the K15 treatment ($p \leq 0.001$) contained significantly more nitrogen compared to the lowest C treatments.

Phosphorus

In the case of phosphorus (Figure 2), it can also be observed that the leaf had the highest P content (2935 mg kg^{-1}). The values for stem and root parts were in the same range (1655–950 mg kg^{-1}). No significant difference was detected in any of the plant parts during the statistical evaluation. However, it can be observed that the P levels of C treatments are in the lower range for the stem and

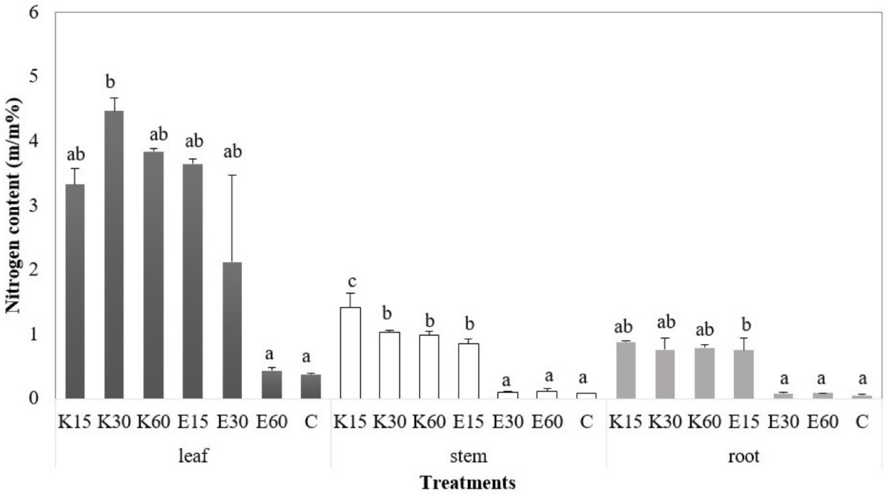

Figure 1: The nitrogen content of the plant parts (leaf, stem and root) at the end of the growing season. The different letters show a significant difference between treatments during the study period, according to the Tukey's test was used at $p \leq 0.1$ level.

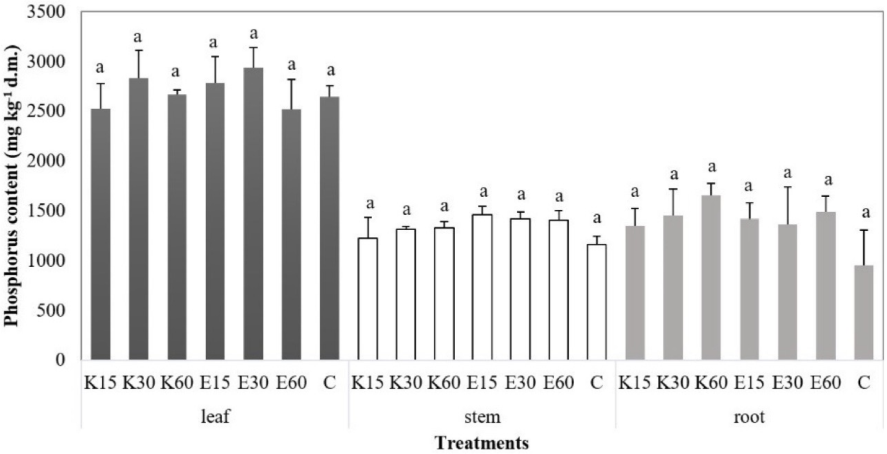

Figure 2: The phosphorus content of the plant parts (leaf, stem and root) at the end of the growing season. The different letters show a significant difference between treatments during the study period, where the Tukey's test was used at $p \leq 0.1$ level.

root plant part.

Potassium

For potassium (Figure 3), the same trend as for phosphorus can be observed, with a higher range of K levels in leaf parts (13630–9505 mg kg^{-1} d.m.). This is followed by the potassium content of the root samples, where K15 treatment (8265 mg kg^{-1} d.m.) produced the lowest and K30 treatment (9390 mg kg^{-1} d.m.) the highest values. The stem parts had the lowest potassium levels. Here, we measured the lowest values for the K15 samples (3655 mg kg^{-1} d.m.) and the highest element levels for the E15 treatment (5180 mg kg^{-1} d.m.). In the one-way analysis of variance, no significant difference was detected between treatments for the root samples. However, in leaf samples, C treatment ($p = 0.096$) had a significantly higher K content compared to K15 and E60 treatments. In

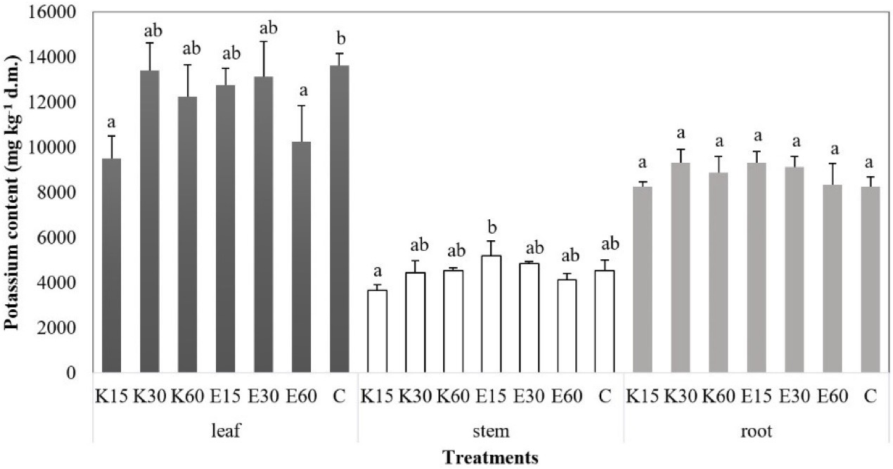

Figure 3: The potassium content of the plant parts (leaf, stem and root) at the end of the growing season. The different letters show a significant difference between treatments during the study period, where the Tukey's test was used at $p \leq 0.1$ level.

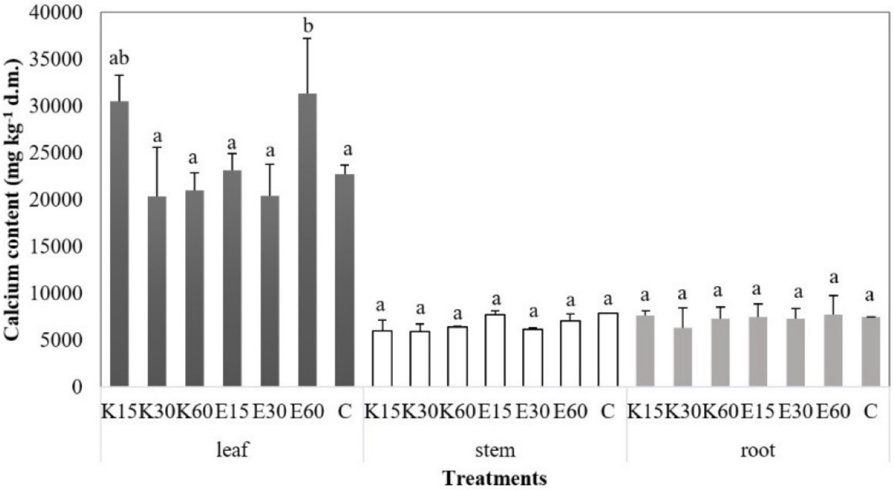

Figure 4: The calcium content of the plant parts (leaf, stem and root) at the end of the growing season. The different letters show a significant difference between treatments during the study period, where the Tukey's test was used at $p \leq 0.1$ level.

the case of stem samples, E15 treatment ($p = 0.061$) had a significantly higher K level.

Calcium

It was also observed that leaf samples contained calcium in the highest proportion (Figure 4). Where the lowest value was measured in the K30 treatment (20310 mg kg^{-1} d.m.) and the highest to E60 samples (31345 mg kg^{-1} d.m.). The stem and root samples moved in the same range. For stem parts, the K30 treatment (5885 mg kg^{-1} d.m.) had the lowest Ca content, while the E15 samples (7730 mg kg^{-1} d.m.) had the highest, but no significant difference between treatments was observed. The calcium content of the root parts ranged from 6295 to 7630 mg kg^{-1} dm. The statistical evaluation showed significant differences only in leaf parts, where E60 treatment samples ($p = 0.047$) had significantly the highest Ca values.

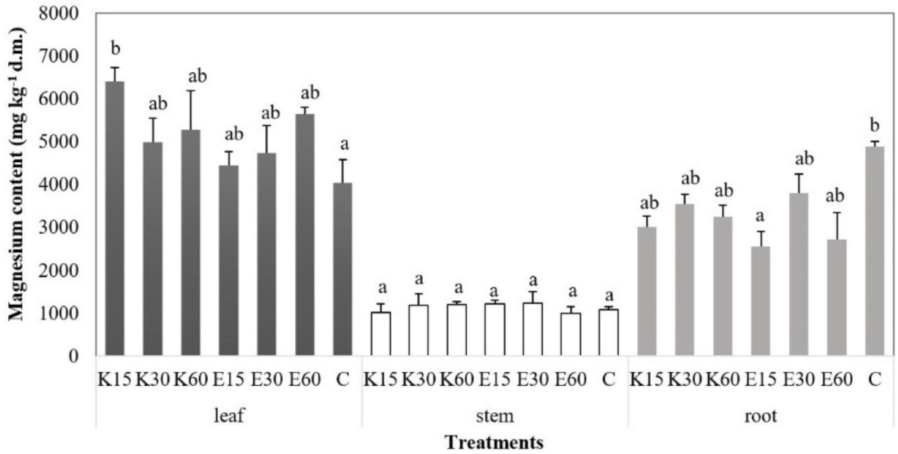

Figure 5: The magnesium content of the plant parts (leaf, stem and root) at the end of the growing season. The different letters show a significant difference between treatments during the study period, where the Tukey's test was used at $p \leq 0.1$ level.

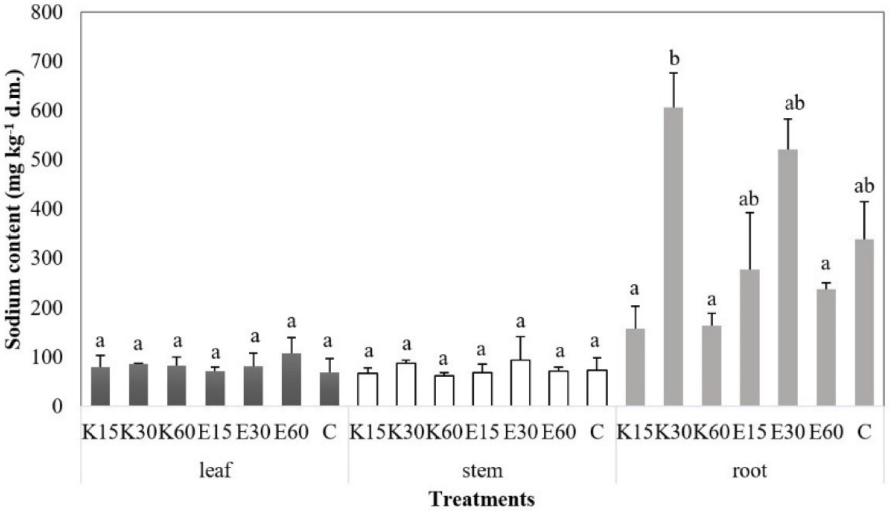

Figure 6: The sodium content of the plant parts (leaf, stem and root) at the end of the growing season. The different letters show a significant difference between treatments during the study period, where the Tukey's test was used at $p \leq 0.1$ level.

Magnesium

In the case of magnesium, the leaf parts also contained the highest concentration (Figure 5). This was followed by the Mg element content of the root parts and then the stem parts. For leaf samples, treatment C (4045 mg kg^{-1} d.m.) had the lowest value, while treatment K15 (6410 mg kg^{-1} d.m.) had the highest value. In the case of the stem part, the Mg content was between 999 and1225 mg kg^{-1} d.m. The lowest element content was measured for the root samples in the E15 treatment (2555 mg kg^{-1} d.m.) and the highest in the C samples (4895 mg kg^{-1} d.m.). According to the one-way analysis of variance, compared to the C treatment the K15 sample ($p = 0.075$) had significantly higher Mg levels in the case of the leaf samples. Furthermore, compared to the E15 treatment the C sample ($p = 0.081$) detected significantly higher values in the root part. No significant difference was observed between stem treatments.

Sodium

The sodium content of the plant parts developed differently from the mineral elements presented above (Figure 6). In this case, the willow leaf and stem parts stored significantly less Na in the tissues. This value ranged from 62 to 108 mg kg^{-1} d.m. In contrast, in the case of root samples, the K15 treatment (157 mg kg^{-1} d.m.) with the lowest value also had higher Na levels. The Na content of the root samples of the highest K30 treatment reached 606 mg kg^{-1} d.m. During the statistical evaluation, there was a significant difference between the treatments for the root samples between K30 ($p = 0.003$) and K15, K60, E60.

Discussion

The effect of effluent from an intensive African catfish farm on the mineral content of plant part was investigated in a short rotation coppice plantation in 2014. In the case of nitrogen, it can be observed for all parts of the examined plants that the C treatments and the samples irrigated with 30 and 60 mm effluent water had significantly lower N content. For treatment C, this decrease was caused by water deficit, and for the samples irrigated at 30 and 60 mm, it could be due to irrigation of effluent water with higher EC. Similarly, as nitrogen, phosphorus is an essential macronutrient for all plants. In addition, it is a component of many cellular compounds that are essential for energetic and photosynthetic metabolism (Maathuis & Diatloff, 2012). During the measurement the leaf samples had the highest phosphorus value. Potassium is the most abundant cation in plants and its amount decreases as the growing season progresses (Gierth & Mäser, 2007). The highest concentration was measured for leaf samples.

Mg^{2+} and Ca^{2+} are essential for plant growth because magnesium is a structural component of chlorophyll and calcium is a component of the cell wall and a receptor for environmental stimuli (Ranty et al., 2016). According with the study of Akter and Oue (2018) measured magnesium levels in root samples irrigated with high salinity irrigation water were lower than in non-irrigated C treatments. In the case of calcium, leaf samples irrigated with 60 mm of effluent had the highest concentration.

High salinity can induce nutrient deficiencies in plants. In addition to altering the ionic balance of cells, salt stress can also generate oxidative stress in plant cells and tissues. In halophytic plants (which are well adapted to the saline environment), they increase the presence of compounds with high antioxidant activity, such as the production of polyphenols (Mansour et al., 2018). Under the study, there was a significant difference between the treatments for the root samples. During which the highest Na concentration reached 606 mg kg^{-1} d.m. The same result as in our previous study was obtained during effluent water irrigation of silage sorghum (Kolozsvári, Kun, Jancsó, Bíróné Oncsik, et al., 2021).

In summary, in areas where irrigation water is not available or we have poorer quality soil, the effluent of the intensive fish farm we studied can be a suitable alternative. At the same time, it is necessary to monitor the irrigated area, in particular to monitor changes in soil parameters.

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Investigation of different nutrient levels applied during irrigation in the self-rooted and grafted watermelon production

Patrik KRIZSÁN[1,2] – Gábor BALÁZS[2]

1: Institute of Environmental Sciences Department of Irrigation and Land Improvement, Hungarian University of Agriculture and Life Sciences, 5540 Szarvas, Petőfi u. 9., Hungary, e-mail: Krizsan.Patrik@uni-mate.hu
2: Institute of Horticulture, Department of Vegetable and Mushroom Growing, Hungarian University of Agriculture and Life Sciences, 1118 Budapest, Villányi út 29-43., Hungary

Abstract: Our work in the form of water-soluble fertilizers for self-rooted and grafted watermelon cultivation, applied simultaneously with irrigation, it concentrates on examining different nutrient levels during the growing season. Within that, we focused on the application of macronutrients - nitrogen, phosphorus, potassium. Therefore, we set up 4 different nutrient levels for both types of seedlings, in two replicates, of which we developed a phosphorus, a nitrogen, and a potassium overweight nutrient level, and a nutrient level in which all three nutrients were in equal proportions. The latter formed the control. For both self-rooted and grafted seedlings, we wondered whether changes in nitrogen, phosphorus, and potassium would affect, and if so, the positive or negative direction of plant development, or the quality or the weight of the crops. Our research pointed out that at the beginning of the growing season, before or during the first flowering period, higher amounts of phosphorus applied simultaneously with irrigation have a positive effect on the development and yield and quality of grafted plants throughout the growing season. Higher phosphorus content applied by irrigation before and during the first flowering period also promotes flowering of self-rooted plants and improves their crop quality. But in their case, the higher potassium active substance applied during the ripening period has the most positive effect on their yield results. Respectively, the experiment showed that the nutrients applied during nutrient solution are of great importance.

Keywords: watermelon, irrigation, water-soluble, fertilizer, grafted

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Introduction

Watermelon cultivation in Hungary has a history dating back decades. Irrigation and nutrient replenishment are essential to produce the best possible quality and quantity of goods, which can take the form of both organic and fertilizer. Irrigation is becoming increasingly important these days, mainly for the cultivation of vegetables in the field, due to extreme weather and prolonged periods of low rainfall. In addition, the importance of nutrients applied during irrigation is widespread. That's why, our work in the form of water-soluble fertilizers for self-rooted and grafted watermelon cultivation, applied simultaneously with irrigation, it concentrates on examining different nutrient levels during the growing season. In the case of both self-rooted and grafted seedlings, we wondered whether changes in the amount of nitrogen, phosphorus and potassium would affect, and if so, in a positive or negative direction the development of the plant or the quantity, quality or weight of the crop. Therefore, we set up 4 different nutrient levels for both types of seedlings, in two replicates, of which we developed

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a phosphorus, a nitrogen, and a potassium overweight nutrient level, and a nutrient level in which all three nutrients were in equal proportions. The latter formed the control.

The water requirement of watermelon is 400–500 mm (Nagy, 2005), the approx. during its 4-5 month growing season, thus it can be classified as a water-intensive vegetable plant (Hodossi et al., 2004). For this reason, it cannot be successfully grown in Hungary without irrigation. It needs the greatest amount of water during germination, rapid shoot growth and during the period of crop development (Nagy, 1997).

Its transpiration coefficient is 600 (S. Balázs, 2004). In summer, the evaporation of watermelon can reach 1-2 liters per plant per day (Nagy, 2005). Watermelons have a very suboptimal and higher water supply, both in plant development and in crop quality (Nagy, 1997).

In watermelon cultivation, July and August are the most critical months in terms of water supply (Nagy, 2005), as the lowest rainfall falls during the growing season, when the average temperature is the highest, so the evaporation of the melon and the development of the plant occur even the most water-demanding periods (Nagy, 1997). During the growing season, 30-40mm of water replacement irrigation is required several times, depending on the soil binding and the depth of rooting of the plant (Hodossi et al., 2004) The advantages of watermelon irrigation are that higher yield averages (100, 150 t / ha), higher yield safety, higher yield quality, and more balanced crop development and growth can be achieved (Nagy, 2005).

There are several aspects to consider when planning to irrigate a watermelon. It is very important that irrigation should be implemented differently on different soil types (Knott & Tamás, 1973). In addition, it is important to choose the right time and method of watering. Drip irrigation proved to be the best method, which was confirmed by experiments (Nagy, 2005).

Drip irrigation belongs to the group of micro-irrigation. It is generally characteristic of micro-irrigation that at low water pressure, in a short period of time, small cross-section water dispensing elements deliver the irrigation water directly to the root of the plants (Tóth, 2006). One of the main features of drip irrigation is that the use of irrigation water is economical, as it supplies it directly to the root zone of the irrigated plant, thus it can immediately compensate for the emerging water demand of the plant. In addition, in the cultivation of vegetables, nutrients are increasingly being applied in the form of water-soluble fertilizers during drip irrigation, thus enabling nutritious irrigation. The process of this can be fully automated (Kiss & Rédai, 2005). Because of all this, it is favorably used in vegetable production. Initially, it was widespread in greenhouses and film tents (Kiss & Rédai, 2005), but due to its advantages, it has been used more and more often in field vegetable production in recent years (S. Balázs, 2004).

Regarding the nutrient requirements of watermelon, it belongs to the group of high-nutrient vegetable species. It is particularly fond of organic fertilizer. Watermelons need 12.3 kg of nitrogen, 3 kg of phosphorus and 17.9 kg of potassium to produce 10 tonnes. Of the macronutrients - in descending order of watermelon demand – watermelon needs: K, N, Ca, P and Mg. It requires the most potassium and the least magnesium (Nagy, 2000).

Among the micronutrients, the following are essential for watermelon: Fe, Mn, Zn, Ni, Cl, B, Mo (Nagy, 2005). An American study has also pointed to the paramount importance of zinc as well as its yield-enhancing effect in watermelon cultivation (Locascio et al., 1966).

Watermelons belong to the group of the most high-nutrient vegetable species, so it is very important to pay attention to their nutrient supply in order to have the right amount and quality of fruit. With proper nutrient replenishment and irrigation, yields of up to 100-150t/ha can be achieved (Nagy, 2005).

Many nutrients play an important role in watermelon cultivation. These include nitrogen, phosphorus, potassium, calcium, magnesium and molybdenum. Nitrogen is one of the most important macronutrients for watermelons, as it determines the development, shoot growth, flowering, fruit attachment and development of plants (Kertészek Áruháza). An experiment in Croatia in 2000-2001 also highlighted the importance of nitrogen in watermelon cultivation. In the experiment, increasing the nitrogen supply from 115kg/ha to 275kg/ha under optimal and less optimal growing conditions resulted in more intensive shoot growth in the 4th and 7th weeks after planting (Goreta et al., 2005).

A study in Florida also looked at the changes in watermelon cultivation caused by different amounts of phosphorus active ingredients. The largest change was between 0 kg/ha P and 25 kg/ha P nutrient levels, both in terms of average crop weight and yield per hectare. Further increase of phosphorus resulted in only minimal increase, but in some cases deteriorated yields (Hochmuth et al., 1993).

Potassium also plays an important role in watermelon cultivation, as it plays a very important role in the speed of ripening and in ensuring the quality of the crop. In the case of potassium deficiency, the development of the plants is delayed, the fruit will have a low sugar content, water taste and an uncharacteristic flesh color (Nagy, 2000). Calcium has a very important role in the development and flowering of watermelons and also influences the quality of the crop (Scott & McCraw, 1990). In the case of magnesium deficiency, yellowish-green spots initially appear on the leaves of the plant, and then the whole leaf turns yellow, whitens, and dies (Nagy, 2000). Lack of molybdenum can lead to poor plant development, low yields and, in the worst case, plant death. It most commonly occurs on acidic soils (Nagy, 2000).

In the cultivation of watermelons we can also use basic fertilization, nest fertilization, starter fertilization, top fertilization and foliar fertilization. However, the importance of nutrient solution is also growing in the most modern plantations. The nutrient solution is applied by water-soluble fertilizers via a drip system (ICL, 2015). This is actually the application of the topsoil in dissolved form with irrigation water (Nagy, 1994). It is used during the growing season in order to achieve a more efficient and even nutrient application, a continuous supply of nutrients to the plant and better yield data. Thus, yields of up to 50 tons per hectare can be achieved (Nagy, 2005). This is the most effective way of supplying nutrients in mulch cultivation.

Nutrients (mainly nitrogen) applied simultaneously with drip irrigation significantly increase the yield of watermelon, especially on looser soils (Rolbiecki et al., 2020). Other advantages are that the composition and amount of nutrients can be formulated and delivered according to the current phenological stage of the plant, and that it allows immediate intervention in the event of a nutrient deficiency (ICL, 2015).

The advantages of using watermelon grafting is that watermelon becomes much more resistant to various environmental effects, has a positive effect on nutrient and water uptake, as well as the quantity, weight and quality of the crop, and the harvesting season can be better extended to grafted plants. In addition, grafting watermelons is also a solution for controlling infectious pathogens (*Verticillium*, *Fusarium*) and pests (*Meloidogyne* spp.) From various soils. Due to this, watermelons can be grown in the area for up to several years (G. Balázs, 2013; Davis et al., 2008).

Figure 1: Rubin F1 watermelon variety (Photo: Patrik Krizsán).

Table 1: Treatments and their labeling

	Repeat 1	Repeat 2
Grafted seedlings, control treatment	O/1/I.	O/1/II.
Grafted seedlings, phosphorus overweight treatment	O/2/I.	O/2/II.
Grafted seedlings, nitrogen overweight treatment	O/3/I.	O/3/II.
Grafted seedlings, potassium overweight treatment	O/4/I.	O/4/II.
Self-rooted seedlings, control treatment	S/1/I.	S/1/II.
Self-rooted seedlings, phosphorus overweight treatment	S/2/I.	S/2/II.
Self-rooted seedlings, nitrogen overweight treatment	S/3/I.	S/3/II.
Self-rooted seedlings, potassium overweight treatment	S/4/I.	S/4/II.

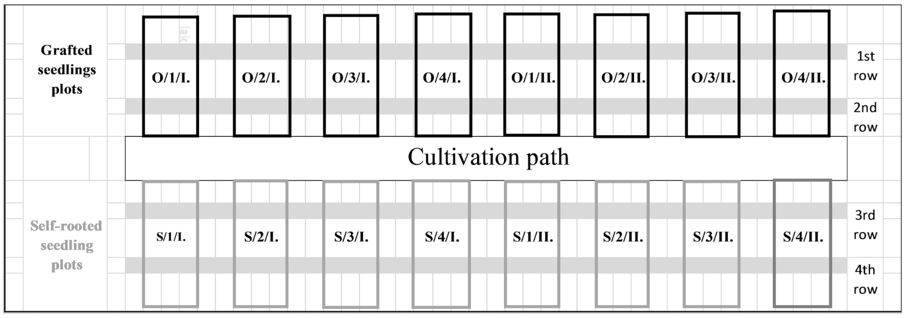

Figure 2: Diagram of the experimental area and arrangement of treatments.

Materials and Methods

Our experiment was carried out in Medgyesegyháza in 2020-2021 on an area of 1000 m^2, during which we examined the effect of different nutrient levels applied simultaneously with irrigation on the development of self-rooted and grafted watermelons, as well as on the quantity, quality and average weight of the crops. The experiment took place in the same area for both years. In the experiment, we also examined the Rubin F1 watermelon variety included in the Syngenta variety selection list for the self-rooted and grafted seedling types, which is illustrated in Figure 1.

We developed a total of 16 experimental plots of about 20 m^2 in the whole area. Each plot consisted of 2 adjacent rows. We examined 3–3 seedlings in both rows, so a total of 6 seedlings were placed in one plot. The plant spacing within the plots was 120 cm between each seedling. From the product of the seedling distance and the 250 cm row spacing, it can be stated that one plant had 3 m^2 of growing area.

The 16 plots were distributed in the area by examining the grafted seedlings in 8 plots and also the self-rooted seedlings in 8 plots. The 8 plots were composed of a control, a phosphorus overweight, a nitrogen overweight, and a potassium overweight nutrient level, which we examined in duplicate.

We distinguished the 16 experimental plots by marking them, which are illustrated in Table 1. The entire experimental area and the location of the treatments are shown in Figure 2. The area did not receive basic fertilization in any of the years to avoid inaccuracy in the experiment.

Nitrogen, phosphorus, and potassium applications were also performed in the most appropriate phenological phases of the plant. For each treatment, all three nutrients were applied in the same period, we only changed their amount to suit the nutrient level. Phosphorus application after planting, before and during the first flowering period; nitrogen application after fruit set during crop growth; and potassium application was taken during the ripening period. Each excess active ingredient was administered in several smaller doses, for better absorption and utilization. We used various water-soluble fertilizers to apply the active ingredients, which I applied simultaneously with irrigation. The water needed for irrigation and fertilizer dissolution was taken from a 11 meter deep well in the experimental area using a pump. However, the salinity of the water obtained from it proved to be high at 1.09 mS/cm and 1.24 mS/cm, which was revealed by the salinity measurements of the water samples taken in the spring.

The application of the additional active ingredients was carried out in such a way that the amount of active ingredient dispensed in the additional treatments was approx it should be 6 times that applied in the control plot. During the experiment, the nutrients could only be applied in the form of complex water-soluble fertilizers, which is why the amount of the other two nutrients increased minimally when the additional active ingredients were dispensed. For this reason, when formulating the fertilizers, we constantly made sure that the 1:2:1 ratio was maintained in favor of the given additional active substance. The total amount of NPK active ingredients applied to the treatments during the whole growing period is shown in Table 2.

Uniform and optimal amounts of fertilizers for the treatments were dispensed through a drip belt using an irrigation system. On the other hand, the application of the additional active substances was carried out in several smaller doses, with an irrigation can, irrigated to the watermelon stems, because this was the only way to carry it out due to the high pressure of the irrigation system. For each plot, we dissolved the excess fertilizers in 5 liters of water and distributed this amount among the 6 seedlings inside the plot. Accurate measurement of fertilizer doses was performed using a gram balance.

In addition to nitrogen, phosphorus and potassium, we also applied calcium and various trace elements (iron, manganese, boron, copper, zinc, molybdenum) during the development of watermelon. In order to examine the utilization of the applied nutrients, we

Table 2: Amount of total NPK active ingredients applied per plot during the growing season 2020-2021

	Control plots (S/1/I., S/1/II., O/1/I., O/1/II.)	Phosphorus overweight plots (S/2/I., S/2/II., O/2/I., O/2/II.)	Nitrogen overweight plots (S/3/I., S/3/II., O/3/I., O/3/II.)	Potassium overweight plots (S/4/I., S/4/II., O/4/I., O/4/II.)
N	24.93 g	66.63 g	144.58 g	63.67 g
P	21.48 g	132.48 g	60.52 g	59.25 g
K	21.35 g	59.05 g	65.645 g	136.35 g

performed the counting of female and male flowers, as well as the measurements and calculations related to the yield, weight and average weight during the growing season. In the course of our work we also performed refraction measurements, the examination of crop weight loss and the sensory examination. Most of the measurements were in both years, but there were some that we only did in 2021.

Results

The results of the measurements, tests and calculations performed in both years of our experiment (2020, 2021) will be described in this chapter in accordance with the development of the watermelon. The weather in the 2020 pilot year made it very difficult for different work processes as well as nutrient deliveries. In addition, the extreme vintage had an adverse effect on both the development and yields of the watermelon, which is why we mostly relied on the average results of the year 2021 and the two experimental years to judge the conclusions.

When processing the results for all measurements, tests and calculations, both for self-rooted and grafted treatments, we used the average of the two replicates for ease of reference. From the sum of the average data obtained every 4 days during flowering-related measurements, it can be seen that during the experimental year, during the experimental year 2020, the application of a higher phosphorus active substance did not result in the formation of a significantly higher number of female flowers, in contrast to the year 2021, when both O/2. and S/2. treatments, more significant female flower differentiation was observed in an area of 1 m^2 (Figure 3). For the other treatments, there was no significant change based on the mean results of the two years.

In the case of male flowers - similarly to female flowers - the application of the higher phosphorus active substance in the experimental year 2020 did not result in a significant change in the number of male flowers in the O/2. and S/2. treatments. This is due to the vintage effect. However, in 2021, and based on the average of the results of the two years, the excess phosphorus in the two mentioned treatments resulted in the formation of higher amounts of male flowers (Figure 4).

Based on the average of the data of the two years, it can be said that the number of crops per treatment was not significantly affected by the different nutrient levels (Figure 5). It follows that the higher yields of each treatment were more significantly due to the higher average weight of the crops (Figure 6).

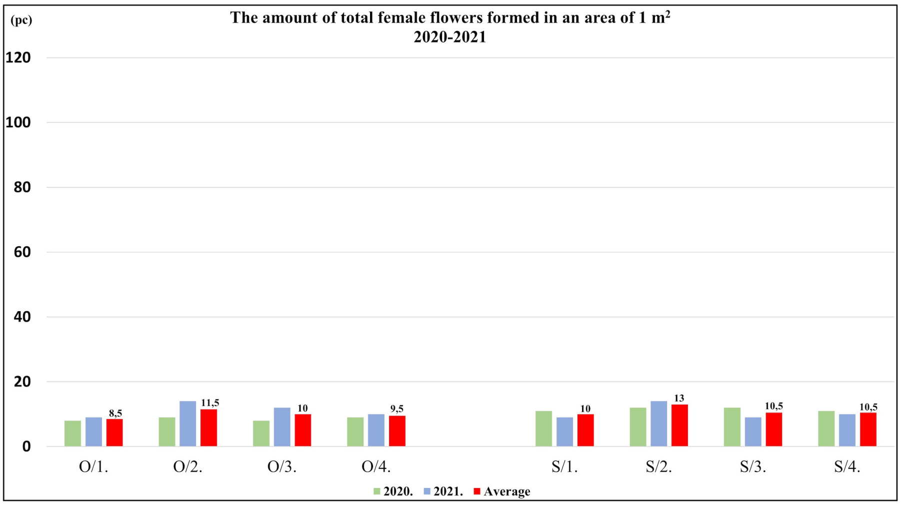

Figure 3: Total amount of female flowers formed in different treatments in an area of 1 m^2 in 2020 and 2021, as well as the average of the data for the two years.

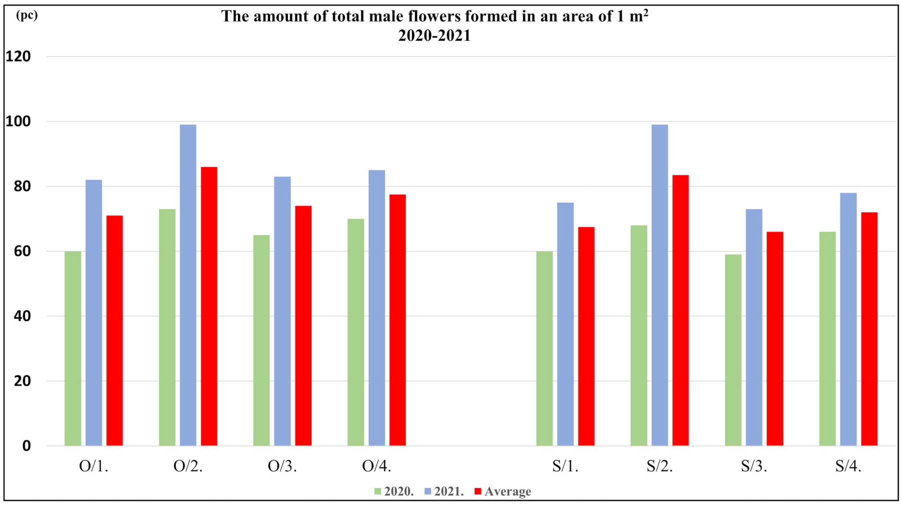

Figure 4: Total amount of male flowers formed in different treatments in an area of 1 m^2 in 2020 and 2021, as well as the average of the data for the two years.

Based on the average data of the two experimental years, it can be said that the higher amount of female flowers differentiated in the S/2. and O/2. treatments resulted in a minimally higher number of harvested crops only in O/2. Looking at the average of the results of the two years, it can be said that in the case of grafted seedlings, the watermelons with the highest average weight were obtained by O/3. treatment, where the growth of the yield was positively influenced by the high nitrogen active substance.

For self-rooted seedlings - based on the average of the data for the two years - the excess active substance application resulted in lower weight crops in both the S/2. and S/3. treatments compared to the control. However, comparing the results of the average yield and number of crops of the S/3 treatment, it can be said that despite the lower average weight, about 10% more yields were formed compared to the control. There was

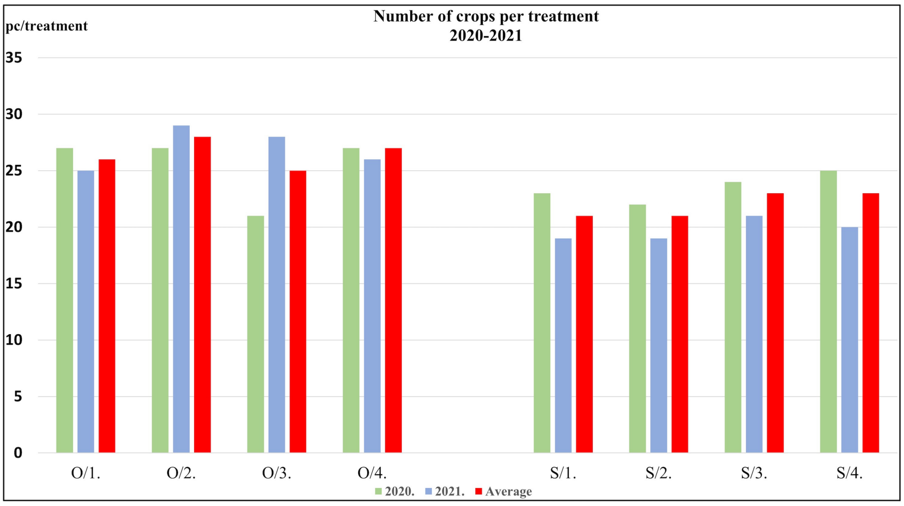

Figure 5: Crops number results per treatment (2020, 2021) and average of data for two years.

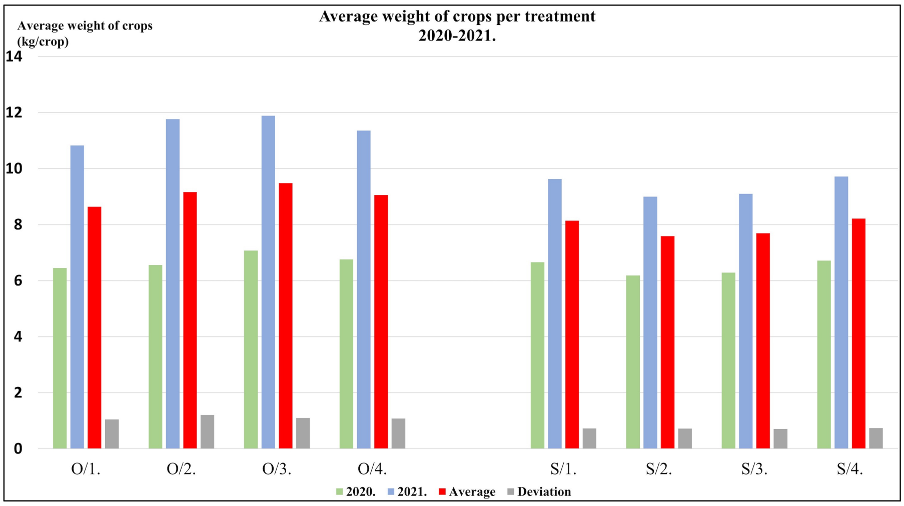

Figure 6: Average crop weight per treatment results (2020, 2021) and the average and standard deviation of the data for the two years.

no significant change in S/4. treatment.

Based on the results of the refraction measurements performed during the two experimental years (Figure 7), it can be stated that only the O/4. treatment had a negative effect on the refraction of the crops. The results of the other treatments did not show a significant difference. For self-rooted plants, S/2. and S/4. treatment resulted in an increase in yield refraction, in contrast to S/3., which showed a small decrease compared to the control.

Sensory examination was performed only in the experimental year of 2021. During the study, the judges did not know which treatment was being tested, so this did not affect the scoring process for them. The tested crops could be scored from 1 to 10, with 1 being the least and 10 being the tastiest watermelon. At the end of the study, we averaged the scores obtained with the number of reviewers (by 10). Thus, for both repetitions of each treatment, we obtained an average score ranging from 1 to 10, which is indi-

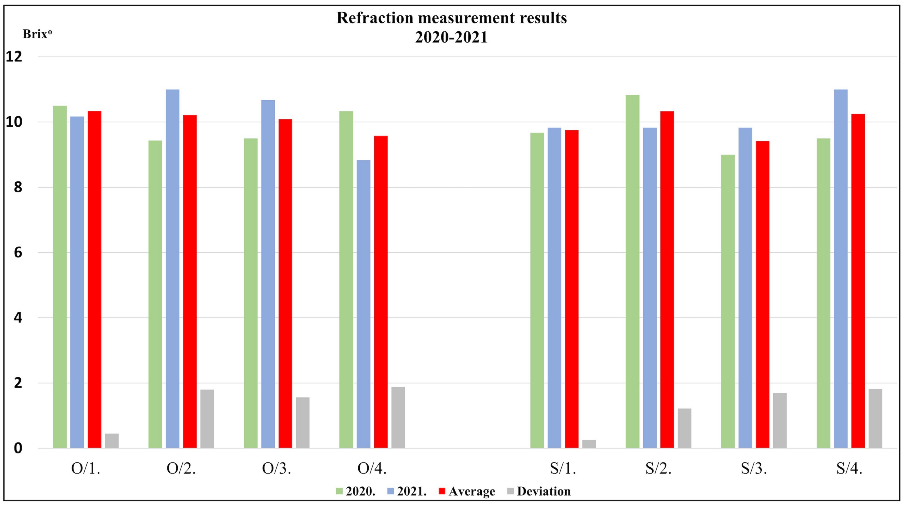

Figure 7: Results of refraction measurements (2020, 2021) and the mean and standard deviation of the data for the two years.

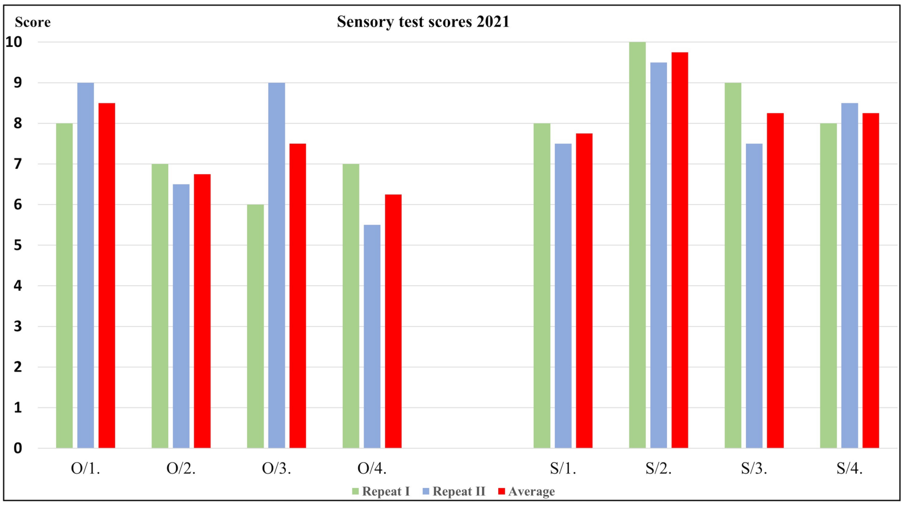

Figure 8: Sensory test scores (2021) and mean scores for replicates.

cated in Figure 8.

Based on the averaged scores, it can be seen that the watermelons grown in the control (O/1.) proved to be the tastiest of the grafted treatments, despite the fact that the refraction values in 2021 were not the highest for this treatment. It is true that, based on dry matter content measurements, O/2. treatment showed the highest value in 2021, however, in the opinion of the reviewers, it was not the tastiest.

Among the self-rooted plants, the yield of S/2. treatment received the highest score based on the averaged scores. Refraction measurements in 2021 showed the highest value in the crop of the S/4. treatment, however, according to the reviewers, the watermelons grown here were not the tastiest.

Crop weight loss was also examined only in the experimental year of 2021. The aim of our study was to investigate the shelf life of watermelons grown in different treatments to see if different nutrient levels in this area affect the quality of the crop. To this end,

Table 3: Weight loss of crops of different treatments (2021)

	Repeat I.	Repeat II.	Average of repetitions
O/1.	3.9%	4.32%	4.11%
O/2.	2.29%	2%	2.15%
O/3.	2.61%	4.64%	3.63%
O/4.	2.04%	4.21%	3.13%
S/1.	3.1%	2.33%	2.72%
S/2.	2.49%	1.91%	2.2%
S/3.	2.25%	2.05%	2.15%
S/4.	1.59%	2.27%	1.93%

we took a crop from each of the two repetitions of each treatment, the weight of which was measured and recorded one by one, after which, for 12 days, the temperature of a store was approx I placed them in a 20°C room. When collecting the samples, I tried to make them approx have the same mass to ensure the accuracy of the results obtained. Then, after 12 days, we again measured the weight of each crop one by one, and the percentage difference between the two measurements gave the degree of decay. The results obtained in the studies are shown in Table 3. After averaging the results of the different treatments, it can be stated that the decrease in the weight of the examined crops was the smallest among the grafted treatments O/2. and among the self-rooted treatments the S/4. treatment. In addition, it can be observed that the crop of self-rooted plants decreased to a lesser extent than the crop of grafted plants.

Discussion

Our experiment showed that at the beginning of the growing season, before or during the first flowering period, higher amounts of phosphorus applied simultaneously with irrigation have a positive effect on the development and yield and quality of *grafted plants* throughout the growing season.

In addition, we were convinced that in the case of self-rooted plants it has a positive effect on the results of the higher amount of potassium active substance applied during the ripening period, also during irrigation, especially in terms of the average weight of the crops and the number of crops per treatment. We found that – similarly to the grafted plants – the higher phosphorus active substance released before and during the first flowering period also promotes the flower formation of the self-rooted and improves their yield quality. All of this proves that it is really necessary to use different nutrient replenishment in the cultivation of self-rooted and grafted plants.

In addition to the results obtained, the experiment showed that the nutrients applied during drip irrigation are of great importance for the development of the plants and the quantity and quality of the crop. Respectively, the efficiency of irrigation is greatly influenced by the vintage effect.

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MAGYAR AGRÁR- ÉS ÉLETTUDOMÁNYI EGYETEM

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Sexual differences in morphology and winter diet of the Eurasian magpie (*Pica pica*) in Hungary

Miranda IMERI[1] – Krisztián KATONA[1]

1: Hungarian University of Agriculture and Life Sciences, Institute for Wildlife Management and Nature Conservation, Department of Wildlife Biology and Management, H-2100 Gödöllő, Páter Károly u. 1., Hungary, e-mail: Imeri.Miranda@hallgato.uni-mate.hu

Abstract: Eurasian magpie (*Pica pica*) is a widely distributed, common species of the Corvidae family. Since magpies have lived close to humans for centuries, we have much information about the species. However, there are few data about morphological and dietary differences between sexes, primarily due to their monomorphic, omnivorous, and opportunistic characteristics. The aim of the study was to analyse the sexual differences in the morphological characteristics, simultaneously provide the body measurements for both sexes with a high level of accuracy and determine the diet composition through stomach content analysis during the winter. The samples were provided by the local gamekeepers from a hunting in February of 2020, in Hungary. The linear measurements of body parts (eight variables considered) have been done for all individuals ($n = 30$), and the values were compared between the sexes. The stomach contents were categorized among five main food components, and comparisons of stomach contents and their weights were also performed between males and females. The results concluded that there were no significant differences between the sexes in the studied morphological variables. The dietary analysis revealed that during the winter magpies fed on a range of different food types, with seeds, invertebrates, and vertebrates being the most frequently consumed food. We revealed slight differences between sexes in the consumption of the two latter categories. Our investigations supported earlier findings on the high morphological and dietary similarities of the two sexes also in case of a Hungarian magpie population. These results can serve as a potential basis for further research on magpies in Europe.

Keywords: body measurements, monomorphic birds, food composition, stomach analysis, Corvidae

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Introduction

The Eurasian magpie (*Pica pica*) is a resident breeding bird throughout Europe, much of Asia, and northwest Africa (Johnson, 1993). Females and males are difficult to distinguish in the field. Among the Corvidae sexes are monomorphic, making accurate sexing a formidable task (Kavanagh, 1988). However, male Eurasian magpie tends to be larger than female (O'Connor, 1985). Application of morphometric analyses becomes more complicated especially when the body size and feather colour vary among different geographical regions (Kahn et al., 1998; Shephard et al., 2004).

Field studies of wild avian species often require the determination of their sex. The difficulty of sexing avian species stems from the absence of external sex organs in birds (Cerit & Avanus, 2007). Accurate prediction of sex has been successfully performed by analysing external measurements (Green, 1982; Kavanagh, 1988; Wood, 1987). However, in case of magpies there is a considerable overlap between females and males in almost all morphological measurements for adults and juveniles. Due to this reason, sex determination in the field is difficult in the absence of behavioural cues (Tatner, 1992).

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To classify certain physical parameters, such as body size, it is difficult to quantify in a single measure. Perhaps the best estimate of overall body size is total mass, but reliable information on mass is often difficult to obtain (Rising & Somers, 1989); so, combinations of several measurements are often required. Beside sexing, body measurements of the species have their important aspect. Among many other parameters, body size is a fundamental characteristic in birds and as such also an important distinctive criterion for species, populations, and sexes. Body measurements of birds provide information on the relative ratios of their body parts at different taxonomic levels and the data provide access to ecomorphological research questions (Leisler & Winkler, 1991). The measure of overall body size in birds is required to test hypotheses predicting patterns of geographic variation (James, 1970). Furthermore, the body mass maintained by a wintering bird can be viewed as a trade-off between the risk of starvation and the risk of predation. A bird should be as fat (or heavy) as possible to minimize its starvation during food scarcity periods, however, a bird should be as lean as possible to minimize its probability of being killed (Lima, 1986).

Dietary habits, as basic elements in constructing the niche of the species, are also essential for revealing the ecology of birds (Woodroffe et al., 2005). The feeding habits of the Eurasian magpie give rise to controversial interpretations between researchers, conservationists, and hunters (Díaz-Ruiz et al., 2015). In Europe, magpies are generally considered as harmful bird species by nature conservation or game management points of view due to their predation on eggs and chicks of songbirds and gamebirds (Birkhead, 1991). The diet of magpie has been the object of several studies focusing on different issues, *e.g.*, seasonal differences, food selection, diet of nestlings or differences between rural and urban magpies (Kryštofková et al., 2011; Ponz et al., 1999; Soler & Soler, 1991). As reported by studies, magpies are generalist consumers that feed on a broad spectrum of food types, including both vegetal and animal resources (Díaz-Ruiz et al., 2015).

In this context, the main objectives of the study were to obtain data and knowledge about: (i) the morphological characteristics and potential sexual differences in case of the Eurasian magpie in Hungary; (ii) the diet composition of males and females during the winter period.

Materials and Methods

Study area and field sampling

Carcass samples of magpies were collected by the gamekeepers of Csíkvölgyi Wass Albert Hunting Association in Mogyoród, Hungary. Hunting was organized for one day as a group hunting, in Csömör, Pest County, Hungary, during the winter period, in February 2020. The covered area composed of habitats such as a meadow-dominated landscape with some interspersed patches of natural vegetation with shrubs and edges of agriculture fields. Altogether 30 magpie individuals were shot and collected for further analyses. Samples were stored in the freezer until laboratory investigations.

Morphological data collection

First, in this study, the body measurements of the carcasses have been conducted. The manual for bird measurements written by Oschadleus (2012) was followed. Total body weight was measured on an electronic scale, measuring in gram with an accuracy of two decimals. For body measurements we used transparent plastic rulers and tape measures. To precisely measure the length of the wings, a ruler with a zero-stop was applied using the measurement lines in centimetres (accuracy: 0.1 cm). Wingspan measurements were taken with the bird lying on its back on top

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Table 1: Description of the different diet components during the stomach analysis of magpie

Diet component	Indicators
Vertebrates	Egg shells, bone parts, feathers, and hairs
Invertebrates	Arthropoda (insects, caterpillars, larvae), Arachnids (spiders), Gastropods and Molluscs (snails, shell fragments, shell apices)
Plants (Seeds)	Cereal, sunflower, barley, wheat seeds and cracked corn
Grit	Grit and stones of 1-2 mm length
Miscellaneous	Grey liquid; brown, dry particles; difficult to quantify

of a ruler, with its wings outstretched. The half wingspan was measured from the centre of the back to the tip of the wing. For total body length the measurements have been done from the tip of the bill to the tip of the tail. Tail length was measured from between the two innermost traces where their bases emerge from the skin to the tip of the longest tail feather in the naturally folded tail, from the dorsal side. Round circle body measurements were taken with a tape measure, starting from the belly of the bird toward the back, touching the rump part of the body. The bill length was measured from the tip of the bill to the angle at the front of the skull. Sexes were determined visually by opening the carcass body cavity and examining the inner reproductive organs.

Stomach content analysis

Investigations of the diet of the magpie have been carried out based on Tatner (1992)'s work. Each sample was prepared, and the stomach contents were set into an appropriately labeled petri dish, separately to all carcasses. The content of each stomach was dried out and weighed (accuracy: 0.01 grams) and investigated by macroscopic analysis under a stereomicroscope and a magnifying glass. The small amount of content in the stomachs prevented the use of nesting sieves. Food items were grouped into the following categories: vertebrates, invertebrates, plants (seeds), grit, and miscellaneous. Description of the different diet components are given in Table 1.

Data analysis

Based on body measurements we compared the average values between sexes for each body parts. From the data obtained from the diet composition analysis, we calculated and compared between sexes (i) the average dry weight of the total stomach contents, (ii) the frequency of each food item (number of samples containing the given food components, %). Statistical comparisons were performed by unpaired t-tests. We processed and analysed data using Microsoft Excel and GraphPad Prism.

Results

Morphological characteristics of magpie

Based on the investigation of the sexual organs we could identify 15 carcasses as female and 15 as male. The results of the linear measurements (Table 2) showed no significant differences between females and males regarding their total body weight (unpaired t-test: $t = -0.014$, $p = 0.98$), both sexes having an average value around 176 g. Neither the body length ($t = 0.95$, $p = 0.34$) showed a significant difference between sexes (43 vs. 42 cm for females and males, respectively). Similarly, we could not reveal any statistical difference in case of the beak length ($t = 0.59$, $p = 0.55$), wing length ($t = 0.70$, $p = 0.48$), wingspan length ($t = 1.15$, $p = 0.25$),

Table 2: The body measurements for female and male magpies: Values for total body weight, body length, beak length, wing length, wingspan length, half wingspan length, round body circle, tail length are compared. $N = 15$ for both sexes. Measurement units are given in centimetre (cm) for the length variables and in gram (g) for the body weight.

Measurement	Sex	Mean	SD.	Min.	Max.	*P* value
Total weight	Female	176.22	20.34	147.5	211.4	0.988
	Male	176.92	18.76	138.5	211.2	
Body length	Female	43	2.47	39	49	0.349
	Male	42.06	2.52	37	48	
Beak length	Female	3.63	0.29	3	4	0.558
	Male	3.56	0.31	3	4	
Wing length	Female	18.73	3.13	17	20	0.483
	Male	18.53	0.63	18	20	
Wingspan length	Female	53.66	3.13	49	60	0.258
	Male	52.2	3.80	44	60	
Half wingspan length	Female	24.2	1.85	21	28	0.543
	Male	23.8	1.69	21	27	
Round body circle	Female	20.53	0.85	19	22	1.000
	Male	20.53	0.63	19	21	
Tail length	Female	24.53	2.26	20	30	0.825
	Male	24.1	2.26	19	28	

half wingspan length ($t = 0.62$, $p = 0.54$) round circle body ($t = 0$, $p = 1.0$) or for the tail length ($t = 0.22$, $p = 0.82$).

Diet composition of magpies

We found that the dry mass of stomach contents of females can weigh 1.2 g in average, while that of males is only 1 g, although this difference was not statistically significant due to the variability of data (t-test: $t = 1.06$, $p = 0.29$). The analyses of the stomach contents of the 30 individuals showed that seeds (found in 46.67% of all samples) and invertebrates (30%) were the predominant winter food sources of the magpies, following the categories of vertebrates (20%). Miscellaneous items appeared in 13.33% of the samples, while the grit was revealed in 6.67% of them (Figure 1) (Appendix 1).

The results on Figure 1 reveal the category of seeds, represented as the most frequented food component for both sexes, almost with the same frequencies (40 and 46.67% for males and females, respectively). The second category, invertebrates (Arthropoda, Arachnids, Gastropods and Molluscs) was represented twice higher (40%) for the females, compared to the males (20%). Contrarily, in case of the category of vertebrates, the higher frequency value was clearly noticeable for the males (26.67%) than for females (13.33%). The category of grit (grit and stones: 6.67% for both sexes) and miscellaneous contents (grey liquid, brown, dry particles: 13.33% for both sexes) showed identical frequencies between sexes.

Discussion

The results of the study yielded interesting knowledge about morphological differences and winter diet of magpies in Hungary. According to our results we could not find any

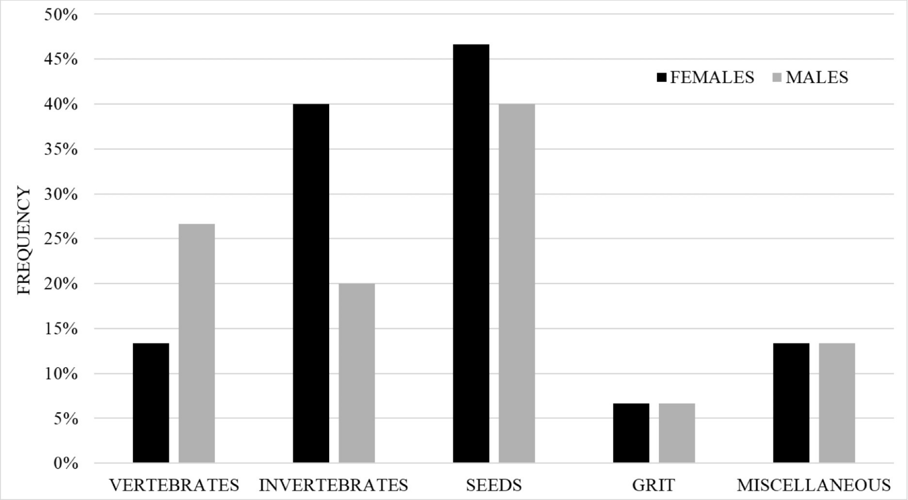

Figure 1: The comparisons of stomach content categories between the sexes (frequency of occurrence of diet components). $N = 15$ for both, females and males.

clear sign of sexual differences of the measured morphological characteristics in case of the species. It means we are not able to recommend any simple body measure for sex identification. Our results are supported by earlier findings that states for magpies as monomorphic, making accurate sexing a formidable task (O'Connor, 1985).

Monomorphism is assumed to be the ancestral state, where there is no obvious signature of selection differentiating the sexes. However sexual monomorphism, can also be a derived condition, evolving from sexual dimorphism (Staub, 2020). Results obtained by Owens and Hartley (1998) suggested that size dimorphism is associated with intrasexual competition described by the mating system, meanwhile plumage colour dimorphism is linked to the frequency of extrabond paternity. Santos et al. (2007) demonstrated that the European Magpie has sexually dichromatic plumage characteristics that are invisible to the human eye.

But even if body measures are not eligible to distinguish sexes, they can serve for other purposes. A measure of overall size is required to test hypotheses predicting patterns of geographic variation (Handford, 1983; Murphy, 1985). In addition, species must be ranked by body size to test models that predict size ratios among coexisting species in ecological communities (Brown & Maurer, 1986; Miles & Ricklefs, 1984). In physiology, standard measures of metabolic activity are frequently expressed as a function of body size, and it is often useful to examine the relationship of structures or organs relative to overall body size (Packard & Boardman, 1988; Paladino, 2015).

Regarding the diet, our finding clearly indicates the seeds as the predominant food sources (40%) for both sexes during the winter period for the magpies in Hungary. In the study by (S., 1928) the vegetable material was a major constituent of the adult magpie diet during the winter and spring in America, but there is a difference in the type of plant material involved. In Manchester, seeds (mainly grain) and root material were the most abundant forms of vegetable matter (Holyoak, 1968). Besides, winter resources are generally good for farmland corvids; invertebrates and stubble grain are available and other food sources appear sporadically, for example when fields are plowed, pastures are mucked, or stock food put out (Feare et al., 1974; Waite, 1985). Moreover, during snow cover harrowed fields are avoided, more birds frequent ploughed fields during snow cover and frost compared to thaw and no snow cover, thus, during winter event avoided habitats were utilized to a high degree by magpie (Møller, 1983).

Beside plant materials, animal food was also important for magpies. Previous studies conducted in different parts of the world like Korea, Spain, France also indicated that magpies presented a generalist diet which included a wide range of food types (Bravo et al., 2020; Díaz-Ruiz et al., 2015; Song et al., 2012). The relatively frequent occurrence of vertebrates (eggshell, hair, fur, and mammal remnants) with 20% in their diet, suggests that magpies can opportunistically consume small mammals, songbirds, or carcasses. The stable presence of invertebrates (30%) in the late winter diet of magpies suggest that these birds are able to find the active or hiding insects even when this prey type is less available. Magpies can select food items independently of their availability, as reported for some invertebrate groups (Kryštofková et al., 2011; Martínez et al., 1992), At the same time, we revealed that invertebrates were consumed with higher frequency by females and vertebrates were more eaten by males. This dietary shift can be due to the different needs of the two sexes leading to different prey searching strategies, but this question needs further investigations. It is interesting to note that the frequency occurrence of the grit (stones of 1–2 mm) was 6.67%. This finding can be supported by the fact that many extant animals such as different birds, seals, turtles, or crocodiles possess stones in their stomach (Wings, 2007). For birds, it is generally assumed that these stones contribute to the mechanical crushing of food (Ziswiler & Farner, 1972).

The comparisons of the total weight of the stomach content between sexes show that for females the stomach weight was a little bit heavier than that of males in average. Although it was not a statistically significant difference, it can have some biological meaning. Nilsson et al. (2020) showed that female birds benefit more from extra food in the winter. If females receive additional food, they do not need to reduce their body temperature as much as they would have otherwise, and the chances of surviving cold nights increase.

Conclusions

With the respect to the present study, essential morphological data of magpie were obtained. Overall, based on the linear body measurements and comparisons between sexes, we confirm that no phenotypic feature based on which males and females of this species can be distinguished in the field by hunters or birders. However, trapping of magpie can be performed very effectively, which can promote to gain deeper insight into the population structure and potential sexual differences of this bird species. Furthermore, the outcome of this study showed that the main winter diet components of magpies in Hungary were the plant seeds supplemented with the consumption of invertebrates and vertebrates, but these two latter with a bit different importance for males and females. However, these studies did not consider every period of the year. Thus, we propose a year-round investigation of both magpie diet and food supplies to gain a better knowledge of the species feeding preferences and utilization. More studies on the magpie (especially on its effects on other species (e.g., nest-predation experiments) can help elucidate its role in the population dynamics of threatened bird and invertebrate species.

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Effect of cereal-legume intercrops on the soil enzymatic activity

Attila RÁCZ[1,2] – Melinda TAR[1] – Marianna VÁLYI NAGY[1] – Apolka UJJ[2] – István KRISTÓ[1]

1: Hungarian University of Agriculture and Life Sciences, Plant Production Scientific Institute, Crop Production Research Center, Crop Production and Agrotechnical Research Station, Alsó Kikötő sor 9. 6726, Szeged, Hungary, e-mail: Racz.Attila@uni-mate.hu
2: Hungarian University of Agriculture and Life Sciences, Institute for Sustainable Development and Management, Páter Károly u. 1. 2100, Gödöllő, Hungary

Abstract: Sowing and harvesting cereals with legumes is an old crop production practice. The main goal of cultivation is to make the best use of the area and to increase the quality and yield of the crops. The intercropping of cereals and legumes can stimulate the biological activity of the soil, thus increasing the recycling of soil organic matter. Competition between two or more plants has a positive effect on the nitrogen fixation of legumes. In organic form the soil enzyme activity increasing is more effective which is provided by the winter pea (*Pisum sativum* L.) in this crop production system. We set up our experiment at the experimental sites of the Hungarian University of Agriculture and Life Sciences, Plant Production and Agrotechnical Research Station, Szeged-Öthalom and Fülöpszállás in 2020/2021. The experiments were performed on 10 m^2 plots, in four replicates, with four cereals and one winter pea species, in different phenological phases. We were used fluorescein diacetate to determine the total microbial activity of the soil. As the phenophases progress, the enzymatic activity of the soil decreases, and activity is affected by soil type. The soil enzyme activity was lower on meadow chernozem soil and higher on calcareous meadow soil. Cereal-legume intercrop systems are better able to adapt to drought. The values are higher in cereal-legume intercropping system than in cereals sowed alone. Based on our results, it can be concluded that the enzymatic activity of the soil can be increased by using soil inoculation with bacteria and mycorrhiza fungi preparations.

Keywords: soil enzyme activity, cereal-pea intercrops, plant associations, winter pea

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Introduction

If we are looking at Hungary's arable land, it can be seen that five main crops (wheat, barley, maize, sunflower, rapeseed) dominate, of which almost three quarters of the crop area is dominated by cereals (KSH, n.d.). With the development of crop production, the yield of our cereals has tripled. For this reason, the area under cereals has started to increase, which has contributed to the increase in the number of animals consuming forage. Due to the feeding of the animals, there was a high demand for protein. Which was not satisfied by the dissonant sowing structure and the low yield of legumes (Bocz, 1996). Since the turn of the millennium, the demand for protein in the country has become even more serious. We do not currently have enough sources of animal (insect protein, fish meal, bone meal, meat meal) or vegetable protein. Hungary is only capable 15-20% self-supply, thus our country needs a large amounts of import (http1, 2019). Our demand are 600,000 tons of soybeans a year, which we often covered by low-quality genetically modified organism imports (http2, 2017). In the National Protein Program, the objectives include that increasing the sowed area of soybeans. However, the experience of

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recent years has made it clear that regardless of the vintage and the site of production, we do not produce enough protein despite the subsidies. The program also recommends the cultivation of our forgotten protein crops (winter pea, horse beans, grass pea, lupine etc.) that would perform better yield than soybean in some production sites (http3, 2018). The transformation of our sowing structure would be important from an economic and agronomic point of view. We need to increase the sowed area of protein crops economically (Kristó et al., 2021).

The choice of protein crops is large therefore we can think of winter pea as an alternative source of protein which has the second highest yield of our cultivated legumes in the world (Antal, 2005). Legumes are excellent preceding crops that stimulate the microbiological life of the soil by nitrogen fixation (Stefanovits et al., 1999). The role microorganisms in the nitrogen cycle are the most important of the nutrient cycling. Elemental nitrogen which makes up 78% of the air, enters the biological cycle through its uptake by bacteria (Stefanovits et al., 1999). The organic and chemical fertilizer use to improve the nutrient supply capacity of soils have a strong effect on the nitrogen content and microbial community (Bandick & Dick, 1999). Several groups of microorganisms, such as *Rhizobium* sp., *Bradyrhizobium* sp. are capable of biological nitrogen fixation in soil (Szabó, 2008). Peas are able to bind large amounts of nitrogen by the nitrogen fixing bacteria (*Rhizobium leguminosarum*) (Láng, 1976; Radics, 2002) The quantity of nitrogen fixation by legumes is important for maintaining the fertility of our soils (Füleky, 1999).

Global climate change is a major problem that is also showing signs in agriculture (Birkás et al., 2008). Unfavorable climatic effects can be reduced by suitable variety selection, timely and professional agrotechnics (Jolankai & Birkás, 2007). By growing a mixture of species with nearly the same growing season but different environmental needs, we are able to adapt better to changing climatic and economic conditions. In Hungarian practice, it was a habit to sow pea with support crops (wheat, barley, oats etc.) (Kurnik, 1970). Winter wheat and winter pea are compatible for sowing and harvesting time. Suitable technology can be developed to increase the sowed area of winter pea by using cereal legumes plant associations (Kristó et al., 2021; Murray & Swensen, 1985). Higher plant diversity is needed in agricultural production for sustainable development (Baulcombe et al., 2009).

Growing legumes and cereals together is an ancient crop production practice. The main goal of cultivation is the best use of resources (area, light, nutrients) (Li et al., 2003) and to increase the quality and quantity (Dahmardeh et al., 2009; Mpairwe et al., 2002). By combining legumes and cereals we can effectively reduce the negative effects of water stress (drought or high rainfall). The plants which used in the intercropping system are morphologically diverse, thus they can more efficiently use of climatic conditions than as a sole crop (Singh et al., 2008). Winter wheat and winter pea plant association is a special form of cereal-legume intercropping system which based on complementarity, offers greater financial stability and allows lower inputs which reduce environment impacts of agriculture (Vályi-Nagy et al., 2021). The plant association increases biodiversity (Tscharntke et al., 2005) the plants used in the association provide suitable habitat for insects and soil organisms which are not present in monoculture system (Cai et al., 2010). The association of cereals and legumes could help increase soil biological activity, resulting in higher cycling of organic matter in the soil (Dick et al., 1988)ting effect on nitrogen fixation in legumes (Hardarson & Atkins, 2003). Determining the amount of fluorescein diac-

Table 1: Soil sampling data

	Soil depht (0-20 cm)		
Parameters	Units of measure	Szeged-Öthalom	Fülöpszállás
KA	KA unit	41	50
pH (KCl)	pH unit	7.5	7.9
All salt	m/m%	0.03	0.02
Humus	m/m%	2.5	2.8
$CaCO_3$	m/m%	1.7	18
P_2O_5	m/m%	235.1	266.4
K_2O	mg/kg	237.1	624.8
NO_3–N+NO_2–N	mg/kg	35.2	27.5
SO_4^{2-}-S	mg/kg	10.9	6
Na	mg/kg	60.4	249.3
Mg	mg/kg	195.1	429.4
Cu	mg/kg	1.4	2.3
Zn	mg/kg	5.8	1.9
Mn	mg/kg	11.9	23.5

Figure 1: Location of the experimental plots in four repetitions, Szeged-Öthalom (2021).

etate (FDA) is a widely accepted, simple, and sensitive method for measuring total microbial activity in soil. Colorless FDA is hydrolyzed by both free and membrane-bound enzymes, releasing a colored final product that can be measured with a spectrophotometer (Adam & Duncan, 2001). The results of the microbial enzyme activity method indicate the functionality of the total microbial mass which is to determine the amount of degrading organizations involved in processes (Biró et al., 2012).

Our research aimed to determine the cereal-legume intercrops how influenced the soil enzyme activity. In two different locations (Szeged, Fülöpszállás) examine the effects of pure cereals, pure pea, cereal-pea intercrops and different nitrogen treatments on

Table 2: Agrotechnical methods that were used in the experiment

Agrotechnical methods	Date	Ingredient	Preparation	Dose
Stubble cultivation	August, 2020	-	-	-
Fertilizer	October 2, 2020	NPK	NPK complex (15:15:15)	200 kg/ha
Grubber	October 10, 2020	-	-	-
Combinator	October 20, 2020	-	-	-
Soil inoculant + combinator	October 27, 2020	*Rhizobium leguminosarum*	Biofil	1 l/ha
Sowing	October 27, 2020	-	-	-
Weed control	October 28, 2020	pendimetalin	Stomp Aqua	3 l/ha
Fertilizer	March 10, 2021	ammonium-nitrate (34%)	ammonium-nitrate	30 kg/ha
Fungicide treatment	March 26, 2021	azoxistrobin	Blister	0,7 l/ha
Insecticide treatment	April 12, 2021	alfa-cipermetrin	Eribea	0,1 l/ha
Fertilizer	April 27, 2021	ammonium-nitrate (34%)	ammonium-nitrate	30 kg/ha
Insecticide treatment	May 12, 2021	gamma-cihalotrin	Rapid CS	0,08 l/ha
Harvesting	July 5, 2021	-	-	-

the soil life. Two microbial treatments, how influenced the total soil enzymatic activity on cereal-legume intercropping system in Szeged-Öthalom. In winter wheat – winter pea intercrops which is the best seed setting which can increases the soil's enzyme activity.

Materials and Methods

Our plant association investigations were set up at the experimental site of the Hungarian University of Agriculture and Life Sciences, Plant Production and Agrotechnical Research Station in Szeged-Öthalom and Fülöpszállás, in 2020/2021. The soil type of Szeged-Öthalom is meadow chernozem and Fülöpszállás has calcareous meadow soil (Table 1).

The cereal-legume intercropping systems were examined in four repetitions on random block plots of 10 m^2 (Figure 1). The agrotechnical methods were used in the experiment are summarized in Table 2.

The preceding crops of the plant association experiments was winter wheat (*Triticum aestivum* L.). At the end of October, the plots were sowed with parcel grain machine (Wintersteiger Plotman). Row width was 12.5 cm and sowing depth was approximately 4–5 cm. We sowed GK Csillag and Cellule winter wheat varieties in Szeged-Öthalom. In Fülöpszállás the winter wheat variety was GK Csillag as a basis for comparison. The winter barley (*Hordeum vulgare* L.) variety was GK Aréna, the winter triticale (*Triticosecale*) variety was GK Maros, and the winter pea (*Pisum sativum* L.) variety was Aviron at both production sites. They were also sowed in pure and mixed crops where cereals sowed in association with legumes (in-

Table 3: Overview table of treatments (pure cereals, pure pea, cereal-legume intercrop, nitrogen treatments) were used in Szeged-Öthalom and Fülöpszállás

Szeged-Öthalom	Fülöpszállás
Pure cereals	Pure cereals
• Winter wheat (GK Csillag)	• Winter wheat (GK Csillag)
• Winter barley (GK Aréna)	• Winter barley (GK Aréna)
• Winter triticale (GK Maros)	• Winter triticale (GK Maros)
Pure legume	Pure legume
• Winter pea (Aviron)	• Winter pea (Aviron)
Cereal-Legume	Cereal-Legume
• GK Csillag + Aviron	• GK Csillag + Aviron
• GK Aréna + Aviron	• GK Aréna + Aviron
• GK Maros + Aviron	• GK Maros + Aviron
Pure cereals + Nitrogen	Pure cereals + Nitrogen
• GK Csillag + 30 kg/ha nitrogen	• GK Csillag + 30 kg/ha nitrogen
• GK Csillag + 60 kg/ha nitrogen	• GK Csillag + 60 kg/ha nitrogen
• GK Aréna + 30 kg/ha nitrogen	• GK Aréna + 30 kg/ha nitrogen
• GK Aréna + 60 kg/ha nitrogen	• GK Aréna + 60 kg/ha nitrogen
• GK Maros + 30 kg/ha nitrogen	• GK Maros + 30 kg/ha nitrogen
• GK Maros + 60 kg/ha nitrogen	• GK Maros + 60 kg/ha nitrogen

tercropping system). In order to be able to monitoring the nitrogen effect and to be able to compare pure and plant associations, were set up plots where the cereal sowing alone was treated with half (30 kg / ha N) and full (60 kg / ha N) fertilizer (Table 3).

Plant associations were treated with microbiological preparations also examined in Szeged-Öthalom. Before sowing our experiment, we performed seed treatment with mycorrhiza fungi (*Glomus* sp.) and soil inoculant with *Rhizobium leguminosarum* bacterium. (Table 4).

Plant associations and pure sowings were sowed with 3–3 seed numbers. The sowing density of 5 million seed / ha was considered 100 % for cereals and 1 million seed /ha for winter pea. In our experiment the 75 seeds/m^2 quantity for cereals was 3.75 million seed/ha and 750 000 seed/ha for winter pea. In cereals, 50 seeds/m^2 was 2.5 million seed/ha and 500 000 seed/ha for winter pea. All possible combinations of 100 seeds/m^2, 75 seeds/m^2 and 50 seeds/m^2 sowing density were set up in our experiment (Table 5).

Soil samples were collected at three different times: before sowing (October), during pea flowering (May), before harvest (end of June). Soil samples were collected from each plot from the upper (0–20 cm) layer of the soil in four replicates. The name of the process is the determination of total microbial activity using fluorescein diacetate. First of all, 1 gram of soil was weighed from the samples into plastic test tubes. After potassium phosphate buffer solution was added to the soil. The samples were placed in a shaker which was heated to 30 °C for 30 minutes. After fluorescein diacetate solution was added to the samples and placed in shaker which was heated at 30 °C for 1 hour. As a result of time and heating the soil solution becomes discoloured. The process was stopped with acetone these coloured end-

Table 4: Extension of previous treatments with microbial preparations were applied in Szeged-Öthalom

Szeged-Öthalom
Pure cereal
• Winter wheat (Cellule)
• Winter barley (GK Aréna)
Pure legume
• Winter pea (Aviron)
Cereal-Legume
• Cellule + Aviron
• GK Aréna + Aviron
Pure cereals + Nitrogen
• Cellule + 30 kg/ha nitrogen
• Cellule + 60 kg/ha nitrogen
• GK Aréna + 30 kg/ha nitrogen
• GK Aréna + 60 kg/ha nitrogen
Cereal-Legume + Microbial preparations
• Cellule + Aviron + Soil inoculant
• Cellule + Aviron + Seed treatment
• Cellule + Aviron + Soil inoculant + Seed treatment
• GK Aréna + Aviron + Soil inoculant
• GK Aréna + Aviron + Seed treatment
• GK Aréna + Aviron + Soil inoculant + Seed treatment

Table 5: Agrotechnical methods that were used in the experiment

		Pea seed numbers (million/ha)			
		0	0.50	0.75	1
Cereal seed numbers (million/ha)	0	-	0:50	0:75	0:100
	2.5	50:0	50:50	50:75	50:100
	3.75	75:0	75:50	75:75	75:100
	5	100:0	100:50	100:75	100:100

products can be measured by spectrophotometry. The absorbance at 490 nanometer was measured in the samples and the results were recorded in Excel spreadsheet (Adam & Duncan, 2001).

Statistical processing of data obtained was performed using SPSS 27 statistical program. I used Microsoft Excel program to make the figures and tables. The change of the soil enzyme activity was determined by One-Way ANOVA analysis and T-test, refer to $p < 0.05$ significance level.

Results

The five figures in the results show the averages of soil enzyme activity in different

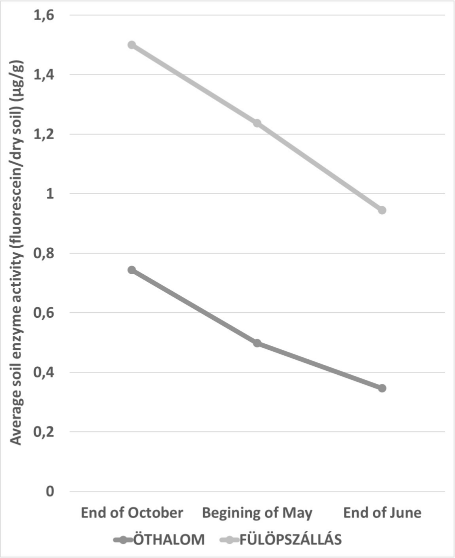

Figure 2: The change of the soil enzyme activity at winter wheat and winter pea intercrops in Szeged-Öthalom and Fülöpszállás.

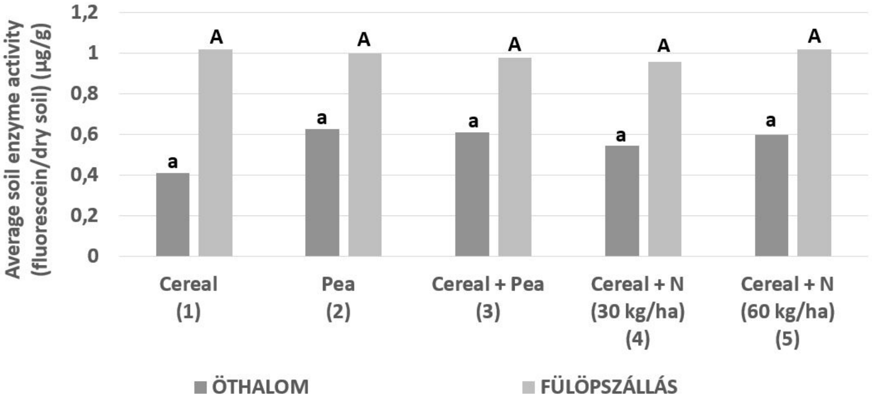

Figure 3: The effect of locations and different treatments on soil enzyme activity in Szeged-Öthalom and Fülöpszállás.
(1) Averages of GK Csillag, GK Aréna, GK Maros
(2) Average of Aviron
(3) Averages of GK Csillag + Aviron, GK Aréna + Aviron, GK Maros + Aviron
(4) Averages of GK Csillag + 30 kg/ha N, GK Aréna + 30 kg/ha N, GK Maros + 30 kg/ha N
(5) Averages of GK Csillag + 60 kg/ha N, GK Aréna + 60 kg/ha N, GK Maros + 60 kg/ha N

treatments. In the second figure, we compared winter wheat – winter pea intercrops datas at two locations which has different soil types. The second figure shows that there is a large difference between the production sites in measurement of the total microbial enzyme activity in the soil. Between sowing and the beginning of the harvest, the experiments set up in Szeged-Öthalom had the lowest values of soil enzyme activity. However, the soil enzyme activity in Fülöpszállás higher values could be measured during the vegetation period. The progressed time, increased the distance between the values of soil enzyme activity at two experiment sites. In Fülöpszállás we measured 2.0 times higher values at the end of October, 2.4 times higher values at the beginning of

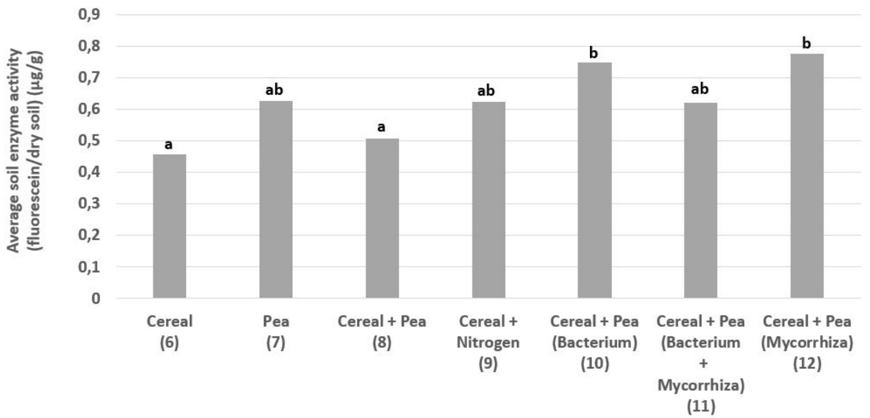

Figure 4: The effects of pure cereals, pure pea, cereal-pea intercrops, nitrogen treatment and microbial products on soil enzyme activity in Szeged-Öthalom.

(6) Averages of Cellule, GK Aréna
(7) Average of Aviron
(8) Averages of Cellule + Aviron, GK Aréna + Aviron
(9) Averages of Cellule + N, GK Aréna + N
(10) Averages of Cellule + Aviron + Soil inoculant, GK Aréna + Aviron + Soil inoculant
(11) Averages of Cellule + Aviron + Soil inoculant + Seed treatment, GK Aréna + Aviron + Soil inoculant + Seed treatment
(12) Averages of Cellule + Aviron + Seed treatment, GK Aréna + Aviron + Seed treatment

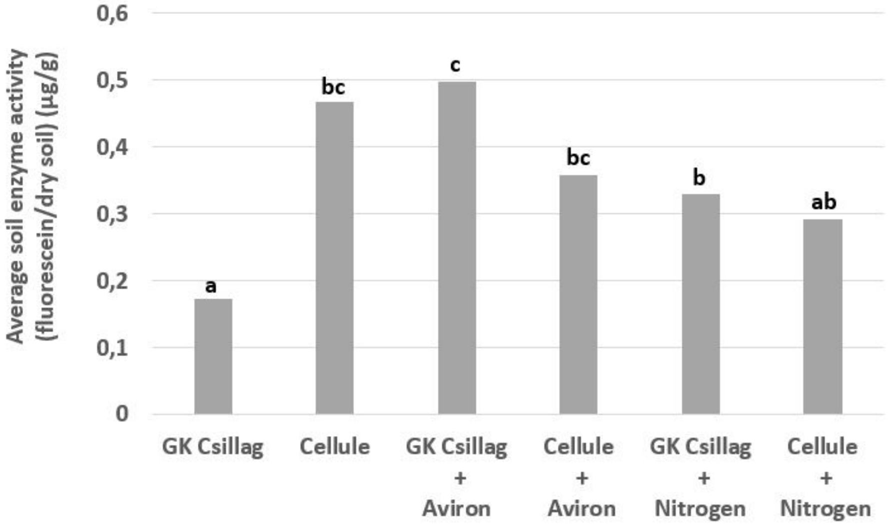

Figure 5: The effects of different winter wheat varieties (GK Csillag and Cellule), wheat-pea intercrops and nitrogen treatments on soil enzyme activity in Szeged-Öthalom.

May, and 2.7 times higher values at the end of June than in Szeged-Öthalom. The highest value of soil enzyme activity (1.49 μg/g) was measured in Fülöpszállás and the lowest value (0.34 μg/g) was measured in Szeged-Öthalom. Based on T-test, there are also significant differences ($p < 0.05$) between the locations in October, May and June enzyme activity values (2).

The soil enzyme activity values were higher in Fülöpszállás than Szeged-Öthalom. In Fülöpszállás we measured almost 2.5 times

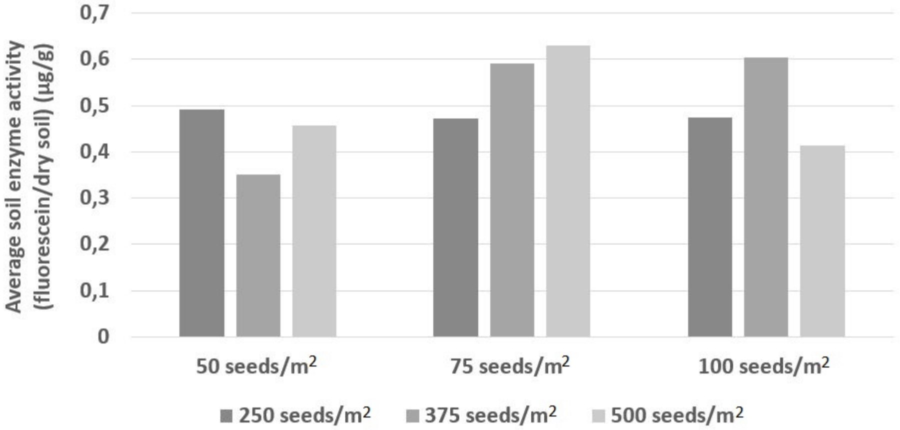

Figure 6: Different seed number effect in winter wheat – winter pea intercrops (GK Csillag + Aviron) on the soil enzyme activity.

higher values in the control plot (pure cereals) than in the soil of Szeged-Öthalom. The lowest value (0.41 μg/g) measured in the control (pure cereals) plot was found in Szeged-Öthalom. The highest (0.62 μg/g) value was in pure winter pea, which had almost the same value in cereal-pea intercrops (0.61 μg/g). The values of soil enzyme activity were lower in the plots treated with fertilizer, 0.54 μg/g in the plots treated with 30 kg/ha nitrogen and 0.59 μg/g in the plots treated with 60 kg/ha nitrogen. In Fülöpszállás calcareous meadow soil's values had approach 1 μg/g. As a result on the One-Way ANOVA analysis there is no significance differences between different treatments. Columns marked with different letters, are not significantly different at the $p < 0.05$ significance level (3).

Microbial preparations were applied in cereal-pea intercrops in Szeged-Öthalom, 4 showed the results. The control plot (pure cereals) had the lowest value (0.45 μg/g) of soil enzyme activity and the highest value (0.77 μg/g) was in the cereal-pea intercrops were treated with mycorrhiza fungi. Comparing pure cereals and cereal-pea intercrops, it can be seen that the soil enzyme activity is higher in plant associations (0.50 μg/g). Higher values (0.62 μg/g) were measured when plant associations were treated with nitrogen (0.62 μg/g). Furthermore, the values are even higher (0.74 μg/g) when we applied soil bacterial inoculants in cereal-pea intercrops. According to the result of the One-way ANOVA analysis, columns marked with different letters, are significantly different at the $p < 0.05$ significance level (4).

Of the two winter wheat varieties which were applied in plant association, the highest value (0.49 μg/g) of soil enzyme activity was measured in GK Csillag was associated with Aviron. The lowest value (0.17 μg/g) of soil enzyme activity was measured in GK Csillag (pure cereal). The microbial enzyme activity of the soil was lower in the plots were treated with fertilizer (0.32 μg/g and 0.29 μg/g) than in the cereal-legume intercropping systems. For plant associations with two different winter wheat varieties, GK Csillag + Aviron 0.49 μg/g and Cellue + Aviron produced 0.35 μg/g when measuring soil enzyme activity. According to the result of the One-way ANOVA analysis, columns marked with different letters, are significantly different at the $p < 0.05$ significance level (5).

6 shows the change in soil enzyme activity of plant association combinations were sowed with different seed counts in GK Csillag + Aviron. Increasing trend could be measured

in the plots with sowing densities of Aviron 75 seeds / m^2 and GK Csillag 250, 375 and 500 seeds / m^2. The highest activity was in the treatments of 75 seeds / m^2 of winter pea and 500 seeds / m^2 of winter wheat (0.62 μg/g). The lowest (0.35 μg/g) was in plots sowed with 50 seeds / m^2 of winter pea and 375 seeds / m^2 of winter wheat (6).

Discussion

In cereal-pea intercrop system, the microbial activity of the soil decreases as the phenological phases progress. Based on the research of Adam and Duncan (2001), it can be said that the change in soil enzyme activity is greatly influenced by soil type. We can also support this statement by our experiment, according to which the total microbial activity of the soil is lower in the meadow chernozem of Szeged-Öthalom and higher in the calcareous meadow soil of Fülöpszállás. Plant associations have higher measured values than pure cereals. Comparing the two winter wheat varieties (GK Csillag, Cellule), it can be stated that the measure of enzyme activity of the soil is higher in the plant associations when GK Csillag variety is sowed with Aviron winter pea variety. However, the activity was lower in the nitrogen treated plots than plant associations. For sowing with different seed counts, the optimal sowing density is 75 seeds/m^2 for winter pea and 500 seeds/m^2 for cereals. Bacterial inoculation and mycorrhiza fungi can stimulate the total microbial activity of the soil.

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Marginal note on wastewater recycling margins from the perspective of simultanism of sustainability and technological development

Róbertné KOVÁCS[1] – Chao-Tang WANG[2] – Valeria NAGY[1]

1: University of Szeged, Faculty of Engineering, Szeged, Hungary, e-mail: veszelov@mk.u-szeged.hu
2: Chaoyang University of Technology, College of Science and Engineering – Taiwan

Abstract: The main feature of our time is the "duality": we demand livable environment, on the other hand we use it in an unsustainable way to ensure the overflowing comfort of welfare societies. As a result, the use of the environment (namely the environmental elements and their systems, processes and structures) has now led to overloading (pollution, damage). So the state of our habitats are reflecting our actions there is no doubt about that. That is, our activity is an imprint of our thinking. Changing/modification requires innovations that facilitate the development and application of the embedded technologies of the future, building on the intersubjectivity of individuals. One of the cornerstones of the European Green Deal is that "economic growth should be decoupled from resource use". Among our resources, water especially drinking water is a scarce commodity. However, with prudence, care and ingenuity we can do a lot to reduce the amount of wastewater. Our short paper, as the title indicates, does not attempt to present the partial results of a specific research but tries to shed light on the topic from another perspective. It demonstrates through an example of wastewater recyclability, that increasing volumes are no longer just a problem to solve. Rather, it is a challenge, and technological development offers a way out of its trap, so that the society does not have to face the negative effects of declining water supply. Similar to the arts, simultanism can be interpreted in the engineering sciences as well, which is spatially distant but simultaneous phenomena and activities, and temporally distant but related phenomena, activities, etc. it carries its simultaneous existence.

Keywords: water, wastewater, utilization technology, possibilities

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Introduction

Water is essential to sustain life on Earth. In addition, humans use water, in many cases drinking water, not only for their own life processes but also to accomplish their day to day activities even when this may not be justified. World Water Day is on the 22nd of March every year which is an annual United Nations Observance started in 1993, that raises awareness of people currently living without access to safe water. This day was first formally proposed in Agenda 22 of the 1992 United Nations Conference on Environment and Development in Rio de Janeiro. In December 1992, the United Nations General Assembly adopted by which 22 March of each year was declared World Day for Water.

World Water Day as a means of focusing attention on the importance of freshwater and advocating for the sustainable management of freshwater resources. This day is an opportunity to learn more about water related issues, be inspired to tell others and take action to make a difference. It is more than just essential to quench thirst or protect health. Water is vital for creating jobs and supporting economic, social and human develop-

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ment. In this way every year the themes focus on topics relevant to clean water, sanitation and hygiene, which is in line with the targets of Sustainable Development Goal 6: ensure availability and sustainable management of water and sanitation for all by 2030 (UN-Water, 2022a, 2022b; UNDP, 2022).

It is necessary to facilitate the uptake of water reuse whenever it is appropriate and cost-efficient (European Parliament and the Council, 2020). Thanks to the best available techniques and technologies, modern wastewater treatment and recovery are part of our daily lives. This short paper demonstrates through an example of wastewater recyclability that increasing volumes are no longer just a problem to solve. Rather, it is a challenge, and technological development offers a way out of its trap.

Simultanism of sustainability and technological development

The value of water is about much more than its price because water has enormous and complex value for our households, culture, health, education, economics and the integrity of our natural environment. The UN World Water Development Report is released each year around World Water Day. A core focus of World Water Day is to inspire action towards European Green Deal and Sustainable Development Goals. Main goal 6 is water and sanitation for all by 2030. The concrete tasks are in this field by 2030 (UN-Water, 2022a, 2022b; UNDP, 2022; European Commission, 2019):

- Improve water quality by reducing pollution, eliminating dumping and minimizing release of hazardous chemicals and materials, halving the proportion of untreated wastewater and substantially increasing recycling and safe reuse globally.
- Substantially increase water-use efficiency across all sectors and ensure sustainable withdrawals and supply of freshwater to address water scarcity and substantially reduce the number of people suffering from water scarcity.
- Expand international cooperation and capacity-building support to developing countries in water- and sanitation-related activities and programmes, including water harvesting, desalination, water efficiency, wastewater treatment, recycling and reuse technologies.
- Support and strengthen the participation of local communities in improving water and sanitation management.

And indicators can be (UN-Water, 2022a, 2022b; UNDP, 2022):

- Proportion of wastewater safely treated
- Change in water-use efficiency over time
- Level of water stress: freshwater withdrawal as a proportion of available freshwater resources
- Proportion of local administrative units with established and operational policies and procedures for participation of local communities in water and sanitation management

World Water Day is about focusing attention on the importance of water. This year's theme is 'groundwater', draws attention to the hidden water resource that has always been critically important but not fully recognized in sustainable development policy-making. Groundwater is invisible but its impact is visible everywhere. Out of sight, under our feet, groundwater is a hidden treasure that enriches our lives. Almost all of the liquid freshwater in the world is groundwater. As climate change gets worse, groundwater will become more and more critical. We need to work together to sustainably manage this precious resource. Groundwater may be out of sight but it must not be out of mind.

The groundwater has vital role in water and sanitation systems, agriculture, industry, ecosystems and climate change adaptation. The overarching message is that exploring, protecting and sustainably using groundwater will be central to surviving and adapting to climate change and meeting the needs of a growing population (UN-Water, 2022a, 2022b; UNDP, 2022).

While access to fresh drinking water is getting more costly and rather a challenge, usage of drinking water for domestical, agricultural and industrial use, which are in need of substantial water quantities, is a major problem. Furthermore, the growing general demand for water, the amount of wastewater during (industrial) production and the environmental effect (load, pollution, damage) are continually increasing. Despite its increasing volume wastewater can be a cost-optimized and sustainable energy source and a possible type of alternative water source if it can be recycled and resource can be recovered, moreover it may also contain nutrients, organic substances and other useful by-products. From this point of view wastewater is no longer a problem that requires a solution but rather a solution to the challenges that society faces today (UNESCO World Water Assessment Programme, 2017). In Hungary, households and certain industries generate 13.7 million p.e. of waste water every day, which is an amount equivalent to around 2.74 million m3. The urban waste water is treated in 605 plants across the country before it is discharged (WISE Freshwater, 2022).

Number of treatment plants by type of treatment:

- 536 (Biological treatment with nitrogen and phosphorus removal)
- 68 (Biological treatment)
- 1 (Primary treatment)

Overall, 52% of the urban waste water in Hungary is treated according to the requirements of the Urban Waste Water Treatment Directive. This is below the EU average of 76%. Hungary generated over 189,284 tonnes of waste water sludge in 2018: 57.4% was reused in agriculture, 13.4% was reused in other uses, 5.4% was landfilled, 0.1% was incinerated and 23.7% was disposed in another way (WISE Freshwater, 2022).

Industrial wastewater treatment/utilization requires unique solutions and special wastewater treatment systems. Being that industrial wastewaters can be very diverse. Without completeness, here are some types:

- wastewater related to food production (e.g. dairy, slaughterhouse, brewing, fruit and vegetable processing)
- metal industry effluent
- wastewater from the glass industry
- wastewater from the rubber industry
- pharmaceutical waste water
- waste water from the textile industry

The tightened wastewater discharge standards and variable and increasing volumes are challenges for water and wastewater treatment. Technological developments and engineering solutions, new findings and new insights are increasingly needed because emerging contaminants (e.g. microplastics) have appeared in recent years.

If the different kind of wastewater usually contains different minerals, nutrients and organic matter, and these act as an appropriate source for the growth and development of various microorganisms, algae and plants which can be used to produce various renewable energy products (Koch et al., 2015). The chemical, thermal and hydraulic energy contained in wastewater can be recovered in the form of biogas, heating/cooling and electricity generation through on-site (in wastewater treatment plants) and off-site (in centralized plants) processes (Meda et al., 2012).

Organic matter rich wastewater, when decomposed in an oxygen-free environment, releases methane gas. This methane can be collected and utilized as heat and electricity generation instead of released into the atmosphere (Bhatia et al., 2020). So the current state of science and technology offers very diverse opportunities for the development of a modern innovative wastewater technology which is also a complex environmental technological innovation.

But the most common on-site application is energy recovery, namely biogas production from chemical energy contained in organic substances in wastewater through the anaerobic digestion of organic matter. Biosolids in wastewater mainly consist of microbial cells and extracellular polymeric substances produced by the cells as part of their metabolic activity. The microbial cells and extracellular polymeric substances form a matrix that is the substrate for the anaerobic digestion. With respect to their physical state, microbial cells represent a relatively unfavourable substrate for subsequent microbial degradation, since large part of the organic matter is within the microbial cell membranes. This microbial cell wall contains glycan strands cross-linked by peptide chains which give a semi-rigid structure providing sufficient intrinsic strength, protecting the cell from osmotic lysis, giving the walls resistance to biodegradation. Because of this resistant structure, conventional biological digestion techniques require long hydraulic retention times. Approach for improve digestion efficiency and make the organic material inside the cell walls available is to disrupt the microbial cell walls in the sludge (Pavlostathis & Giraldo-Gomez, 1991). Numerous methods can be used physical (mechanical, thermal etc.), chemical (ozonolysis, acid hydrolysis, alkaline hydrolysis, etc.), biological (fungi, enzymatic hydrolysis, etc.) pretreatment or combination of them (Mosier et al., 2005; Sun & Cheng, 2002). Among the different handling methods, microwave (MW) radiation is successfully applied in the pre-treatment stages of anaerobic digestion. Treatments by microwave irradiation offer advantages such as rapid warming in the total volume of the material and a higher energetic efficiency than conventional heat transfer due to the different ways of energy transfer (Leonelli & Mason, 2010). Apart from the thermal effect, some researchers believe that there is a non-thermal effect of microwave radiation, which leads to the possible breaking of hydrogen bonds, and helps to degrade complex organic components into shorter chains (Gole & Priya, 2017; Hong et al., 2004; Tyagi & Lo, 2013; Yu et al., 2010). The unique advantages of microwave-assisted pre-treatment contribute to intensive investigation of it on effectiveness in environmental actions. These unique advantages of microwave-assisted pre-treatment have led to the intensive research into its applications in environmental techniques.

Materials and Methods

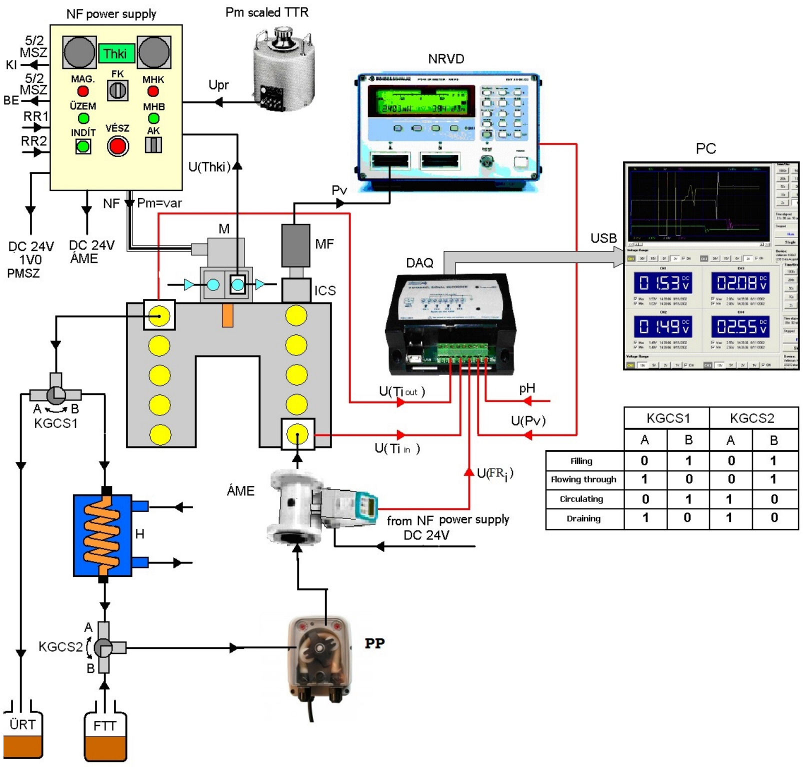
In order to achieve the objective of this paper, the choice has been made for industrial wastewater. Wastewater was collected in a Hungarian medium-sized meat processing company. Table 1 contains the characteristics of wastewater.

The sampling point was after the grease trap. Wastewater originates from meat processing technology, mainly from the flushing and rinsing process of equipment (slicing and packaging machines, smoking chambers). A cloth filter was used to remove grit, particles and other large-sized solids. The pre-treatment was carried out in a continuous flow microwave treating system which was developed at University of Szeged, Faculty of Engineering (Figure 1).

It contains a water-cooled, variable-power magnetron (M) operating at 2450 MHz. Highvoltage power supply (HV) feeding the magnetron consists of two transformers, one of them produces cathode heating voltage and heating current, the other produces the anode voltage which can be controlled by the primary circuit of an external auto-transformer. With this device (PM scaled TTR) the power of the magnetron can be set as well. Electromagnetic energy of the magnetron spread over a resonant slot. Get-

Table 1: Characteristics of wastewater

Parameters	Values
Total solid (TS) [mgL−1]	3210±296
Total organic carbon (TOC) [mgL−1]	834.1±35.3
Lipid [mgL−1]	115.1±21.7
Protein [mgL−1]	379.4±21.2



	KGCS1		KGCS2	
	A	B	A	B
Filling	0	1	0	1
Flowing through	1	0	0	1
Circulating	0	1	1	0
Draining	1	0	1	0

Figure 1: Microwave pre-treating system. PP – peristaltic pump; M – magnetron; ICS – converter probe; MH – measuring head; HV – highvoltage power supply; NRVD – network analyzer; DAQ – data logger; TTR – auto-transformer; PM – power of magnetron; Pv – microwave signal; VFM – volume flow meter; U – voltage V1 – one-way ball valve; V2 – one-way ball valve; DRAIN – draining container; FILL – filling container

ting through this slot the energy gets in the toroidal resonator (Kovács et al., 2012).

During the operation of toroid resonator energy is given to the treated material. Material is transferred in the continues-flow microwave treating system by a peristaltic pump (PP) with variable flow. Filling, flowing through, circulating, and draining cycles can be switched using one-way ball valves (V1, V2). The volume flow of the material entering the microwave toroidal cavity resonator is measured by a (volume) flow meter (VFM).

The microwave signal (Pv) decoupled from measuring head (MH) of the cavity resonator through the converter probe (ICS) is processed by the NRVD microwave power meter. The DC signal (U(Pv)) proportional to the measured power, the electrical signal of the flow meter (U(FRi)) and material inlet (U(Ti in)) and outlet (U(Ti out)) temperatures are received by the measurement data logger (DAQ) records the data online or displays them in the computer screen.

The anaerobic digestion tests were carried out under controlled mesophilic temperature range (35 × 0.2°C) in 12 mini continuously stirred laboratory scale reactors with 250 mL total volume, equipped with Oxitop C measuring system.

Results and discussion

The results demonstrate how microwave-assisted pre-treatment helps the wastewater (from meat processing technology) reuse. The tests have been carried out at two different magnetron powers (PM 300 W, PM 700 W) and flow rates (FR 6 L, FR 25 L) in order to study the influence of microwave pre-treatment on the kinetics of biogas synthesis (retention time of 29 days). Microwave-assisted pre-treatment could enhance the biogas production potential resulting in enhanced ultimate biogas yield as shown in Figure 2. In all cases, the treatments enhanced the yields compared to the control. It can be observed from day 7–9 to 18–20 there is a steep increase, and the effect of microwave pretreatments at lower volume flows is more significant. Of course, in all cases, the energy efficiency of the pretreatment must be determined and it is useful to prepare an energy map in addition to increasing the yield. As a continuation of the research, the composition of the biogas generated in the case of different treatment parameters will be examined (especially with regard to the methane content) in the light of which the economic aspects will also come to the fore.

Complementing the previous basic and applied research results described in the introduction and the literature chapter, these experimental results of the research work also prove that there are many forms of wastewater treatment, purifying and utilization. The current task of researchers and scientists is to synthesize, combine and make these research results suitable for solving a global problem with a holistic approach.

The anomalies caused by human activities and the capabilities of natural resources can be made harmonious through such complex thinking and work. The following figure shows a simplified model of the harmonious relationship between water and wastewater (Figure 3).

The best available techniques and technologies enable efficient water use (urban and industrial water use) and modern wastewater treatment (especially for special types of wastewater). Based on the above, it is feasible the wider reuse of treated wastewater while ensuring a high level of environmental protection. Water reuse in combination with the use of water efficient technologies in industry may choose to apply to achieve good qualitative and quantitative water status for surface water bodies and groundwater bodies. So the treated wastewater should be reused whenever it is possible (European Parliament and the Council, 2020).

Conclusion and outlook

The results of this short study confirmed the effectiveness of the microwave-assisted pretreatment, which, of course, is highly dependent on the composition of the wastewater in addition to the physical parameters. But beyond that, the technical requirements for wastewater treatment and recovery technologies can be outlined:

- increasing system performance
- increasing system efficiency
- minimizing maintenance and downtime
- regulatory completeness

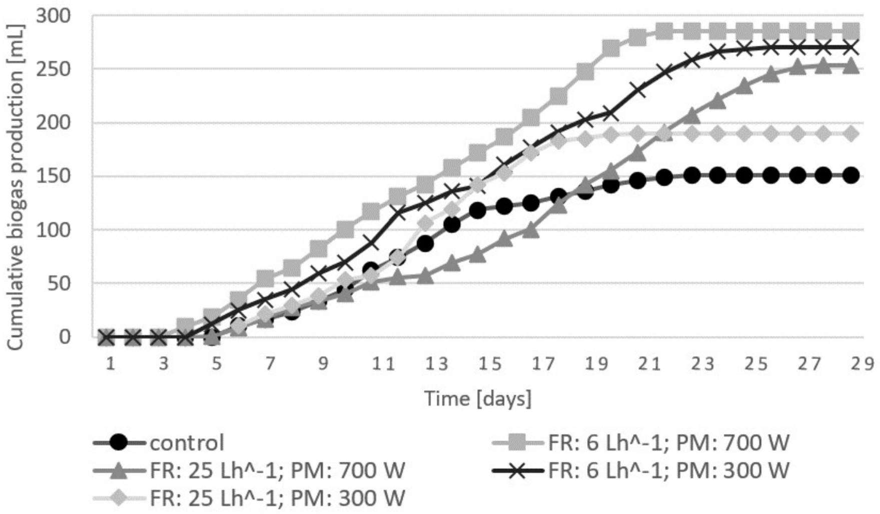


Figure 2: Cumulative biogas production of samples treated at different settings.

Figure 3: Integrated strategy.

- environmental and economic sustainability
- emerging system
- anti-odour system

Compliance with minimum requirements for water reuse should be consistent with water policy. Furthermore, it should contribute to the achievement of the Sustainable Development Goals of the United Nations 2030 Agenda for Sustainable Development, in particular Goal 6, to ensure the availability and sustainable management of water and sanitation for all, as well as a substantial increase in recycling of water and safe water reuse globally (European Parliament and the Council, 2020).

Risk management is required and water reuse risk management plans should ensure that reclaimed water is safely used and managed and that there are no risks to the environment or to human or animal health. But it is required to adapt the key elements of risk management to technical and scientific progress.

There is great potential for the recycling and reuse of treated wastewater: it is possible to the use of reclaimed water for other purposes, including industrial, amenity-related and environmental purposes, as considered necessary in the light of national circumstances and needs, provided a high level of protection of the environment and of human and animal health is ensured (European Parliament and the Council, 2020).

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The integrated water strategy and wastewater management strategy is also part of the national environmental programme. The challenge for the coming period will be to put rapidly evolving techniques and technologies at the service of societal goals.

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The effects of tillage practices on water regime of soybean (*Glycine max* L.)

Boglárka BOZÓKI[1] – Péter Gergő KOVÁCS[1] – Márta BIRKÁS[1] – Zoltán KENDE[1] – Csaba GYURICZA[1]

1: Institute of Agronomy, Hungarian University of Agriculture and Life Sciences, Páter Károly u. 1., 2100 Gödöllő, Hungary, e-mail: Bozoki.Boglarka@phd.uni-mate.hu

Abstract: Continuous world population growth imposes the need to produce higher-quality food. Due to the high content of valuable protein and high concentration of carbohydrates, vitamins and minerals, soybean (*Glycine max* L.) is one of the most essential leguminous and oilseed crop that contributes to human alimentation and animal nutrition. This study assesses the possible impacts of soybean seedling development and seeds' quality indicators correlate to water supply aboveground and in the root zone. The level of water management is crucial in and out of the growing season; however, the increase in temperature may adversely affect climatic conditions. As a consequence of water contained in soil, leguminous crops can improve soil texture and the capacity of minerals if admissible water is available for the crop. Soil tillage is cardinal for agricultural water management; by practising proper tillage continuously, soil properties can increase, and exposedness can decrease in the long term.

Keywords: Glycine max L.; soybean; water regime; soil tillage; climate change

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Introduction

Due to the economic importance, soybean (*Glycine max* L.) is one of the most widely planted leguminous and oilseed crop that contributes to human alimentation and animal nutrition. The plant and its derivatives provide the raw material for the food industry, mainly in cereal and meat-based products as it contains numerous compounds that can act as antioxidants and are beneficial to human health, as they diminish the risk of many diseases (Kumar et al., 2014).

Among the main traits of soybean genotypes, two particularly important ones are the oil and protein content (Nascimento et al., 2010). In addition to this, soybean is considered as a kind of highly efficient nitrogen-fixing crop for improving acidic soil fertility (Yang et al., 2012). Nitrogen is the nutrient element that most limits plant growth and development. Plant available N in soils originates from mineral fertilizer and mineralization of organic matter and plant residues (Vinther et al., 2004). Inorganic N in the soil is subject to lose through processes like leaching, volatilization and denitrification. Accumulation of inorganic N, leaching of nitrates into ground water, or move through the soil could affect soil microorganisms (Lupwayi et al., 2010, 2012). Besides fixing the atmospheric nitrogen, this crop has the ability to grow in a range of environments, reduce soil erosion, suppress weeds and to suit inter as well as sequential cropping pattern (Jain et al., 2018).

To meet the increasing demand for soybean production, it is necessary to increase crop yield, even in low water availability conditions since there is a growing focus on grow-

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ing water use efficiency in crops in recent years. Since rainfall occurs seasonal, water is an important limiting factor to subsequent growing crops especially soybean (Aliverdi et al., 2021). The aim of this review is to assess the relation of the effects of prevalent soil tillage practices and water regime induced by soybean and to summarize the latest scientific findings on the soil properties, especially in conventional soil tillage and minimum soil tillage systems. As known, tillage management can have positive and negative short-term effects on the agroecosystem. Therefore, searching for optimal tillage management is crucial for the maintenance and improvement of soil functions (Brezinščak & Bogunović, 2021).

Correlation between soybean production and water supply

Food legume crops play an important role in the farming system and contribute to food security in the developing world (Engels et al., 2017). However, in many regions, their production has been adversely affected by climate change which have impacted the water regime of the rains, causing severe drought in agricultural regions, and affecting the production of several crops (Mousavi-Derazmahalleh et al., 2019). This issue will cause many economic challenges and social impacts in agriculture (TerAvest et al., 2015; Werner & Vanneuville, 2012). Although water scarcity is a severe abiotic constraint of legume crops productivity, it remains unclear how the effects of drought covary with legume species, soil texture, agroclimatic region, and drought timing (Daryanto et al., 2015).

Water availability is one of the climate elements that most affect soybean development and productivity (Anda et al., 2020; Dong et al., 2019; Minosso et al., 2021) and to meet the growing demand for food, it is necessary to increase soybean yield, even in environments with low water availability. Soybean has a water requirement of 450–700 mm (Critchley, Siegert, & Chapman, 1991), which does not mean much water, however, water availability is needed in the early stage of growth, flower period, and filling of pods. Moreover, the most sensitive stage to possible yield loss under water shortage is the reproductive period. In general, short-term moderate soil water deficits during the vegetative stage do not impact soybean production (Comlekcioglu & Simsek, 2013; Karam et al., 2005; Oya et al., 2004). However, a more serious or persistent water deficit may result in decreased soybean production (Turan et al., 2019).

Narolia et al. (2021) reported a significant increase in yield, dry matter production, and growth rate by giving irrigation at the flowering and pod development stage. The proper arrangement of plants in appropriate plant density is one of the requirements to achieve high and stable yields during intensive production of soybean. Changing the shape of growing space and row spacing leads to change in microclimate growing conditions (light, relative humidity, aeration) where soybean is very sensitive (Kolaric et al., 2014).

Water regime system is needed to support the cultivation system on crops (Aminah et al., 2021) as soybean plants cultivated on different soil managements respond water stress differently (Jarvis & McNaughton, 1986; Jordan & Ritchie, 1971). The characteristics of plants, the supplied water, the irrigation methods, and the soil characteristics related to water are significant factors to provide sufficient water in crops. In addition, the local agro-ecological conditions, such as soil types, availability of water, and climate can also influence the water supply to the crops (da Silva et al., 2019).

The increase in rainfall is evidence of climate change, reduced water availability, and other unsuitable weather (Osman, 2018).

However, increased rainfall as a part of climate change can provide some local benefits. There will also be several adverse effects, including reduced water availability and other extreme weather conditions (Arnell et al., 2011; Gosling & Arnell, 2013; Mancosu et al., 2015; Ummenhofer & Meehl, 2017).

Besides soil degradation and heat stress, drought is the abiotic factor that most adversely affects legume production. It turns, however, that the largest producers of pulses are located in regions that experience water shortage (India, China and many African countries) (Rockström et al., 2009). These countries thus rely heavily on variable rainfall to support agriculture production, which consequently is highly vulnerable to drought. It is also important to recognize that the impact of drought on crop yield can be variable, and therefore there is a need to consider legume crop and management factors such as species selection or planting date as these can determine crop response to water shortage and ultimately yield loss (Daryanto et al., 2015). When experiencing drought, soybean productivity can decrease by 40-65% (Engels et al., 2017). J. Omondi et al. (2017) reported that soybean, a crop whose production is being promoted in Sub-Saharan Africa is adversely affected by mid-season drought. This is due to the continuous erratic rainfall distribution and amount, which mostly occur at the important stages of soybean growth; flowering, pood filling and seed filling stages (J. O. Omondi et al., 2015).

Determination of water requirement for crops in resource limited areas in challenging yet worsened by the common assumption that all crop varieties within a species have similar water requirements (J. Omondi et al., 2017). Due to depleting water supplies and the cultivation of high water-demanding crops like soybean, water deficit in crop production has become a major concern. Soybean has been considered a possible substitution for high-water-demand crops with improved water productivity and nutrient quality. However, due to inefficient and injudicious water regime, the overall productivity and profitability of soybean is quite low (Rajanna et al., 2022). The optional soybean sowing date is an important factor affecting the plant growth and yield, and it changes depending on the climate conditions and the accompanying reactions of cultivars to the day length (Bastidas et al., 2008; Sincik et al., 2011). Next to cultivar earliness, the soybean yielding in Europe, similarly as in other countries, is much affected by water deficit, which essentially shortens both the vegetative and generative stage and thus lowers the yield (Borowska & Prusiński, 2021; Desclaux & Roumet, 1996).

Cover cropping, conservation tillage and mulching are some soil water regime techniques (Itabari et al., 2011; Wakindiki et al., 2007) practiced during mid-season drought. The objective of the study, which has been published by J. Omondi et al. (2017) was to indirectly determine crop evapotranspiration of soybean varieties, using reference evapotranspiration and shoot water content under tillage and no-tillage cultivation. Standard cores were used to collect soil samples at depths of 10, 20 and 30 cm, for soil water content measurement at 50% full bloom, pod filling and seed filling. These are the important stages of soybean growth in soil moisture studies (Doss et al., 1974). They reported that soil moisture content was not significantly different from tillage method and soybean variety interaction, neither was it significant for the interaction between tillage and soil depth. However, soil moisture content under interaction of soybean variety and soil depth was significant. Soil moisture content increased with depth under all varieties except for one at full bloom. According to another study conducted by Aminah et al. (2021) their result showed that the watering technique using the waterlogging method at the same time at the age of 15 days and full flowering had the potential to increase the yield production of soybean. Water use, economic benefits, and reduced environmental burdens can be obtained through innovative irrigation practices (Levidow et al., 2014). This study aimed to get the best irrigation method and determine the best time-effective provision of water to maintain optimum soil moisture for increased soybean crop production.

Coexistence of tillage and water balance in soils

Soil quality can be evaluated by the integration of chemical, physical and biological soil properties (Chen et al., 2003; Dominy & Haynes, 2002). Soil is a complex and dynamic biological system whose functions are mediated by a diversity of living organisms (Doran & Zeiss, 2000; Nannipieri et al., 2003). The structure and functioning of soil microbial communities reflect the interaction between a host of biotic and abiotic factors (Bending et al., 2002). Their number, diversity and activity is influenced by soil organic matter content, soil texture, pH, moisture, temperature aeration and other chemical, physical and biological factors such as water content (Chen et al., 2003).

The rhizosphere, defined as the layer of soil influenced by root metabolism (Berg et al., 2005), is greatly important to plant health and soil fertility (Yang et al., 2012). Root exudates are currently recognized to differ according to plant species (Rengel, 2002). Bacteria respond differently to the compounds released by roots, and thus the differences in root exudation are believed to explain the plant-specific bacterial communities in the rhizosphere (Berg et al., 2005; Jaeger et al., 1999).

Tillage and crop rotation are crucial factors influencing soil quality, crop production and the sustainability of cropping practices (Munkholm et al., 2013). Soybean plants are exposed to soil moisture stress at any age of their lifecycle will harm their development, yield, and yield components (Mahmoud et al., 2013; Rana et al., 2018). No-tillage is defined as the planting of crops in previously unprepared soil by opening a narrow slot, trench, or band only of sufficient width and depth to obtain proper seed coverage. No other soil preparation is performed (Phillips & Young, 1973). However, the elements of conventional soil tillage (basic working, preparation of the germinal layer, maintenance of the field, etc.) result in immediate positive effects. Some negative effects also manifest themselves. One of the main objectives for the soil tillage system is to create an optimal physicochemical condition of the soil and to preserve this condition over the whole vegetation period (Moraru & Rusu, 2010).

The book published by Phillips and Young (1973) shows that in the tests made on soybeans cultivated in the no-tillage (without ploughing) system by the USA experts from the University of Iowa, the soil humidity was a few percent higher compared to the soybeans cultivated in the conventional system (Sarpe, 2010). Influence of inter-row spacing on a productivity of soybean yield was studied by Kolaric et al. (2014) on the experimental field on a low carbonate chernozem soil. Amount and distribution of rainfall per year varied so that water regime in a year with less rainfall significantly affected the production of soybean. In the first year, when the weather was unfavourable for growing soybean, there was less rainfall in April, May and especially in June than during the previous years. In relation to a long-term average, rainfall deficit, combined with high temperatures especially in May and June, has caused a drastic reduction in grain yield of soybean.

According to another study conducted by Sarpe (2010), tests with genetically modified soybeans were made on an alluvial soil from the Danube Meadow. The soil moisture content was measured at 0–20; 20–40 and 40–60 cm depths, meaning in the soil layers where most of the soy roots start to grow. The soil moisture content was measured in three different periods of the year, respectively in June, August and before harvesting the soybeans. Almost the same moisture content values were registered for the no-tillage system, where the soil was neither ploughed nor prepared as in the classical system, the differences appeared to be part of the experimental errors. The result obtained in August is very important because this is the period in which the soybean reached the maximum development level as regards the vegetal mass and the roots. The explanation is the following: more water had evaporated from the soil when using the classical system because of the mechanical weeding/hoeing operation, while the 0–20 cm depth soil layer remained untouched when using the no-tillage system. Wang et al. (2009) has once proposed the triple intercropping system of wheat-maize-soybean as a new conservation tillage pattern which is highly efficient, ecological, and water saving.

Most studies investigate soil respiration in a single crop field. Few research cases deal with multiple cropping, crop rotation and relay intercropping (Zhang et al., 2016). Moraru and Rusu (2010) demonstrated that increased soil organic matter content, aggregation, and permeability are all promoted by minimum tillage systems. Krauss et al. (2020) reported a 15-year study on reduced tillage with organic manures revealed a that reduced tillage with organic farming practices enhances yield, soil organic carbon, and soil microbial biomass over conventional tillage. Soil moisture and crop yields have been shown to increase with improved land settings, tillage options, and residue retention as mulch (Mozafari et al., 2020; Parihar et al., 2017; Rajanna et al., 2022).

Statistical analysis of the results showed that the differences in accumulated soil water depended on the variants of soil tillage and type of soil. Soil texture and structure have a strong effect on the available water capacity. The results clearly demonstrate that minimum tillage systems promote increased humus content (0.85–22.1%) and increased water stable aggregate content (1.3–13.6%) at the 0-30 cm depth compared to conventional tillage. The implementation of such practices ensures a greater water reserve even across different soil types. The practice of reduced tillage is ideal for enhancing soil fertility, water holding capacity, and reducing erosion. The advantages of minimum soil tillage systems can be used to improve methods in low producing soils with reduced structural stability on sloped fields, as well as measures of water and soil conservation on the whole ecosystem. Careful planning and management are needed for the efficient use of water and nutrients in soybean-based cropping systems with suitable land modifications to enhance soil quality, production and profitability (Boutraa, 2010; Davies & Bennett, 2015; Evans & Sadler, 2008; Obalum et al., 2011). Thus, more effective irrigation techniques, growing tolerant genotypes, longer irrigation intervals, and deficit irrigation methods are all needed to reduce plant water consumption (Mahmoud et al. 2013). This irrigation management techniques would save a significant amount of irrigation water while providing comparable economic returns (Montoya et al., 2017).

Conclusion

The results of studies conducted in soil tillage and water regime entitle us to say that real soil conservation is represented by the complexity of soil, water regime and climate change. However, soybean adapts to non-extreme soil types effortlessly, which is demanding of soil water regime. Towards an increased food safety perspective, it is essential to ensure the environmental stability of crop production as in this scenario, soybean deserves to be highlighted due to its economic importance in the world market. Agricultural experts and farmers need to provide adequate knowledge of irrigation practices to adapt and implement appropriate solutions on the field since weather and soils properties can affect the variation of tillage operations, while future researches should investigate the effects of climate change measures and their potential to optimize the environmental benefits of conservational tillage. Altogether, the results suggest that conservation technologies can save soil and water, upgrade soil moisture content, and increase crop yield, all of which are important to long-term agricultural sustainability based on profitable plant production and environmental protection. These results indicate that conservation tillage can be a viable approach to increase production by significantly reducing the potential environmental risks.

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Examination of water and salt stress for five different maize hybrids

Ádám KOMLÓSI[1] – Gábor BENCZE[1] – Zoltán FUTÓ[1]

1: Hungarian University of Agriculture and Life Sciences, Department of Irrigation and Land Improvement, Hungary, e-mail: adamkomlosi24@gmail.com

Abstract: In today's climatic conditions, the yield-reducing effects of drought are increasingly being felt. Irrigation is the easiest and most effective way to eliminate the damage caused by drought. The production of drought-tolerant hybrids is a new trend that can easily affect the amount and quality of crops to be harvested in a drought year. In the course of the research, we investigate the drought responses of five different hybrids, in three different water doses, in an environment closed from external precipitation in three replicates. We set up our experiment at the Department of Irrigation and Land Improvement of the Hungarian University of Agriculture and Life Sciences in Szarvas. The test was performed in pots. In addition to different water doses, the salt tolerance reactions of maize hybrids on saline soils were also investigated. The highest SPAD values were achieved with a water supply of SWS80%. Relative chlorophyll content results decreased by the end of the growing season, but the decrease was lowest with SWS80% water doses. The biomass weight of maize hybrids improved in all cases with increasing water supply (from 0.307 ± 0.04 to $0,440 \pm 0.07$) . The biomass weight of the drought-tolerant hybrids decreased the least under drought stress, while the decrease in biomass weight of the sensitive hybrids was much stronger during the experiment. The root mass of maize hybrids decreased significantly due to drought stress (from 0.555 ± 0.08 g to 0.328 ± 0.06 g). The smallest decrease was achieved by the roots of drought-tolerant hybrids. The maize hybrids were able to achieve the best LAI values at the SWS80% (good water supply) level. LAI values decreased by 19.5–21.7% due to drought stress. As a result of the drought stress, the decreased LAI values of the hybrids as well as the reduced root mass resulted in smaller cob weight. A significant mean positive correlation was found between LAI values and cob weight values of maize hybrids at $r = 0.493$. Hybrids showed more significant drought stress on saline soils, which worsened the yields achieved (from 11.2% to 18.7%). The production of maize hybrids under saline conditions was significantly decreased, but significant differences were found between the hybrids.

Keywords: SPAD, LAI, drought-stress, corn

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Introduction

One of the cornerstones of high maize yields is high-quality soil preparation, which consists of autumn tillage, spring seedbed preparation and fertilization. We must take care of a deep summer / autumn deep cultivation, because maize prefers airy soils (Birkás & Szieberth, 1998; Hegedűs, 1984; Radics, 2003).

Corn has tufted roots. Tasseled root is formed from a primary germ root, auxiliary root, and an auxiliary root emerging from the stem nodules. At the beginning of germination, maize develops only a single germ root that penetrates rapidly down into the soil, up to a depth of 30–40 cm. The side roots branch off from the main root in a fan-like manner in the soil. It is 60% below the surface of the earth to a depth of 10 cm and 90% to a depth of 50 cm. The main task of the side roots is to penetrate the soil into the deeper layers so that the plant can absorb wa-

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ter from as many places as possible. In addition to the secondary roots, we can also talk about additional roots. Additional roots can be called in several ways: air, support or dew roots. Their development can be traced to the second half of the vegetative developmental phase, and the stem nodules from which they originate are often found above ground. These play a role in protection against tipping over, water uptake and nutrient uptake (mainly phosphorus). The size of the root system of maize is influenced by the aeration and water supply of the soil, but it is determined by the varieties. The root development of maize is strongly influenced by the chemical and physical properties of the soil (Kovács, 1981). Adequate seeding density should be used, although there is no relationship between the length of the season and the seeding density (Pepó, 2011).There are also correlations between the size of the leaf area and the size of the grain yield achieved. Corn usually has 8–14 leaves, but rare forms can have 14–38. In addition to the leaf size of the maize, the leaf position is also important due to the purposeful, purposeful breeding work of the leaves, which is an advantageous property in terms of stem compaction (Antal, 2005). According to Nyíri (1997), a balanced supply of potassium and phosphorus is very important in the supply of nutrients to maize, which is incorporated into the soil in the autumn, and a precise supply of nitrogen is also important. The specific nutrient requirement of maize from macro nutrients is 28 kg N / t, 11 kg P_2O_5 / t, 30 kg K_2O / t. After fertilizing the corn with phosphorus and potassium in the fall, the nitrogen must be introduced into the soil in the spring (Füleky, 1999).

Corn has a medium water requirement of 450–550 mm. Its water consumption can reach up to 5.5–6.5 mm / day. From a depth of up to 150–200 cm, corn can absorb water. The lack of water during the period of tasseling can reduce our yield by up to 53%, while the drought at grain saturation can reduce our yield by 30% (Futó & Sárvári, 2015; Menyhért, 1979). According to Gyulai and Sebestyén (2011), the amount of precipitation is not necessarily decisive for the development of maize in terms of water supply, but its distribution during the growing season may be decisive. The water supply of corn consists of three main components. Precipitation retained during autumn and winter, the amount of water stored in the soil by appropriate agrotechnics during the growing season, and water applied by irrigation in addition to precipitation (Petrasovits & Balogh, 1969). Based on the drought index, Szász and Tőkei (1997) found that between 1860 and 1900 the incidence of dry and wet seasons was equal (22.5%), with average vintages accounting for only more than half of the years (55%) were typical, while in the period between 1980 and 2000 the proportion of drought vintages increased significantly (52.6%) at the expense of average vintages (26.3%). The occurrence of drought years is becoming more and more important and the role of drought control in agriculture is becoming increasingly important.

According to Pepó (2011), we can only perform successful selection in genetically diverse populations, so new directions in plant breeding include maintaining biodiversity through different methods. According to Basal (2020), it is not the SPAD results for soybeans but the much more closely correlated leaf area index (LAI) results that will provide reliable data to assess the resulting drought damage. In the maize stock that does not suffer from drought damage, the grain yield per hectare increases linearly up to the value of 5–5.5 LAI and then to 6–7 LAI. There is also a correlation between the size of the leaf area (LAI) of maize and grain yield (Futó, 2003; Antal, 2005).

Many research confirm that drought and salt stress are similar physiological and biological processes and result in similar reactions in plants (Chaves et al., 2003; Chen et al., 2003; Jiang & Zhang, 2004; Liu & Vance Baird, 2004; Shao et al., 2005; Zhu et al., 2004). The concept of water stress includes both salt stress and drought stress too (Kaur & Zhawar, 2015), and it has been observed that salt stress combined with drought stress can cause even greater yield loss (Cong, Pang, Xu, & Wang, 2021).

Materials and Methods

In the course of the research, we examined the responses of different maize hybrids to drought and salt stress in an environment excluded from external precipitation. If we can reduce the negative effects of climate change with a properly chosen hybrid, we can also have a major impact on crop loss and production economy. During the experiment, 5 different maize hybrids were tested, with drought-sensitive and drought-tolerant hybrids among them. The experiment was performed in pot experiments isolated from external precipitation. The first step was to determine the field water capacity of the soil (SWS) that the soil could hold back against gravity and set up 3 different water doses (SWS 40%, SWS 60%, SWS 80%). Secondarily, we also measured salt stress in the experiment, so we also performed treatments where the same water doses are set on moderately saline soils.

Our crop results are greatly affected by the effect of drought stress, so we set up a water supply experiment to study the irrigation response and drought tolerance of different maize hybrids. If, in this world burdened by climate change, we can make the yield of maize more stable in a drier season with a well-chosen hybrid, it could increase the yield and production safety.

In this experiment, the irrigation response and drought tolerance of maize hybrids recognized or pending recognition were investigated. Alternatively, salt tolerance was also tested in the experiment. Drought-tolerant and drought-sensitive hybrids were also included in the research.

In the experiment, the drought and salt tolerance reactions of different maize hybrids were investigated in a pot experiment closed from external precipitation. 11 kg of arable soil was weighed into the culture pots at the time of setting up the experiment and the main physical and soil chemical properties of the arable soil were determined. These parameters are as follows:

- Physical type of soil: clay soil
- Arany's soil plasticity: 46 KA
- Field water capacity: 47 V/V%
- Dead water content: 31 V/V%
- Water content available for plants: 16 V/V%
- pH: 7.07

The following hybrids were included in the experiment: GKT 372 (drought tolerant), GKT 376 (drought tolerant), GKT 3385 (drought tolerant), GKT 4486 (drought sensitive), GK SILOSTAR (drought sensitive). The corn hybrids were sown on April 29, 2020, which emerged on May 8-9. The plants were watered uniformly until the 10-leaf stage, according to the water requirement. From June 9, 2020, we started the treatments with different water doses. The experiment was harvested on September 3, 2020.

Only the changes of the temperature values as monitored from the meteorological data, as the pots were in greenhouse, where the plants closed from external precipitation. Temperature had the greatest effect on evapotranspiration and thus on the daily amount of water discharged. The increasing temperature increased the daily evaporation, which required the use of higher water doses to achieve the planned water supply level.

3 water supply levels were set in the experiment. The first step was to determine the natural water capacity (TAC) of the soil, which was the amount of water that the soil could retain against gravity. For this, we took a soil sample that was saturated with water. The

soil was then placed on dry sand and allowed to drain and weighed. The soil was then dried at a temperature of 105 °C and weighed again. From the difference in weight, we calculated the value of the soil field water capacity. The following treatments were set up experimentally: SWS 40%, SWS 60%, SWS 80% (SWS = Soil Water Storage Capacity).

In the experiment, we measured and calculated the amount of daily evaporation based on the daily temperatures with which we were able to maintain different levels of water supply in the treatments. In the lowest treatment (SWS40%), 361.1 mm less water was released during the growing season than would have been justified for us by plant transpiration. During the experiment, the plants were exposed to significant drought stress. In the highest dose treatment (SWS 80%), the amount of water applied (100% of the evapotranspirated water was replaced) this covered the amount of evaporation, so it was optimal for corn..

In the salt tolerance experiments, different water supply levels (SWS40%, SWS 60% and SWS 80%) were also set. The salt tolerance of hybrids was monitored by applying different Na salts added to irrigation water. This salt mixture contained NaCl, NaSO4 and NaCO3. During the treatments we applied to model the water management properties of a medium quality saline soil (salt% = 0.1–0.25, EC=2–4 mS/cm).

During the research, the following phenological parameters were measured: relative chlorophyll content (SPAD) with Konica SPAD 501 instrument, leaf area (based on Montgomery formula), leaf area index (LAI m^2/m^2), cob weight, biomass weight, root weight.

Data were measured several times during the growing season. Final biomass (leaf and stem weight, root weight, etc.) was measured at harvest, relative chlorophyll content (SPAD) and leaf area were measured every two weeks. The data were processed with Microsoft Excel, while the statistical evaluation of the data was performed with SPSS for Windows 25.0. program, using the method of variance analysis and correlation.

Results

The highest relative chlorophyll content (SPAD) in corn plants was measured during the 2nd measurement, after which the chlorophyll content began to decrease, the process of drying and ripening began (Figure 1). This indicated that the decrease in chlorophyll content was large under dry conditions, but plant aging reduced the relative chlorophyll content to a greater extent.

There were significant differences in SPAD values due to different water doses. At the lowest water dose (SWS 40%), the SPAD value decreased to 41.47 due to drought stress, while it was 45.94 for medium water supply and 46.05 for good water supply (Table 1.).

In drought conditions (SWS 40%), the decrease in the SPAD value of the treatments was significant. The lowest relative chlorophyll content values were at the time of the last measurement, for all corn hybrids. The smallest SPAD depreciation was under excellent water supply conditions, is maize was able to further photosynthesize with adequate water supply. Figure 2. shows that the SPAD values of different maize hybrids are different for different water doses. Maize hybrids do not show us clear changes in SPAD results, as some hybrids (GKT4486 and GK SILOSTAR) achieved the highest SPAD (40.73 and 42.97) in the good water supply (SWS 80%) and others (GKT372, GKT376 and GKT3385) in the medium water dose (SWS 60%) treatment (48.73, 41.72 and 40.1) so we assume that the SPAD is not considered an appropriate consideration in all cases when examining drought stress.

The mass of the above-ground biomass (leaf, stem) of the hybrids was also measured in the

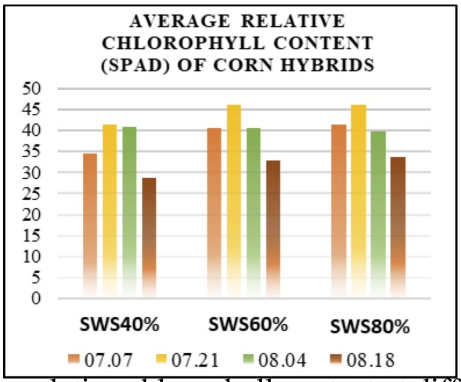

Figure 1: Average relative chlorophyll content at different water doses

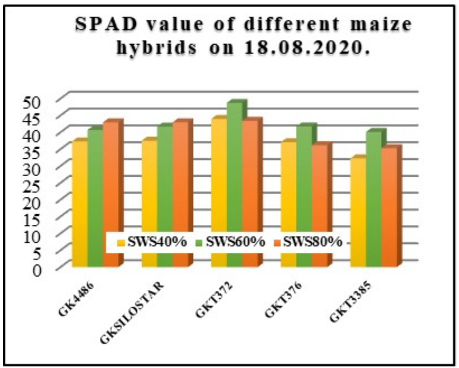

Figure 2: Relative chlorophyll content of different maize hybrids at different water supply levels

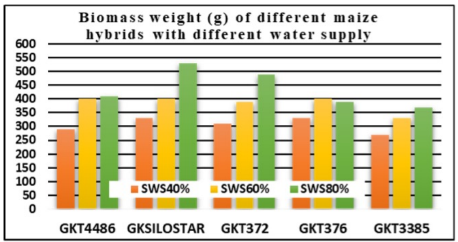

Figure 3: Biomass of different maize hybrids at different water supply levels

Table 1: Variance analysis of SPAD value

SPAD Value	*SS*	*df*	*MS*	*F*	*p*	*Fcrit.*
Between groups	143.5903	2	71.79513	22.43241	0.0000883	3.885294
Within a group	38.40611	12	3.200509			
Total	181.9964	14				

experiment (Figure 3). At all water supply levels, the lowest plant weight was achieved by a hybrid called GKT 3385 (Table 2).

The hybrid named GKT 376 has the smallest difference between the hybrids for different water doses, suggesting that this hybrid has

Table 2: Value of biomass of different corn hibrids and different water supply

	Biomass (kg)					
	GKT4486	GKSILOSTAR	GKT372	GKT376	GKT3385	Mean
SWS 40%	$0.293^{a} \pm 0.09$	$0.333^{a} \pm 0.02$	$0.307^{a} \pm 0.05$	$0.333^{a} \pm 0.02$	$0.267^{ac} \pm 0.02$	0.307^{A}
SWS 60%	$0.400^{ad} \pm 0.00$	$0.400^{ad} \pm 0.04$	$0.387^{a} \pm 0.36$	$0.400^{ad} \pm 0.04$	$0.333^{a} \pm 0.02$	0.384^{B}
SWS 80%	$0.413^{ad} \pm 0.12$	$0.533^{b} \pm 0.08$	$0.493^{b}d \pm 0.40$	$0.387^{a} \pm 0.02$	$0.373^{a} \pm 0.06$	0.440^{B}
Mean	0.369^{C}	0.422^{D}	0.396^{C}	0.373^{C}	0.324^{C}	

(a,b,c,d Different significant groups between hybrid × SWS values;
A,B Different significant groups between SWS average values;
C, D Different significant groups between hybrid average values)

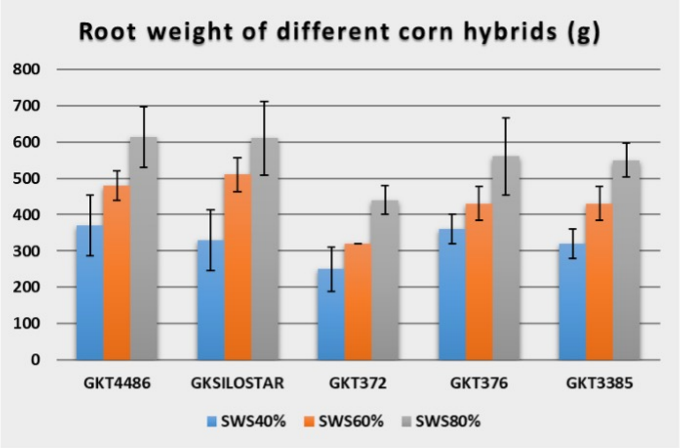

Figure 4: Root mass of different corn hybrids at different water supply levels

Table 3: Analysis of variance of root weight (g)

Tests of Between-Subjects Effects					
Source	*TSS*	*df*	*MS*	*F*	*Sig.*
Intercept	8.642	1	8.642	2431.770	.000
Hybrid	.135	4	.034	9.470	.000
Irrigation	.386	2	.193	54.339	.000
Error	.135	38	.004		
Total	9.298	45			

a. R Squared = .794 (Adjusted R Squared = .762)

Table 4: Means and confidence intervals of root weight (g) under different irrigations

Root weigth (g)				
Irrigation	Mean	Std. Error	95% Confidence Interval	
			Lower Bound	Upper Bound
SWS 40%	0.328^{a}	0.015	0.297	0.359
SWS 60%	0.432^{b}	0.015	0.401	0.463
SWS 80%	0.555^{c}	0.015	0.524	0.586

a-c Values with different letters within treatments (irrigation) differ statistically ($P < 0.05$)

the worst irrigation response. This hybrid did not achieve the highest biomass mass with a good water supply, but with a medium water dose (SWS 60%). GK SILOSTAR achieved

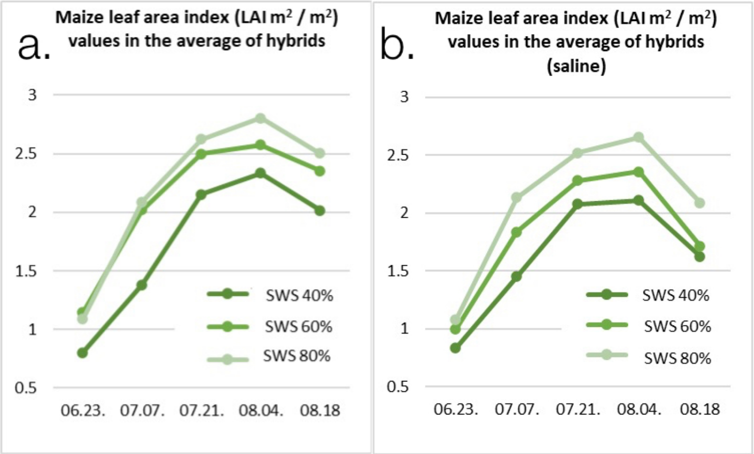

Figure 5: Development of leaf area index (LAI) values in different water supply treatments (a.) and on saline soils (b.)

Table 5: Analysis of variance of LAI (m^2/m^2)

Tests of Between-Subjects Effects					
Source	*TSS*	*df*	*MS*	*F*	*Sig.*
Intercept	1658.650	1	1658.650	4458.801	.000
Hybrid	7.839	4	1.960	5.268	.000
Irrigation	16.877	2	8.439	22.685	.000
Salt	2.452	1	2.452	6.593	.011
Error	164.422	442	.372		
Total	1850.239	450			

the highest biomass mass (530 g), which is understandable due to its genetic background (silage corn), but the difference between the results of different water dose treatments is quite large, which indicates that this hybrid has a good reaction to irrigation.

One of the most important parameters for us is the development of root masses in addition to the leaf area index and cob mass. Research is currently underway to demonstrate that hybrids with higher root mass / root area are much better able to tolerate drought thus being able to achieve higher yields. There may also be significant differences in the root mass of hybrids that affect the water and nutrient uptake of a given hybrid. For all maize hybrids, increasing water doses resulted in increasing root masses. During the experiment, the hybrid named GKT 372 reached the lowest root mass in all irrigation treatments. GK SILOSTAR achieved the highest root weight (610 g) at the SWS 80% water dose, had only 3 g less root weight than the GKT4486 maize hybrid (613 g) in the treatment, which is really good results (Figure 4, Table 3, 4).

The hybrid GK 4486 was able to achieve the highest root weight (370 g) in dry conditions (SWS 40%), which could be an advantage over other hybrids in a drier season. At medium (SWS 60%) water dose, GK SILOSTAR showed that it can achieve significant root mass when medium amount of water is available, as it reached the highest root mass, indicating good water utilization and irrigation response. The GKT 4486 hybrid achieved the highest root mass under good water supply conditions (80% water

Table 6: Means and confidence intervals of LAI (m^2/m^2) under different treatments

LAI (m^2/m^2)				
Hybrid	Mean	Std. Error	95% Confidence Interval	
			Lower Bound	Upper Bound
GKT 4486	2.060^{a}	.064	1.933	2.186
GK Silostar	2.027^{a}	.064	1.900	2.153
GKT 3724	1.873^{ab}	.064	1.747	2.000
GKT 376	1.950^{a}	.064	1.823	2.076
GKT 3385	1.690^{b}	.064	1.563	1.816

LAI (m^2/m^2)				
Irrigation	Mean	Std. Error	95% Confidence Interval	
			Lower Bound	Upper Bound
SWS 40%	1.675^{c}	.050	1.577	1.773
SWS 60%	1.935^{cd}	.050	1.838	2.033
SWS 80%	2.149^{d}	.050	2.051	2.247

LAI (m^2/m^2)				
Salt	Mean	Std. Error	95% Confidence Interval	
			Lower Bound	Upper Bound
without salt	1.994^{e}	.041	1.914	2.074
with salt	1.846^{e}	.041	1.766	1.926

a-e Values with different letters within treatments (hybrid. irrigation and salt) differ statistically ($P < 0.05$

dose of SWS). The size of the water doses in the hybrids had a great influence on the root mass of the hybrids. As a result of the improved water supply, the increase in root masses was significant for all hybrids, increasing between 35.7% and 45.9% in the experiment.

The average leaf area index (LAI) values of the hybrids in the treatment of different water doses are shown in Figure 5. They show that at the lowest SWS water dose of 40%, significantly smaller leaf area was formed in maize hybrids, and their leaf area results remained lower than the SWS 60% (medium water supply) during the growing season. SWS in 80% (good water supply) treatment.The significant leaf area increased due to the 60% water dose of SWS and the 80% water dose of SWS, the values of these water doses increased the leaf area evenly until the measurement on 07.07, but after that the 80% water dose of SWS was able to increase the leaf area of hybrids.

The irrigation results of the salt-treated culture vessels are shown in Figure 5b. On saline soils, after the 40% water dose of SWS, the other two treatments (SWS 60% and SWS 80%) could not increase the leaf area of maize hybrids as much as in the treatments without salt treatment, so salt stress can also suppress the positive effect of increasing water doses. The increase in water supply in saline soils resulted in much weaker leaf area growth than in non-saline treatments. Salt in the soil significantly impairs the nutrient and water uptake of maize, thereby significantly affecting the water management of the medium. In addition to the medium water supply (SWS 60%), we measured only the same leaf area results (2.36 m^2/m^2) as in the experiment without salt treatment under drought stress (SWS 40%) (2.33 m^2/m^2) (Tables 5 and 6).

At the beginning of the vegetation, the treat-

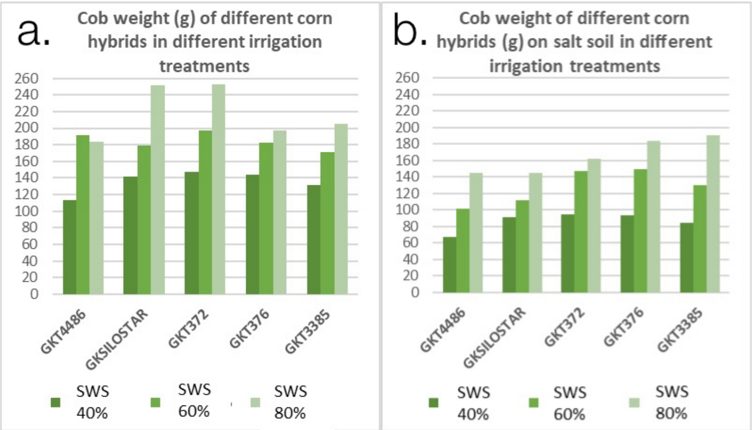

Figure 6: Cob mass of maize hybrids at different water supply levels (a.) and on saline soils (b.)

Table 7: Value of cob weight of different corn hibrids and different water supply

	Cob Weight (g)					
	GKT4486	GKSILOSTAR	GKT372	GKT376	GKT3385	Mean
SWS 40%	$113,123^{a} \pm 52,15$	$141,537^{ad} \pm 8,42$	$146,573^{ae} \pm 20,67$	$143,597^{a} \pm 12,61$	$130,510^{a} \pm 6,54$	$135,068^{A}$
SWS 60%	$192,367^{be} \pm 6,63$	$178,807^{bd} \pm 8,39$	$196,933^{be} \pm 4,86$	$181,633^{bd} \pm 11,91$	$171,247^{bd} \pm 16,40$	$184,191^{B}$
SWS 80%	$184,633^{b} \pm 34,04$	$252,02^{c} \pm 28,38$	$253,380^{c} \pm 28,41$	$196,667^{be} \pm 6,88$	$204,747^{b} \pm 13,15$	$218,291^{C}$
Mean	$163,378^{D}$	$190,788^{D}$	$198,961^{E}$	$173,954^{D}$	$168,834^{D}$	

(a,b,c,d Different significant groups between hybrid × SWS values;
A,B,C Different significant groups between SWS average values;
D,E Different significant groups between hybrid average values)

Table 8: Pearson correlation between LAI and maize cob weight

		LAI	Cob weight
LAI	Pearson Correlation	1	0.478 **
	Sig. (2-tailed)		0.001
Cob weight	Pearson Correlation	0.478 **	1
	Sig. (2-tailed)	0.001	

** Correlation is significant at the 0.01 level (2-tailed).

ments do not show significant differences in the development of the leaf area index, but as the vegetation progresses, they are better able to explain the negative effects of salt stress, which cause drastic leaf area index declines (between 14.9% and 26.8%). Under these conditions, the plants are able to photosynthesize for a shorter time and with a significantly smaller leaf area, which reduces the plant's organic matter production on a large scale. During the experiment, the salt stress caused on the salty soil resulted in faster aging, dehydration and drying of the corn plants. Comparing Figures 6a and 6b, it becomes clear that salt stress significantly reduced the cob weight of each hybrid, but the extent varied from hybrid to hybrid (Table 7).

The greatest yield-reducing effect was on the tube weight of GKT 4486 and GK SILOSTAR. Drought-sensitive hybrids were able to achieve high tube masses in non-saline treatments with a good irrigation reaction, but stress-tolerant hybrids prevailed due to the negative effects of salt stress. In Figure 6a, GK SILOSTAR was able to reach the second highest tube weight (252 g) at the 80%

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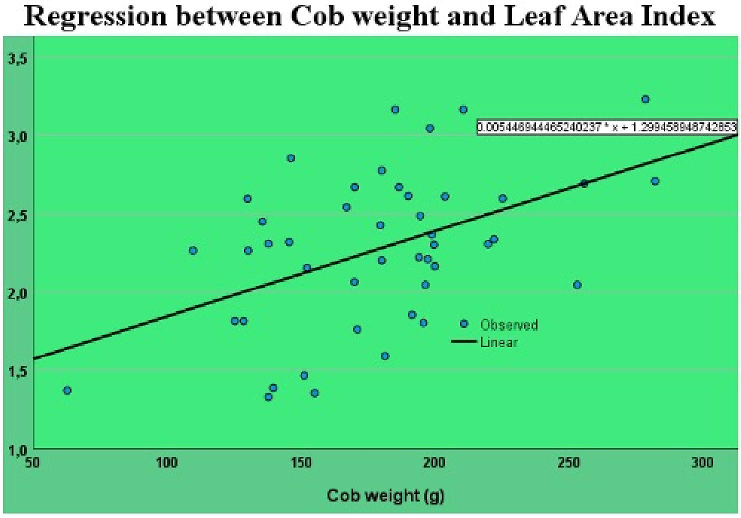

Figure 7: Regression between LAI and maize cob weight

water dose of SWS, but was forced to the penultimate position in the treatments (145 g) due to salt stress.

The effect of salt stress on drought-sensitive hybrids was more pronounced in terms of yield loss. In contrast to salt stress, however, drought-tolerant hybrids showed less decline compared to themselves. The hybrid GKT 372 achieved the highest tube weights in non-saline treatments (253 g) and performed quite well in saline treatments (162 g), from which it can be concluded that it tolerates the yield-reducing effects of salt stress and drought well.

The GKT 3385 hybrid performed best in terms of pipe weights (190 g), so it can be said to have good resistance to drought stress as well as salt stress (only 15 g). Under the effect of salt stress, significant yield loss can be realized, but the experiment shows that a good hybrid selection can reduce yield loss. The degree of correlation between leaf area index (LAI) and tube weight was examined during the statistical evaluation. A correlation study was performed first. It can be stated that the correlation showed a significant correlation, the correlation value was 0.478, the correlation was positive(Table 8). The regression study also clearly confirmed that an increase in leaf area leads to an increase in tube mass, so the negative effects of water scarcity on leaf area (LAI) are strongly correlated with a decrease in subsequent tube mass results (Figure 7).

Conclusions

Based on the experiment, it can be concluded that the hybrids with the best irrigation reaction were GKT 4486 and GK SILOSTAR. These two drought-sensitive hybrids were helped by their good irrigation reaction to achieve high biomass mass. With a good water supply, they were able to achieve a high tube mass, and in non-saline treatments, the two hybrids were able to achieve the highest root mass. These two hybrids were at the forefront of SPAD and LAI results throughout the non-saline treatments, but only at the highest water supply level were they able to achieve good results in tube mass development.

The GKT 372 hybrid was able to achieve good results in non-saline treatments. He had the lowest root weight in the non-saline treatments, but nevertheless had the highest tube weight and the second best result in terms of biomass.

In the saline treatments, the two drought-sensitive hybrids reached the lowest tube weight, and their biomass and root weight loss were also the largest for these hybrids. The GKT 3385 hybrid was able to reach the highest tube weight during the salt treatments, but the GKT 376 and GKT 372 hybrids did not lag far behind. Their stem, tube, and root mass development did not decrease much in the saline treatments, which shows us that these hybrids have good salt tolerance.

The results of the experiment show that the GKT 372 is a great choice in a rainy and in a normal year, but the GKT 372 can be a good choice for us even in a droughty year, but the other drought-tolerant hybrids GKT 376 and GKT can be mentioned here. 3385. GK SILOSTAR has a good irrigation reaction and can achieve a high biomass mass in a normal vintage, which is a particularly important feature because it is a silage corn. GKT 4486 did not give us good results in either the saline or smooth treatments.

Thanks to the experiment, it has been found that a drought-tolerant hybrid can achieve good crop safety in a drier vintage, and if this property is combined with a good irrigation reaction, hybrids can be grown that produce higher yields in both a drier and a normal vintage. The experiment has shown that a good irrigation response can be a key property for a drought-sensitive maize hybrid, but it cannot even compete with the crop safety provided by drought-tolerant hybrids.

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MAGYAR AGRÁR- ÉS ÉLETTUDOMÁNYI EGYETEM

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Effect of precipitation on the nutrient reaction of triticale varieties

István KRISTÓ[1] – Marianna VÁLYI NAGY[1] – Attila RÁCZ[1] – Katalin IRMES[1] – Melinda TAR[1]

1: Hungarian University of Agriculture and Life Sciences, Plant Production Scientific Institute, Crop Production and Agrotechnical Research Station, Alsó-Kikötő sor 9. Szeged, Hungary, e-mail: kristo.istvan@uni-mate.hu

Abstract:Triticale is the first man made genus hybrid of wheat and rye. The basic aim of its production was to combine yield potential and grain quality of wheat with the disease and environmental tolerance of rye. In the past decades, triticale crop area has been increasing in Hungary, which climate change has also contributed. The triticale is produce well in dry climatic conditions, so it becomes more and more popular among farmers. Our country is the one of the top 10 triticale producing countries in the World. In the long-term fertilization experiment, at Fülöpszállás, on calcic meadow chernozem soil we carried out experiments in three growing seasons (2018/2019, 2019/2020, 2020/2021) with three winter triticale varieties (Hungaro, Mv Talentum, GK Maros,) in 4 replications, on 20 square meter random layout plots. In our experiment, we examined 15 different fertilization treatments, in every year, which can be used as different fertilization strategies. From the results of our experiments, we concluded that the yield of triticale is largely determined by genotype and nutrient supply, which is strongly influenced by the average annual precipitation. In the dry year, the effect of nutrients on yield was greater than in the rainy growing season.

Keywords: triticale, variety, nutrient supply, climatic condition, yield

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Introduction

Triticale (× *Triticosecale* Wittmack) is the first man made genus hybrid by the crossing of wheat (*Triticum* sp.) and rye (*Secale cereale*), which has been cultivated (Darvey et al., 2000; Stace, 1987). The purpose of creating triticale was to combine the productivity and good quality of wheat with the resilience of rye (Randhawa et al., 2015). Triticale has a remarkably high Mg, K, P, S, Ca, Mn, Zn, Fe, Se content (Bóna et al., 2006; Hajós, 2008; Kruppa et al., 1999). Its protein content is 12–16%, usually higher than that of wheat with low gluten proportion. The amino acid composition is good, e.g. lysine content is high (Heger & Eggum, 1991). Triticale is primarily used as feed (grain, forage, forage-mixes) (Bona et al., 2014; Gill & Omokanye, 2016; Kruppa, 2004; Wrigley & Bushuk, 2017), but it has a potential in the production of products for human consumption (Cooper, 1985; Dennett et al., 2009; Fraś et al., 2016; Woś & Brzeziński, 2015), such as flour, bread, pastas, doughs, biscuits, flakes, branas well as energy and biomass crop (Demirbas, 2007; McGoverin et al., 2011). The growing area of triticale is in the word 3.8 million ha, in Hungary 7,3 thousand ha (FAO, 2020). It has 3–6 t ha^{-1} yield, depending on production conditions (soil, climate, agrotechnic parameters etc.).

Regarding optimal growing conditions, it is between wheat and rye. Triticale prefers cool and humid climate but it has a good adabtibility: it can be grown under conditions

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suitable for wheat or rye (Erekul & Köhn, 2006). Earlier cultivars were grown on poor sandy soils due to their long stem but current varieties can be grown on soils of better quality without facing the problem of lodging (Kruppa, 2004). Triticale is more modest to soil than most cereals. It is usually worth growing on less favorable wheat soils, such as brown forest soils, medium-compact, meliorated meadow soils, sandy soils, and alkaline soils.

According to Kruppa (2004), triticale can be grown with extensive technology, even with small doses of N. It adapts well tot he specifics of the production area and thanks to its good nutrient utilization, we can also grow it in a production area siutable for rye. However, Kádár et al. (1999) found that triticale cannot be grown economically on acidic sandy soil without nutrient supply. Pure doses of N, P, K and NK were ineffective in themselves, but the crop increased with the NPK, NPK–Ca and NPK–Ca–Mg combinations. However, they say, increasing doses of nutrients did not cause an increase in triticale yield. According to Radics and Pusztai (2011), the nutrient supply of triticale also depends on the purpose of the farmer, as it reacts to increasing nutrient rations with an excess of yield. In a more modest area, even with smaller inputs, it is able to produce a stable crop, similar to rye. On the other hand, it is better off, and it repays the extra costs with a higher yield, similar to wheat. In line with this, statement of (Arseniuk, 2014): under high input and rainfall environments, the best triticales and wheats have comparable grain yield, with some advantage for the triticales. Therefore, more and more farmers in Hungary are growing triticale in a precision system in order to exploit the conditions of the production area, to use the input materials rationally and to manage them more cost-effectively. Knowledge of the topography, nutrient supply and water management of growing area is the basis for the precision cultivation of triticale (Habib-ur-Rahman et al., 2021).

Precipitation, nutrient supply to plants and yield are closely interrelated (Márton, 2002b). According to Kádár et al. (1999), the amount of precipitation affects the yield of triticale more than the nutrient supply. Márton (2002a); Márton (2008) found that the precipitation supply of the years has a major impact on the effectiveness of fertilization: yields of triticale decrease even in drought years and in case of excessive rainfall supply.

The aim of our study was to determine how the yield of triticale is affected by variety, nutrient supply, and year of cultivation. We were also interested in the extend to which the amount of precipitation at different times of the growing year affects the yield.

Materials and Methods

In the long-term fertilization experiment, at Fülöpszállás, on calcic meadow chernozem soil we carried out experiments in three growing seasons (2018–2019, 2019–2020, 2020–2021) with three winter triticale variety (Hungaro, Mv Talentum, GK Maros) in 4 replications, on 20 square meter random layout plots. In our experiment, we examined 15 different fertilization treatments (Table 1), in every year, which can be used as different fertilization strategies. With the applied nutrient treatments used, we can study not only the effect of the amount of nutrients, but also the effect of the ratio of nutrients.

Treatment 1 indicates plots that have been unfertilized for 40 years (untreated control). Treatments 2, 3 and 4 show nitrogen-free, phosphorus and potassium fertilization in 3 nutrient doses. Treatments 5, 6, 7 indicate plots without PK fertilized with nitrogen alone, in 3 doses. Treatments 8, 9, 10 contain a 1:1:1 ratio of N:P:K at different nutrients doses. Treatments 11., 12., 13. contain a 2:1:1 ratio of N:P:K at different doses. Treat-

Table 1: Fertilization treatments in the experiment

No. of the treatment	Sign of treratment	N	P_2O_5	K_2O
		kg ha^{-1} active agent		
1.	$N_0P_0K_0$	0	0	0
2.	$N_0P_{30}K_{30}$	0	30	30
3.	$N_0P_{60}K_{60}$	0	60	60
4.	$N_0P_{90}K_{90}$	0	90	90
5.	$N_{30}P_0K_0$	30	0	0
6.	$N_{60}P_0K_0$	60	0	0
7.	$N_{90}P_0K_0$	90	0	0
8.	$N_{30}P_{30}K_{30}$	30	30	30
9.	$N_{60}P_{60}K_{60}$	60	60	60
10.	$N_{90}P_{90}K_{90}$	90	90	90
11.	$N_{60}P_{30}K_{30}$	60	30	30
12.	$N_{120}P_{60}K_{60}$	120	60	60
13.	$N_{180}P_{90}K_{90}$	180	90	90
14.	$N_{90}P_{30}K_{30}$	90	30	30
15.	$N_{180}P_{60}K_{60}$	180	60	60

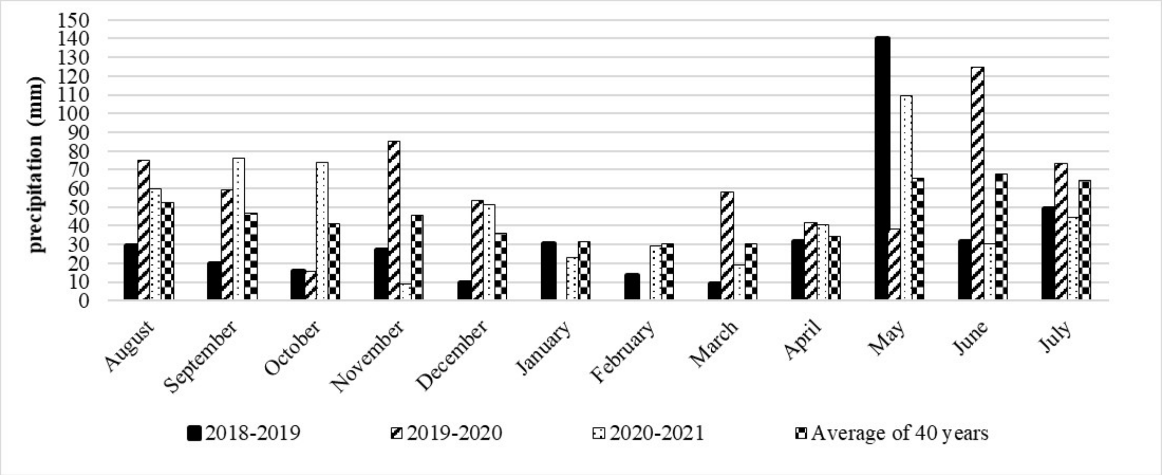

Figure 1: Monthly precipitation in 2018–2019, 2019–2020, 2020–2021 and 40 years of experimental area

ments 14., 15. contain a 3:1:1 ratio of N:P:K at different nutrients doses.

Sowing was carried out in mid-October each year at a seeding density of 4.5 million germs ha^{-1}. Sowing was carried out using a Wintersteiger type parcel seeding machine, which is suitable for sowing 8 rows simultaneously. The agrotechnical and chemical treatments of the plots in the experiment did not differ. Harvesting was performed with a Wintersteiger-type parcel harvester during the full maturation of the triticale. The monthly precipitation of the study years and the average of many years is shown in Figure

1.

The two-factor variance analysis of the annual yields (varieties and nutrient doses) and the three-factor variance analysis of the years effect were carried out using the SPSS 22 programme, the regression analysis was performed using the excel programme.

Results

Table 2 shows the precipitation discrepancies compared to 40 years average. Looking at the total vegetation period of the study years, the year 2018–2019 was drier and the year 2019–2020 more rainy than the average of many year.

In terms of precipitation supply in the autumn–winter period, the first two years were particularly lacking in precipitation, a trend that has increased in the last decade. In the spring of each study year, however, more rainfall fell than the long-term average. There was a severe lack of precipitation in 2018 and 2019 at the time of germination and one month before. There were signs of drought in the pre-harvest period: June 2019 and June 2021.

The data of the variance analysis of yield per year are shown in Table 3. In 2018–2019, the variety (A) and nutrient (B) were significant at 0.1%, while the interaction of the two factors (A×B) was not significant for yield per hectare. In the years 2019–2020 and 2020–2021, nutrient supply had a significant impact on the yield at a level of 0.1%, while the interaction between the variety and the variety × nutrient supply was not significant.

Table 4 shows the yield of three triticale varieties in 2018–2019. In terms of average nutrient treatments for varieties Hungaro and GK Maros achieved significantly higher yields than MV Talentum.

Analyzing the effect of nutrient supply on the average of varieties, it can be stated that the lowest yield was formed in unfertilized control treatment (1.40t ha^{-1}). The yield of unilateral N treatments was not statistically different from the yield of unfertilized control, however, the yield of PK treatments without N was significantly higher than that of unfertilized and unilateral N treatments. As a result of NPK treatments, the yield of triticale quadrupled compared to control, and the dose increase of complex NPK treatments increased the yield more and more. The highest yield was measured in the highest dose 2:1:1 N:P:K (180kg ha^{-1} N, 90kg ha^{-1} P, 90kg ha^{-1} K) (5.66t ha^{-1}), but from this the 90, 90, 90kg ha^{-1} NPK, 120, 60, 60kg ha^{-1} NPK, 180, 60, 60kg ha^{-1} NPK complex treatments did not differ significantly.

In 2019–2020, there was no significant difference in the yield of varieties (Table 5). The lowest yield was still measured on unfertilized parcels (1.89t ha^{-1}) and the largest yields were registered on the highest dose of 3:1:1 ratio of N:P:K treatment plots (5.96t ha^{-1}). This is little more than a triple increase in yield in a relatively rainy growing year.

In 2020–2021, there was no significant difference in the yield of varieties (Table 6). On average of varieties, the 30–30kg ha^{-1} PK treatment had the lowest yield of triticale (1.84t ha^{-1}). The yields of PK and N treatments were not statistically different from the yield of unfertilized treatment. In contrast, complex NPK treatments resulted in significantly higher yields compared to incomplete (unfertilized, N and PK) treatments. The yield decreased with increasing the dose of one-sided N treatments. In contrast, the dose increase of 1:1:1, 2:1:1 and 3:1:1 N:P:K treatments caused an increase in the yield of triticale. In our 3rd study year with average precipitation supply, the yield of triticale on the parcels 180kg ha^{-1} N, 60kg ha^{-1} P, 60kg ha^{-1} K (5.67t ha^{-1}) increased tripled compared to control.

Regarding the yield of study years in the average of varieties and nutrient treatments (Figure 2), it can be stated that the high-

Table 2: Precipitation discrepancies compared to many years average (mm, %)

Year	Total vegetation period (October–June)		Autumn–winter period (October–February)		Spring period (March–June)		Sowing period (September–October)		Month prior to harvest (June)	
	mm	%	mm	%	mm	%	mm	%	mm	%
2018–2019	–72.24	81.09	–87.44	52.54	15.21	107.69	–52.50	40.54	–35.79	47.05
2019–2020	34.76	109.10	–29.94	83.75	64.71	132.73	–13.70	84.49	56.91	184.20
2020–2021	3.46	100.91	1.66	100.9	1.81	100.91	61.80	169.99	–37.29	44.83

Table 3: Analysis of variance for annual yields (MS)

	df	2018–2019	2019–2020	2020–2021
Repeat	3			
Total treatment	180			
Variety (A)	2	5.66***	1.0ns	0.151ns
Nutrient (B)	14	32.014***	21.935***	26.673***
Intercept: (A×B)	26	0.24ns	0.289ns	0.231ns
Error	129	0.258	0.709	0.366

*The mean difference is significant at the $P = 5\%$ level.
**The mean difference is significant at the $P = 1\%$ level.
***The mean difference is significant at the $P = 0.1\%$ level.
ns: The mean difference is non- significant.

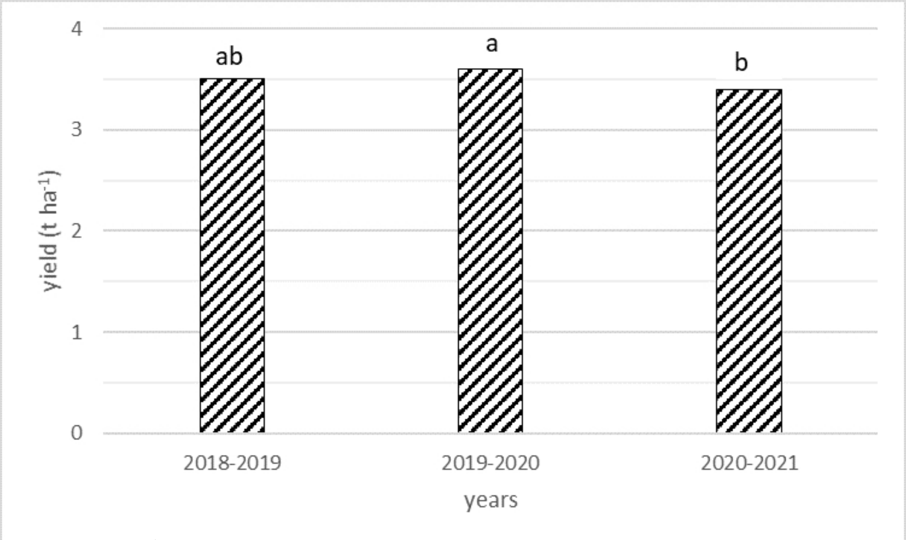

Figure 2: Yield (t ha^{-1}) of triticale in the studied years, on the average of nutrient treatments and varieties

est yield was registered in 2019–2020, from which significantly less yield was produced in 2020–2021. The yield in 2018–2019 was not statistically different from the yield of the

Table 4: Yield (t ha^{-1}) of three triticale varieties in 2018–2019

Fertilizer	Hungaro	MV Talentum	GK Maros	Average
$N_0P_0K_0$	1.40	1.37	1.44	1.40^{a}
$N_0P_{30}K_{30}$	2.66	2.29	2.65	2.53^{b}
$N_0P_{60}K_{60}$	2.96	2.55	3.17	2.89^{b}
$N_0P_{90}K_{90}$	2.80	2.39	2.97	2.72^{b}
$N_{30}P_0K_0$	1.58	1.45	1.70	1.58^{a}
$N_{60}P_0K_0$	1.47	1.33	1.64	1.48^{a}
$N_{90}P_0K_0$	1.36	1.28	1.65	1.43^{a}
$N_{30}P_{30}K_{30}$	4.04	3.44	4.06	3.85^{c}
$N_{60}P_{60}K_{60}$	4.98	3.90	4.90	4.59^{d}
$N_{90}P_{90}K_{90}$	6.05	4.83	5.54	5.48^{e}
$N_{60}P_{30}K_{30}$	4.01	3.79	4.02	3.94^{c}
$N_{120}P_{60}K_{60}$	5.62	4.97	6.33	5.64^{e}
$N_{180}P_{90}K_{90}$	6.23	5.13	5.62	5.66^{e}
$N_{90}P_{30}K_{30}$	4.01	3.64	4.28	3.98^{c}
$N_{180}P_{60}K_{60}$	5.64	5.03	5.90	5.52^{e}
Average	3.65^{A}	3.16^{B}	3.72^{A}	

Table 5: Yield (t ha^{-1}) of three triticale varieties in 2019–2020

Fertilizer	Hungaro	MV Talentum	GK Maros	Average
$N_0P_0K_0$	1.77	1.81	2.10	1.89^{a}
$N_0P_{30}K_{30}$	1.90	2.20	2.23	2.11^{ab}
$N_0P_{60}K_{60}$	2.33	2.82	3.44	2.86^{c}
$N_0P_{90}K_{90}$	2.08	2.31	3.24	2.54^{ac}
$N_{30}P_0K_0$	2.60	2.69	2.81	2.70^{bc}
$N_{60}P_0K_0$	2.44	2.28	2.62	2.45^{ac}
$N_{90}P_0K_0$	2.38	2.46	2.57	2.47^{ac}
$N_{30}P_{30}K_{30}$	3.09	2.69	3.37	3.05^{cd}
$N_{60}P_{60}K_{60}$	4.11	4.53	4.35	4.33^{e}
$N_{90}P_{90}K_{90}$	5.13	5.07	4.85	5.02^{f}
$N_{60}P_{30}K_{30}$	3.81	3.64	3.52	3.66^{d}
$N_{120}P_{60}K_{60}$	5.04	5.15	4.98	5.06^{fg}
$N_{180}P_{90}K_{90}$	5.39	5.83	5.92	5.71^{gh}
$N_{90}P_{30}K_{30}$	4.43	4.26	3.95	4.21^{ed}
$N_{180}P_{60}K_{60}$	5.62	6.24	6.02	5.96^{h}
Average	3.47^{A}	3.60^{A}	3.73^{A}	

next two years.

In Table 7, we can study the results of the regression analysis (r^2 values) of precipitation and the yield of triticale at different de-

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Table 6: Yield (t ha^{-1}) of three triticale varieties in 2020–2021

Fertilizer	Hungaro	MV Talentum	GK Maros	Average
$N_0P_0K_0$	1.85	1.98	1.83	1.89^{ab}
$N_0P_{30}K_{30}$	1.87	1.78	1.87	1.84^{ab}
$N_0P_{60}K_{60}$	1.95	1.83	2.08	1.95^{ab}
$N_0P_{90}K_{90}$	1.75	1.59	1.86	1.74^{a}
$N_{30}P_0K_0$	2.13	2.57	2.19	2.30^{b}
$N_{60}P_0K_0$	1.94	2.62	2.16	2.24^{ab}
$N_{90}P_0K_0$	1.81	2.17	2.05	2.01^{ab}
$N_{30}P_{30}K_{30}$	3.24	3.28	3.59	3.37^{c}
$N_{60}P_{60}K_{60}$	3.90	3.55	4.25	3.90^{d}
$N_{90}P_{90}K_{90}$	4.33	4.19	4.12	4.21^{def}
$N_{60}P_{30}K_{30}$	4.61	4.39	4.37	4.46^{ef}
$N_{120}P_{60}K_{60}$	5.73	5.11	5.31	5.38^{g}
$N_{180}P_{90}K_{90}$	5.64	5.2	5.50	5.59^{g}
$N_{90}P_{30}K_{30}$	4.37	4.48	4.58	4.48^{f}
$N_{180}P_{60}K_{60}$	5.06	6.09	5.86	5.67^{g}
Average	3.34^{A}	3.42^{A}	3.44^{A}	

velopmental periods depending on fertilizer treatments. Based on the average of fertilizer treatments, it can be stated that the amount of precipitation in the spring period, that is, during the period of intensive growth of plant, basically determines the amount of yield. If the herd is in drought during this period, it will not be able to compensate for it later. The amount of precipitation in the month before the harvest, the ripening period (June), also strongly influences the yield of triticale. The effect of the ripening period on yields can be observed mainly in drought years. Extreme high temperature and drought in the early stages of crop development can lead to forced ripening, incomplete grain filling and to the formation of poor quality shrivelled grains of low 1000 kernel weight. The data of Table 7 show that the Autumn–Winter period and the sowing period are even less determinant in terms of triticale yield. The lack of precipitation during these periods can be compensated some extent by the autumn cereals with a large supply of precipitation later on. It can be stated that the amount of precipitation in each period (critical periods), the distribution of precipitation is much more important for the yield of triticale than the amount of precipitation for the entire growing season. It can be seen from the data in the Table 7 that the result of the correlation between precipitation and yield (r^2 values) is significantly determined by the fertilizer treatments, ie the negative effects of precipitation can be offset by the appropriate nutrient supply.

Discussion

In addition to the soil conditions, the climate fundamentally determines the ecological potential of the given production area, such as the range of plants that can be grown there and the efficiency of cultivation. The impact of climate change are increasingly being felt in crop production: the frequency of drought and excessively rainy periods is increasing, adverse weather effects often occur during the critical development stages of

Table 7: Correlation between the amount of precipitation in certain periods and the yield of triticale (r^2 value) in different fertilization treatments (2018–2021)

Fertilizer treatments	Total vegetation period (October–June)	Autumn–winter period (October–February)	Spring period (March–June)	Sowing period (September–October)	Month prior to harvest (June)
$N_0P_0K_0$	0.1618	0.1058	0.8701	0.2478	0.5669
$N_0P_{30}K_{30}$	0.1973	0.0962	0.8983	0.1121	0.6082
$N_0P_{60}K_{60}$	0.1683	0.1131	0.7235	0.2369	0.6063
$N_0P_{90}K_{90}$	0.1555	0.0807	0.7523	0.1298	0.6709
$N_{30}P_0K_0$	0.2947	0.2968	0.7664	0.2319	0.5854
$N_{60}P_0K_0$	0.2931	0.2512	0.7157	0.3748	0.5295
$N_{90}P_0K_0$	0.2721	0.2910	0.6717	0.3571	0.6768
$N_{30}P_{30}K_{30}$	0.3848	0.1467	0.6160	0.3906	0.6347
$N_{60}P_{60}K_{60}$	0.3432	0.1290	0.9132	0.4213	0.6974
$N_{90}P_{90}K_{90}$	0.3210	0.1241	0.8994	0.4287	0.6993
$N_{60}P_{30}K_{30}$	0.4136	0.2544	0.7774	0.6923	0.7036
$N_{120}P_{60}K_{60}$	0.4145	0.3454	0.7186	0.6757	0.7901
$N_{180}P_{90}K_{90}$	0.4249	0.3190	0.8110	0.6512	0.7439
$N_{90}P_{30}K_{30}$	0.5423	0.3541	0.9615	0.6020	0.7770
$N_{180}P_{60}K_{60}$	0.5359	0.3366	0.9309	0.6249	0.7788
Average of fertilizer treatments	0.3892	0.1683	0.8587	0.4869	0.6541

our plants, which leads not only to crop decline, but also to uneconomical cultivation. Recently, mainly the autumn-winter precipitation is lower than usual (Márton, 2002b), which is confirmed by our research data. Farmers need to adapt to the changed conditions, so they need to grow crops and mitigate climate damage by using appropriate species or varieties and using agrotechnical factors. Farmers who can adapt to the changed conditions can not only reduce the damage, but also gain a significant competitive advantage over other farmers. Growing triticale is a very good choice for farmers in the face of climate change. It is produce well in dry climatic and poorer soil conditions, so it becomes more and more popular among farmers (Kruppa, 2004; Radics & Pusztai, 2011). At the same time, the variety selection may also be important, as Abdelaal et al. (2019) showed that different triticale varieties had different nutrient reactions. Although we used three different varieties of genetic origin in our experiment, we found that the effect of the variety was much less pronounced in crop yields than the effect of the nutrient or the precipitation supply of the years. That is, the applied agrotechnical element, the nutrients supply significantly determines the yield of triticale. This is in line with the findings of Gill and Omokanye (2016); Kádár et al. (1999); Kruppa (2004). In our study, the yield loss of crops of the unfertilized control and one-sided N-managed parcels was relatively large in the 2018–2019, the rain-deficient year, but the mitigation effect of the complex NPK treatments prevailed. The yield of triticale in the complex NPK-treated parcels compared to the control increased fourfold in the dry year, while increased only tripled in the average or rainy year. So, in the drier year, the relative effect of nutrients on yield was greater than in the rainy growing season.

However, based on our results, we can state that the precipitation volume of the whole vegetation period is less decisive for the yield of triticale than the precipitation of the individual periods (critical periods). That is, during the growing season, the distribution of precipitation plays a much greater role in the production of triticale than the amount of precipitation for the entire growing season.

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MAGYAR AGRÁR- ÉS ÉLETTUDOMÁNYI EGYETEM

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Comparative experiment of various irrigation technologies in maize (*Zea mays* L.)

Gábor BENCZE[1] – Ádám KOMLÓSI[1] – Zoltán FUTÓ[1]

1: Hungarian University of Agriculture and Life Sciences, Department of Irrigation and Melioration, Hungary, e-mail: bencze.gabor@uni-mate.hu

Abstract:Development of domestic maize cultivation largely depends on the applied agrotechnics. In keeping the increase in crop increases, the goal is to minimize crop fluctuations, and there is also an important role in the proper water supply. In our country, the yield of maize is a good water supply. The yield of maize can be significantly increased by improving the water supply of the plant. In many areas there are only very few water available for professional irrigation, so it is increasingly need to focus on modern, most water-saving irrigation technologies. In our experiment, we compare two irrigation techniques. The rain-like watering with console and the solenoid valve-controlled tape drip irrigation. Our examinations extend to mapping the properties of maize that can cause changes in the effect of irrigation and, of course, to develop crop quantities available by various irrigation technologies, since these results provide the proper income for the producer. The research was carried in Szarvas, at the school experimental field of the Hungarian University of Agriculture and Life Sciences, Department of Irrigation and Melioration, in 2020.

Keywords: maize, irrigation, yield, tape drip, leaf area

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Introduction

The effects of global climate change have also been felt in Hungary in recent years. The effects of the change are mostly shown by the decrease in precipitation during the growing seasons, the distribution of precipitation, the change in temperature and the appearance of extreme weather conditions. Hungary's climate is continental but sometimes ocean and Mediterranean effects also apply. Since 1931, the constructed drought index has been constantly investigated, so significant data is available. According to some studies, between 1951 and 1992 was 15 years of drought and 4 years seriously drought, while only 10 years of water supply was favorable. It seems good that our country had to face the difficulties caused by drought. But since the 1990s, the number of droughts is more and more. The area exposed to the most drought is Tiszántúl, Duna-Tisza and Mezőföld (Pálfai, 2004). The precipitates of falling in Hungary do not cover the water demand for crop production at 30-50 percent. The annual precipitation amount decreased by 50 to 90 millimeters over the past 50 years. Typically, a point in the vegetation period is missing this quantity. Our goal would be to store rainfall in the winter in the soil with high efficiency (Nyíri, 1997). According to Antal (2005), the maize sowing area of 140 million ha and the yield of approximately 4.3 t/ha. The largest grower of maize is the US, nearly 30 million ha at 9 t/ha over yields. In Europe, Italy produces 11 t/ha around 1.1 million hectares, while France reaches 10 t/ha yield over 1.7 to 1.8 million hectares. We are currently grown in the world at 190 million hectares. In Hun-

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gary, the sowing area can be around 1.2 million hectares and is 5.5–6 t/ha around the yield. The development of maize cultivation in Hungary is extremely dynamic in the 1980s, and since 1970, the use of chemicals, technical background and modern biological funds (hybrids) have been cultivated and the expertise has also increased, which, thanks to their maize production, belonged to the leading edge of the world. At this time, our genetic forward progress between 1960 and 1980 was 151.5 kg/ha, while in America at the same time only 124.0 kg/ha. Worldwide, we were third in a hectare yield behind the US and France. Our annual yield fluctuation was only 10–20%, and today it exceeds 40–50%. The crop of maize is influenced by a number of factors, such as insufficient water and nutrient supply. These factors affect the leaf area of maize where the process of photosynthesis takes place. All factors include increasing nutrient supply – which increases the photosynthically active leaf area of maize, it also increases the yield of maize (Futó, 2003).

In our country corn is the plant grown in the largest area. It costs 26–27% of all field, there were 1.2 million hectares in some years. Its main use is animal feeding, this number in Hungary is about 90% of the crop. However, with the increasing growth of the world's population, the use of the food industry will be increasingly promoted. The reasonable nutrient supply and irrigation are essential for corn. Optimal nitrogen (N) fertilization and irrigation are the main factors influencing plant growth, but excessive water and nitrogen application not only wastes water resources, but also seriously damages the ecological environment (Ahmad, Ahmad, Yang, et al., 2021; Ahmad, Ahmad, Kamran, et al., 2021; Ali et al., 2019; Meng et al., 2021; Xu et al., 2020). Development of domestic maize cultivation largely depends on the applied agrotechnics. In keeping the increase in crop increases, the goal is to minimize crop fluctuations, and there is also an important role in the proper water supply. Unfortunately, the results of the yield from the world's yield and yield growth are significantly behind. The yield of maize can be significantly increased by improving the water supply of the plant. In many areas there are only very few water available for professional irrigation, so it is increasingly need to focus on modern, most water-saving irrigation technologies. The maize water requirement is 450–550 mm, which can be said to be medium. Daily water consumption is 4.5–5.5 mm/ha. The static water requirement of maize is 67–79, which means the number of the soil's pore volume fills water and how many of the air. The transspiration coefficient of maize is 350 l/kg, which we know how much water is used to produce a unit of dry matter. The water consumption and water absorption of maize are characterized by several different factors. The corn can also add water from 150 to 200 cm depth. The drought arriving at the time of the coat of arms is 53%, while the drought in the absorption can reduce the crop by 30%. The maximum amount of yield available is not only affected by precipitation in the breeding time, but also the amount of precipitation stored in the autumn-winter period. Maize crops may not be prominent in the precipitation year, but in the following year when the temperature is favorable for it. Soils can store up to 500 mm water (up to 200 cm depth), half of which are positive water. At the beginning of development and during the period of wholesaling, the smallest of maize water consumption, while from the coat of arms is the largest (Futó & Sárvári, 2015; Menyhért, 1979). In our research, we compared two irrigation technologies. The rain-like irrigation with the winding wicker console and the solenoid valve-controlled tape drip irrigation. Our studies covered the mapping of the properties of maize that can show changes in the impact of irrigation and, of course, to develop crop quantities available by various irrigation technologies, since these results give the producer the right income. The research was carried in Szarvas, at the school experimental field of the Hungarian University of Agriculture and Life Sciences, Department of Irrigation and Melioration, in 2020.

Materials and Methods

Satisfaction of maize water demand was performed in the knowledge of the average temperature of the experimental area and the evapotranspiration of the stock, the area had a natural water capacity around 85–100%. Control parcels did not receive any irrigation, the natural precipitate determined the natural water capacity of the area. Since the precipitation of the year was favorably formed, the water capacity of the control parcels varied between 40 and 75%. During the research, the impact of irrigation significantly affects the water supply of the given vintage and the amount of fallen precipitation. It was very varied from this point of view in our regions. The weather data of the given year was summarized in Table 1 for the average temperature and precipitation.

From the data we can see that in the pre-sowing period and at the time of sowing, we struggled with relative water shortages compared to 30 years of data. This water scarcity persisted for summer months. In the most important period of maize, at the same time, at the same time, the same amount of natural precipitation fell. Compared to the 30-year average, 58.6 and 15.2 mm in July 15.2 mm were more. In August, in the month of the highest average temperature and in September, in the time of crop training, there was a shortage of rainfall. The effect of irrigation in these months was well demonstrable and necessary. In October, the precipitation arrived again, which greatly slowed down the prostration and made it difficult to harvest. According to previous soil tests, the experimental area is deeply carbonate chernozem soil. The main characteristics of the soil of the experiment can be summarized according to the soil tests carried out (Table 2) below. According to soil tests, soil's physical perception of loam, the cultivated layer of $CaCO_3$ does not contain, based on the humus content, the excessive amount of soil N-service is high, with the excessive, Zn well, while Cu and Mn are satisfactory. The water management of the soil is characterized by weak water conductivity and high water retention capability. The cultured level of the soil was closed, and the proportion of gravitational pores is smaller.

When preparing the soil protection plan, analyzing the water management parameters measured and calculated in the area, it was established that the natural (field) water capacity of the soils of the studied area is high, exceeding the value of 38 mm/10 cm. However, the dead water content is very high (22 mm/10 cm), reaching 65% of the water capacity. These properties of the soil in the area are explained by the fact that the combined ratio of the very small particle size sludge fraction (0.01–0.002 mm) and the clay fraction (< 0.002 mm) in the soil is high, exceeding 60% in the case of the typical profile.

It follows from the above that the useful water shows values of 15.29 mm/10 cm. In typical soil profiles, the K-factor indicates hydraulic conductivity weak. The test soil was compacted from the surface. The total porosity of the studied soils is 47% v/v. The gravitational pore space, which includes the macro- and megapores that determine the air supply of the soil, is relatively small, and the capillary pore space (micro- and mesopores) is relatively large. In summary, the soil of the experimental area can be classified into the water management category of soils with medium water absorption capacity.

Experimental parcels size 10 m × 5 m. The 5 m parcel width allows you to get 6 lines with a 76 cm row spacing in each one. The sowing

Table 1: Data of weather between jan. of 2020. and okt. of 2020. Source: Author's own editing

Months	jan.	febr.	march.	apr.	may.	jun.	jul.	aug.	sept.	oct.	sum/average
Temperature (°C)	-1	5.3	7.1	11.9	14.9	20.5	22	23.3	18.7	12.4	13.51
Rain (mm)	6.8	53.7	43	10.3	43.9	130	89.6	55.3	15.9	99.7	548.2
Mean of rainfall of 30 years (mm)	30.6	31.4	28.9	41.9	62.9	71.4	74.4	56.4	42.8	46.2	486.9
Difference (mm)	-23.8	22.3	14.1	-31.6	-19	58.6	15.2	-1.1	-26.9	53.5	61.3

Table 2: Characteristics of the soil in the experiment (Szarvas, 0-30 cm soil layer)

pH (KCl)	K_A	$CaCO_3$	Humus (%)	AL-P_2O_5 $mgkg^{-1}$	AL-K_2O $mgkg^{-1}$ $mgkg^{-1}$	Mg (KCl) $mgkg^{-1}$	EDTA Zn $mgkg^{-1}$	EDTA Cu $mgkg^{-1}$	EDTA Mn
4.95	44.6	0.0	2.89	216	260	687	3.26	7.35	428

Figure 1: Irrigation console during operation. Source: Author's own editing

is carried out with a field pneumatic sowing machine to the experimental area as a whole, from which the plannes are harvested after the plan, forming the parcels. The spacing was determined in 17.8 cm, which means approximately 75,000 germs/ha. From 6 rows we can view 2 border lines, avoiding any overlaps between parcels. The samples required for the tests that are "destroyed" from rows 2 and 5 while harvesting and other measurements are carried out in the two central rows. Harvesting is done with manual force.

Using irrigation consoles, it is possible to achieve specially fine, plant and soil-friendly irrigation and have less than 2–3.5 bar connection pressure for operation. The irrigation bandwidth can range from 30m to 90-100 meters. It can be noted here that the wider irrigation consolidations typically move on four wheels to preserve stability, while at-

Figure 2: Dripping tape irrigation in maize. Source: Metra

tributes with narrower irrigation band, the three-wheeled or two-wheeled plus slider solution is the most typical. The height of the consoles is generally infinitely, hydraulically or mechanically adjustable.

In the experimental area, a 30 m width irrigation console was used, which was moved with a rewinding device. The water conservation was carried out from a controllable hydrant with solenoid valve (Figure 1).

One of the big groups of micro-casting is drip irrigation. Its advantage is that using the root zone constantly wet and well-wet and well-aired and are available for less weed pressure, because of the humidified soil surface. The system allows water to be administered with a small loss, so up to 95% utilization is also available. Water does not pass through the air, which may also be a significant amount of evaporation of up to 30%. A non-limiting factor in wind speed and sloping areas can also be provided with a smooth application. Another advantage is that this irrigation mode can be fully automated. By means of a nutrient, nutrients can be supplied according to the process of development of the plant in a suitable amount and concentration.

In the study we used the Aquatraxx tape drip system sold by Metra Kft. Which in the manufacturer's description tab:

- is made with one-time extrusion. No seam of sharp edges or welding,
- Extremely resistant to clogging, a number of built-in filter carcases perceive continuous and uniform water emissions,
- The drip body boasts unique features due to precise design and manufacturing, turbulent section of the risk of clogging,
- Various water-emitting variants are marked with color codes, so red is high water-emitting (1.14L/h), yellow color indicates medium water-emitting tape (0.86L/h) (www.metra.hu, Figure 2).

During the research, the following tests were performed:

- Measuring plant height: At the same sampling time of the corn breeding season, the development phases of plants (BBCH) are included. From the developmental differences in the development of different treatments, we can conclude the physiological characteristics of the plant. The definitive size of plant biomass is a good direction of measuring the plant height. This was completely in the various phenological phases of the plants until the harvest

- Measurement of leaf area: maize's leaf a significant proportion of plant biomass and the light energy required for photosynthesis is the primary influence of the size of the produced biomass and crop. The gross and photosynthically active size of the leaf area has a decisive effect on the size of the emerging crop, so during my studies, leaf samples collected from the arable experiment during sampling were measured in the lab with our eijkelkamp leaf area measuring device and then analyzed quantified data in several ways. Sampling was carried out up to 50% of the drying of leaves,
- Crop average measurement: I harvested the full range of experimental net parcels and then crumbling. After measuring the yield, correction of 15% moisture is obtained by weights per parcella and the hectare result per hectare.

From the point of view of seed, one of the leading breeding housing has been our choice for several years in public yielding hybrids. The P9903 is a FAO300 end hybrid with Optimum®Aquamax®certification. It has been specifically intended for domestic cultivation conditions, so it feels good in the continental climate in Hungary. It is well tolerated by the high temperatures occurring during flowering and blooming. Stress tolerance is outstanding. This is also proven by the fact that in the dummy attempts most of the time gave the highest yield on higher counts. Pipe health is very good.

Different water supply treatments have caused significant differences in yields. Statistical processing of data obtained was performed using variance analysis and using SPSS 9.0 statistical programs. I used Microsoft Office program to make the figures and text evaluation of the results. The change and tightness of the correlation between irrigation and crops was determined by variance analysis, Pearson's correlation analysis and regression analysis. SZD values refer to $p = 5\%$ significance level.

Results

Of the experimental results, the first measurements were related to the development of plant heights in each treatment. During my studies, I measured the height of plants within the parcels several times. The examined maize plants were marked with the formation of the first measurement, ensuring that in the next phenological phase I also examine the same plants, thus making it comparable and quantifiable to compare the pace and extent of development. Figure 3 presents the last measurement results before harvest.

It can be seen from the resulting results that there is a large difference in irrigated files compared to the control conditions, this difference reaches the significant difference, so it can be statistically justified. Not irrigated conditions, the plant heights formed between 230 and 236 cm, while in the case of irrigated parcels, this number can be between 248 and 249 cm. It can be seen, so that between the smallest and the highest value is 19 cm in the experiment. It also shows that there is no statistically justifiable difference between irrigation technologies, thereby declaring that irrigation technologies are non-influencing factors in the field of plant height in the given vintage and the given hybrid. The correlation between irrigation treatments and plant

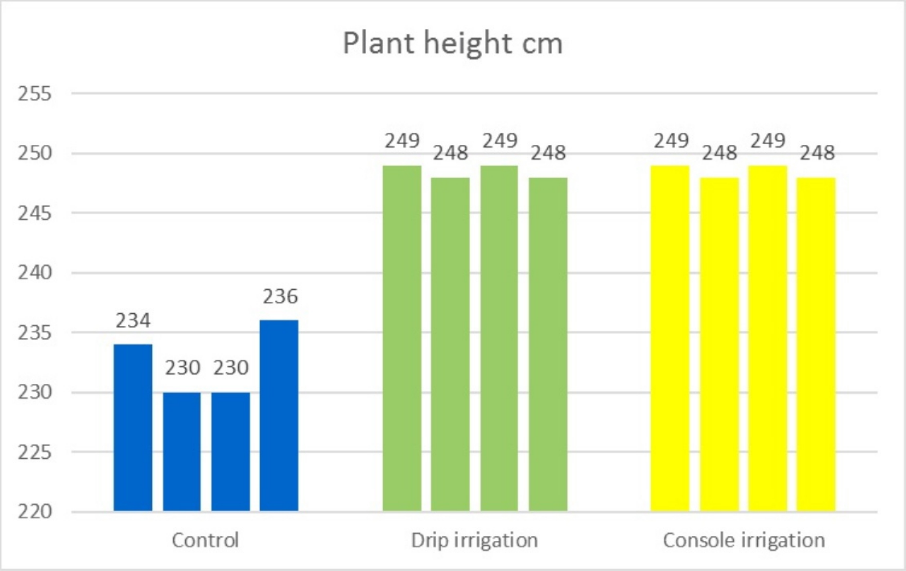

Figure 3: Plant heights. Source: Author's own editing

Table 3: Table of variance analysis of plant height. Source: Author 's own editing

Tests of Between-Subjects Effects
Dependent Variable: Plant height

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	1008.062^a	1	1008.063	181.225	.000
Intercept	925925.063	1	925925.063	166458.438	.000
irrigation	1008.063	1	1008.063	181.225	.000
Error	77.875	14	5.563		
Total	927011.000	16			
Corrected Total	1085.938	15			

a. R Squared = .928 (Adjusted R Squared = .923)

height was substanted by variance analysis, the results of which are shown in Table 3.

Next, the significant difference causing irrigation and height enhancing effects by Pearson's correlation test. As a result of the correlation study, a correlation coefficient of 0.963 shows a positive correlation between irrigation and height resources. The data obtained from the analysis is illustrated by Table 4.

The yield of maize also depends heavily on the size of the photosynthetically active leaf area. In my experiment, I followed the magnitude of leaf areas measured in various irrigation modes and expressed it in the area of leaf area index (LAI m^2/m^2, Table 5), and I also performed the data regression analysis.

It is apparent from the data that there is no statistically justifiable difference between different technologies. However, it can be identified that irrigation and technology had a positive effect on the size of the maize leaf area. I proved the correlation with correlation analysis. According to the result of the analysis, the correlation coefficient is 0.975, which requires a very close correlation (Table 6).

During harvesting with manual power, I took samples to determine harvesting moisture. The maize tubes were dropped by a crum-

Table 4: Correlation between plant height and irrigation in 2020. Source: Author's own editing

Correlations			
		Height	Irrigation
Height	Pearson Correlation	1	.963**
	Sig. (2-tailed)		.000
	N	16	16
Irrigation	Pearson Correlation	.963**	1
	Sig. (2-tailed)	.000	
	N	16	16

** Correlation is significant at the 0.01 level (2-tailed).

Table 5: LAI value in different irrigation technologies. Source: Author's own editing

	LAI m^2/m^2	Average
Control	2.66	2.805
	2.78	
	2.88	
	2.9	
Drip tape irrigation	3.34	3.48
	3.52	
	3.5	
	3.56	
Console irrigation	3.61	3.53
	3.52	
	3.49	
	3.5	

Table 6: Correlation between LAI and irrigation in 2020. Source: Author's own editing

Correlations			
		Height	Irrigation
LAI	Pearson Correlation	1	.975**
	Sig. (2-tailed)		.000
	N	16	16
Irrigation	Pearson Correlation	.975**	1
	Sig. (2-tailed)	.000	
	N	16	16

** Correlation is significant at the 0.01 level (2-tailed).

pling machine, and I measured the parcel's crop. When processing the results, parcel weights were corrected for 15% moisture (Table 7). The average of yield results mea-

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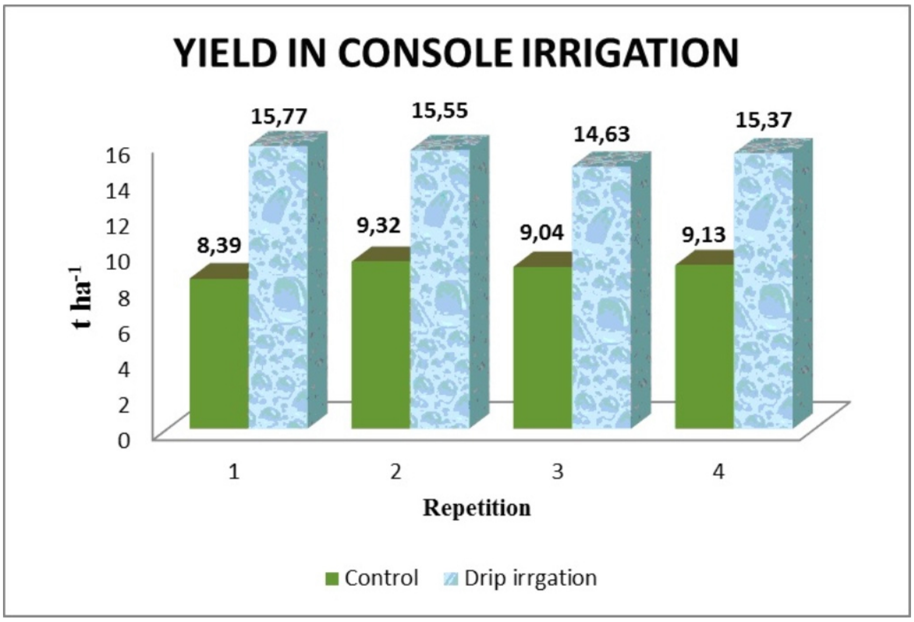

Figure 4: Yield in Console irrigation. Source: Author's own editing

Table 7: Correlation between yield and console irrigation in 2020. Source: Author's own editing

Correlations			
		Height	Irrigation
Console irrigation	Pearson Correlation	1	.974**
	Sig. (2-tailed)		.000
	N	8	8
Yield	Pearson Correlation	.974**	1
	Sig. (2-tailed)	.000	
	N	8	8

** Correlation is significant at the 0.01 level (2-tailed).

sured in the examined treatments is illustrated in Figure 4.

The same analyses were also performed for drip irrigation. The resulting crop data is illustrated in Figure 5.

It is also clearly identified in this irrigation technique for crop enhancing effects. At some repetitions of drip irrigation, the funeral increase has reached 7 tonnes for hectares. This increase was a 80% increase compared to irrigated control parcels for that vintage and hybrid. Of course, the difference can be statistically justified and correlation analysis also has a close correlation (Table 8).

The next step in our studies was comparison of two irrigation technology. As a precise representation of the data, in Figure 6. I compared the yield results obtained based on the two technologies.

It can be seen that by the action of drip irrigation greater yield results have been made. In some repetitions, 3.5 tons exceeded per hectare, but at average repetitions reached 3.1 tons of crop growth per hectare. This increase represents 26%. In order to statisti-

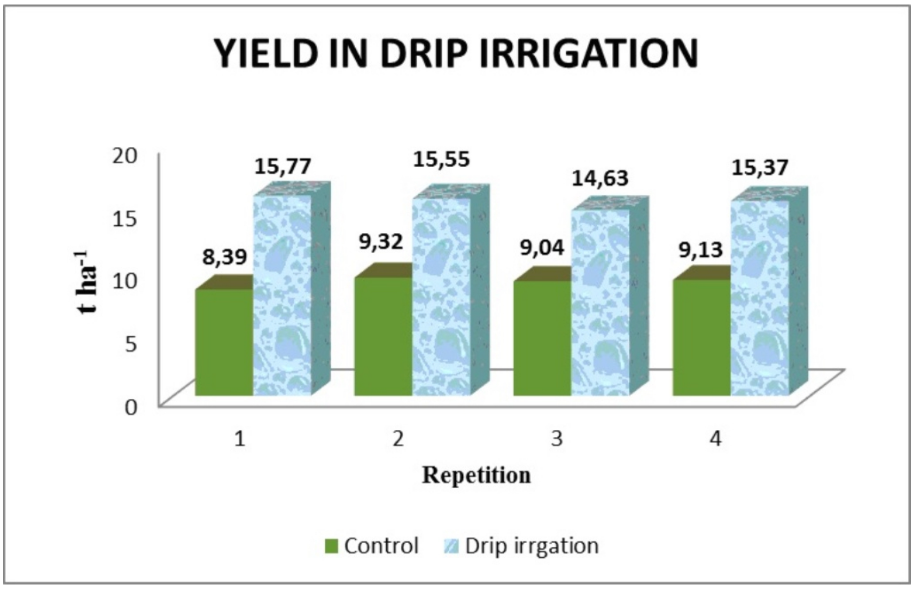

Figure 5: Yield in Drip irrigation. Source: Author's own editing

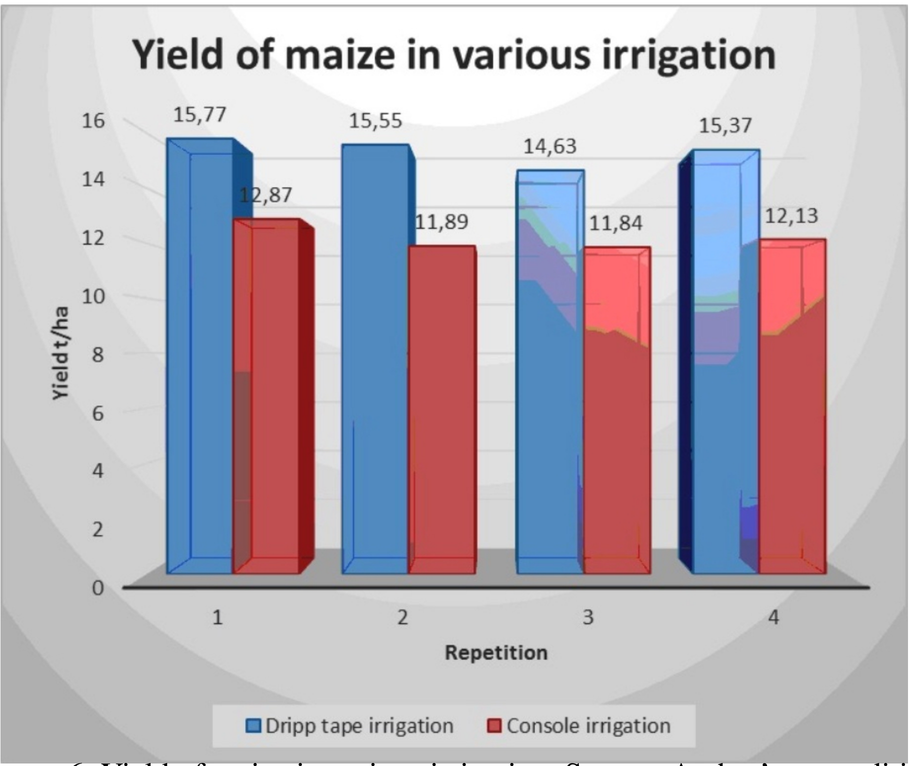

Figure 6: Yield of maize in various irrigation. Source: Author's own editing

cally verify the boundary of the significance of variance analysis, correlation analysis and regression analysis (Table 9).

I followed the variance analysis of the resulting analysis that the change in change reaches the level of significant difference. Based on the variance analysis, it can be stated that drip irrigation has resulted in significantly higher yields. So it's statistically verifiable. The correlation was studied by

Table 8: Correlation between yield and tape drip irrigation in 2020. Source: Author's own editing

Correlations

		Height	Irrigation
Tape drip irrigation	Pearson Correlation	1	.993**
	Sig. (2-tailed)		.000
	N	8	8
Yield	Pearson Correlation	.993**	1
	Sig. (2-tailed)	.000	
	N	8	8

** Correlation is significant at the 0.01 level (2-tailed).

Table 9: Table of variance analysis of Yield. Source: Author's own editing

Tests of Between-Subjects Effects

Dependent Variable: Yield

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	19.814^a	1	19.814	84.201	.000
Intercept	1513.875	1	1513.875	6433.467	.000
Irrigation tech.	19.814	1	19.814	84.201	.000
Error	1.412	6	.235		
Total	1535.101	8			
Corrected Total	21.225	7			

a. R Squared = .933 (Adjusted R Squared = .922)

Table 10: Correlation between yield and irrigation technologies. Source: Author's own editing

Correlations

		Irrigation technologies	Yield
Irrigation technologies	Pearson Correlation	1	.966**
	Sig. (2-tailed)		.000
	N	8	8
Yield	Pearson Correlation	.966**	1
	Sig. (2-tailed)	.000	
	N	8	8

** Correlation is significant at the 0.01 level (2-tailed).

Pearson's correlation analysis between technology and thermal data. According to its result, there is a very close correlation with regard to the examined elements. The correlation analysis is shown in Table 10.

During the regression analysis of yields, I found that the values change most in a linear way. Drip irrigation technology caused a clear growth increase, proving that the correlation between irrigation technology and

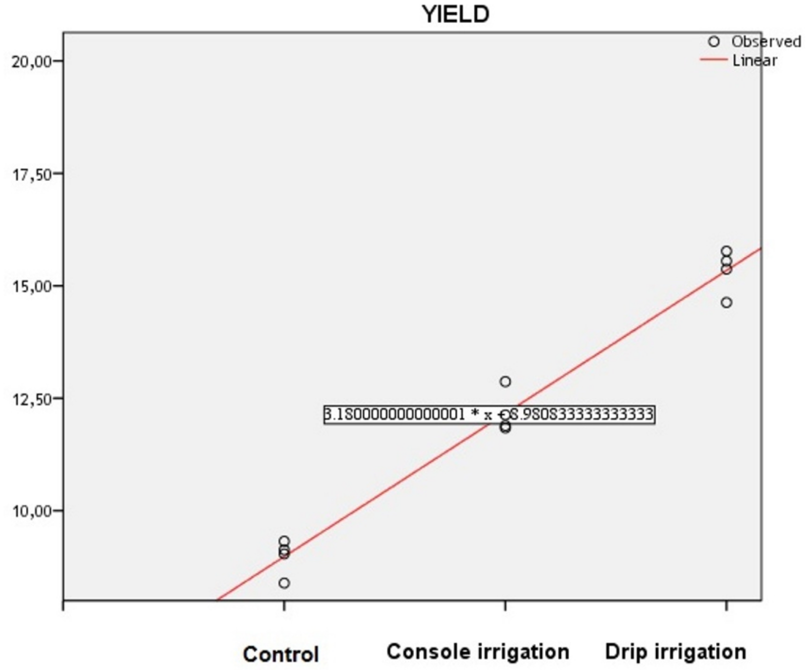

Figure 7: Linear regression of maize's yield and irrigation technologies. Source: Author's own editing

maize production data is very close, the R Squared is 0.977 (Figure 7).

Discussion

In my research, I compared two different irrigation technologies on a maize test plant. The results show that under changing, often extreme climatic conditions, irrigation is almost unavoidable and plays a key role in the economical cultivation of corn. All this is supported by the results of my research. However, it should be noted that, taking into account both water and energy saving aspects, micro-irrigation methods should be given more space in the future. It could be seen from the results that even with the traditional rainwater irrigation method, a better yield was obtained by more than 25% in a vintage when adequate natural rainfall was available at an important time for maize, ie during flowering. Due to this, the control plots also had an average yield of almost 9 t/ha. According to the literature, the experiment also showed that adequate water supply is essential for corn. At the same time, the appropriate hybrid selection also appears as an influencing factor, since in the case of the investigated hybrid, the response to irrigation was clearly realized in the yield results.

At almost all levels of the studies, drip irrigation yielded better results and these differences were also statistically significant. Even so, the experimental area had completely the same nutrient replenishment. If we take into account that the use of drip irrigation also provides an opportunity to apply a continuous nutrient solution, during which we can provide a continuous and targeted supply of nutrients to the plants, it is probable that the growth will move in a positive direction. Nor can it be neglected that the amount of water used in the micro-irrigation technology was nearly 30–40% less than in the case of the traditional rain-like irrigation console. This fact, and the fact that significantly higher yields can be achieved even in a vintage that can be considered almost ideal for rainfall, draws attention to the economic viability of drip belt irrigation under conventional field conditions and among arable crops, and should be increasingly used in the future.

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Statistical analysis of excess water on drainage systems in the northern part of Serbia

Milica VRANEŠEVIĆ[1] – Atila BEZDAN[1] – Boško BLAGOJEVIĆ[1]

1: University of Novi Sad, Faculty of Agriculture, Department of Water Management, Trg Dositeja Obradovića 8, Novi Sad, Serbia, e-mail: milica.vranesevic@polj.edu.rs

Abstract: Drainage systems in Serbia are mainly designed to evacuate excess water generated in the winter-spring period, which occurs as a result of snow accumulation during the long and wet winter and its sudden melting with the parallel appearance of spring rains. Dimensioning of the drainage system is done in such a way as to satisfy the needs of draining the design excess water, which is usually calculated using the water balance. Applying statistical analysis based on distributions of probability, the results of the future occurrence of excess water can be predicted. The paper tests the distribution that best corresponds to the empirical distribution of excess water obtained by applying the water balance. The Kolmogorov-Smirnov, Anderson-Darling, and χ^2 tests were used to test a number of theoretical distributions, and basis on those tests Generalized Extreme Value (GEV) distribution was selected, which is often used in hydrological analyzes. The probabilities of excess water on drainage systems for the return period of 5, 10, 50, and 100 years were obtained. The results of the calculations can be used in the reconstruction of existing drainage systems, since most of them were designed more than 50 years ago, or in the planning and design of new drainage systems.

Keywords: Excess water, drainage systems, statistical analysis

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Introduction

Drainage systems in the northern part of Serbia, Vojvodina were in most cases designed or revitalized in the 70s and 80s of the XX century. Even though the systems were designed to evacuate excess water with an occurrence probability once every 5 to 20 years, it has often been the case lately that systems were unable to respond effectively to excess water that has been occurring. According to previous research by Belić and Savić (2005), on an area of 77% of drained areas, excess water, which is being evacuated by pumping stations into the recipient, comes from climatic factors. In Vojvodina, the systems are mainly designed to evacuate excess water generated during the winter-spring period, which occurs as a result of snow accumulation during the long, cold and wet winter, and its sudden melting, with the parallel appearance of spring rains. The dimensioning of the drainage system is performed in such a way that the need of draining the design excess water is satisfied. It should be emphasized that the average excess water that occurs in a certain area in the winter-spring period is not an appropriate value for dimensioning, but the systems are dimensioned based on the design excess water that occurs in that period and must be evacuated in optimal time frames to avoid the delay in agricultural production (Helmers et al., 2012). This design excess water is usually calculated using the water balance. In water balancing, i.e. when the excess water in an area is being estimated, the most commonly used form of the water balance equa-

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tion is the simplest one, in which the revenue component is precipitation and the expenditure evapotranspiration (Thornthwaite, 1948). As an indicator of soil moisture conditions, reserves in the soil depend on the water-physical properties of the soil and are determined for specific conditions, usually taking into account a layer 1 m deep; however, the maximum water reserves should be determined for a certain land, in order to obtain realistic values that we strive for when designing a drainage system. In order for statistical analyzes of the excess water occurrence on drainage systems to be relevant, it is necessary for the sequence to be at least 30 years long, after which a certain conclusion is reached (Gregorić, 2009). Probability distributions can also be the basis of statistical inference. The conditions in which excess water is formed are covered by the laws of theoretical distribution itself, which adapts to the nature and character of the observed phenomenon. When data representing the empirical distribution are available, it is not possible to assume with which theoretical probability distribution a random variable could correlate. The aim of this research is to be able to reliably predict the results of future events based on empirical probability distributions, which can be achieved by "distribution fitting," that is by finding a theoretical distribution function that corresponds to the sample data, then testing the selected theoretical distribution, on the basis of which the probabilities of events that are not otherwise represented in the sample can be determined (Adams et al., 1986). In this way, we can obtain the probabilities of the occurrence of the relevant excess water on the drainage systems for different return periods.

Materials and Methods

In order for drainage systems to be reliable (well designed) and for exploitation to be efficient, it is necessary to precisely define the relevant amount of water that is evacuated from the drainage system. Excess water is calculated using water balance factors (precipitation, evapotranspiration, and soil water reserves) of a certain occurrence's frequency. The proposed methodology for determining the relevant excess water is shown in Figure 1.

The precipitation used was taken from the meteorological yearbooks of the Hydrometeorological Institute of the Republic of Serbia for the period from 1971 to 2021 for eight climatological observation stations (Belgrade, Rimski Šančevi, Palić, Sombor, Sremska Mitrovica, Vršac and Zrenjanin). Evapotranspiration was calculated according to the Thornthwaite method. The fields of influence of climatological stations by area were determined via Thiessen polygons and it has been adopted that the data valid on them were calculated for the water balance of the soil for each polygon of the pedological map, based on data from the corresponding meteorological station, for the multiannual period from 1971 to 2021. The water reserve in the soil was calculated for each polygon of the digital pedological map, and it was obtained as a product of the depth of the solum and available water. Available water is the difference between the field water capacity and the wilting point. In the area of Vojvodina, the quantities of potential water reserves in the soil range from 10 mm to 150 mm, which is why the water balance is calculated with 10, 50, 100, and 150 mm as critical values.

Following the proposed methodology for determining the design excess water, the next step involves statistical analysis, i.e. calculating the empirical probabilities of the certain excess water occurrence in the non-vegetation period. The non-vegetation period was adopted as the period in which the winter-spring excess water should be evacuated in order for the optimal time frames required by agricultural production to be met.

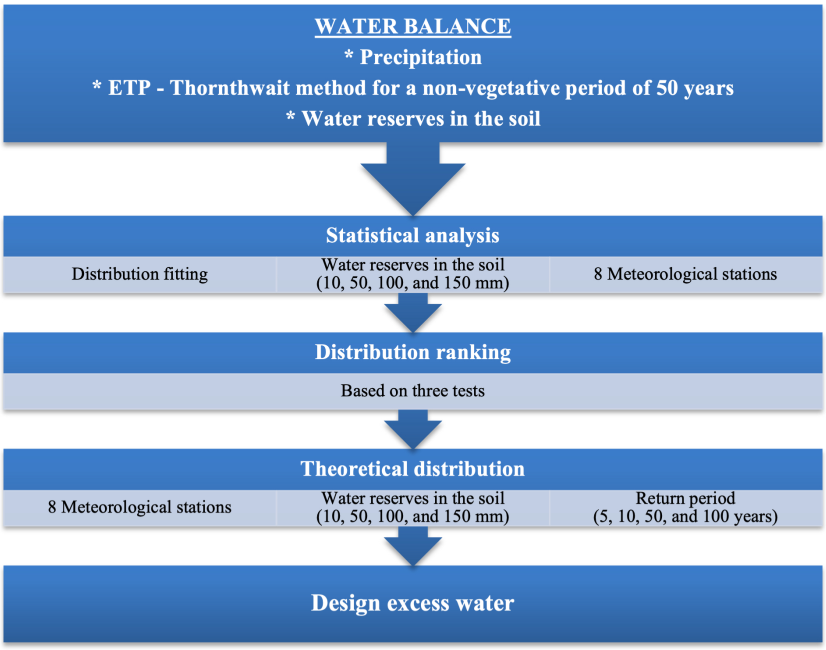

Figure 1: Methodology for determining the design excess water for certain return periods

Table 1: Testing theoretical distribution

Theoretical distributions		
Beta	Gumbel Max	Pareto 2
Burr	Gumbel Min	Pearson 5
Cauchy	Hypersecant	Pearson 6
Chi-Squared	Inv. Gaussian	Pert
Dagum	Johnson SB	Phased Bi-Exponential
Erlang	Johnson SU	Phased Bi-Weibull
Error	Kumaraswamy	Power Function
Error Function	Laplace	Rayleigh
Exponential	Levy	Reciprocal
Exponential (2P)	Log-Gamma	Rice
Fatigue Life	Logistic	Student's t
Frechet	Log-Logistic	Triangular/
Gamma	Lognormal	Uniform
Gen. Extreme Value	Log-Pearson 3	Wakeby
Gen. Gamma	Nakagami	Weibull
Gen. Logistic	Normal	
Gen. Pareto	Pareto	

In order to find the theoretical distribution that most closely matches the calculated values of excess water, the correlation of empirical distributions with the theoretical ones was tested. Table 1 show the 49 theoretical distributions used in this analysis for all values of soil water reserves (from 10 to 150 mm) and eight meteorological stations (Bel-

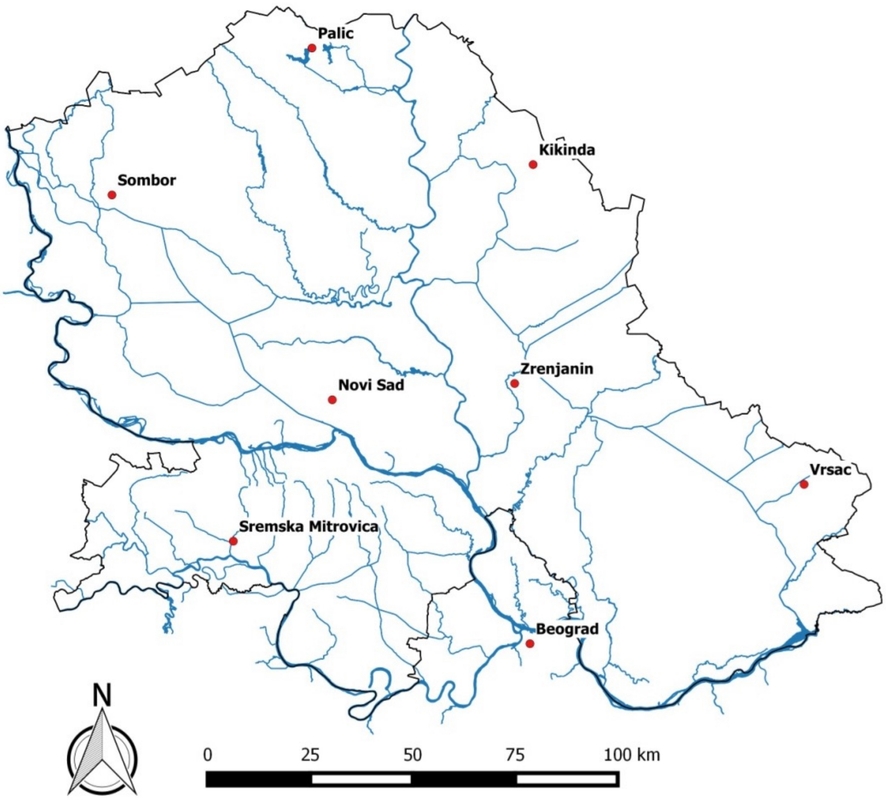

Figure 2: Meteorological stations in Vojvodina, Serbia

grade, Rimski Šančevi, Palić, Sombor, Sremska Mitrovica, Vršac, and Zrenjanin) which are presented in Figure 2.

Finding the theoretical distribution function, which corresponds to the data from the sample, was tested using Chi-square (χ^2) test, Kolmogorov-Smirnov test, and Anderson-Darling test. For the significance threshold $\alpha = 0.05$, there is correspondence for 25 theoretical distributions with empirical values. Other distributions did not show satisfactory correspondence. Based on the three tests, for each solum depth and for each meteorological station, the theoretical distributions were ranked according to the corresponding match with the empirical distribution. According to all three tests, the ranks were summarized and the theoretical distribution with the lowest sum of ranks should be selected because it represents the distribution that most closely matches the empirical distributions of excess water values.

After the selected theoretical distribution, for all values of water reserves in the soil and all eight meteorological stations, the relevant excess water is determined. This excess water is directly related to the dimensions of all facilities on the drainage system. The dimensioning of the system is then reduced to determining the relevant length of the return period. The length of the return period is expressed by the amount of water that needs to be removed from the system and is determined by the time in which the excess is removed from the system. When calculating any part of the system, "economic values" are taken into account, ie. a solution is sought that would minimize damage or optimize flooding time. The technical optimization implies the selection of the minimum capacity for evacuation of the design excess water, which is a prerequisite for minimizing investments, as well as maintenance and operation costs. In this research, the calculation

Table 2: Example of the performed water balance for the hydrological year 2009/2010 for meteorological station Rimski Šančevi

09/10	10	11	12	1	2	3	4	5	6	7	8	9
P	82	63	97	76	66	39	64	114	172	99	169	68
ETP	41	21	6	0	3	23	56	98	126	152	130	75
P-ETP	41	42	91	76	62	15	7	15	46	-53	38	-7
Reserve	41	82	100	100	100	100	100	100	100	47	85	78
ETR	41	21	6	0	3	23	56	98	126	152	130	75
Deficit	0	0	0	0	0	0	0	0	0	0	0	0
Excess water	0	0	74	76	62	15	7	15	46	0	0	0
	Non-vegetation period						Vegetation period					
Deficit sum	0						0					
Excess w. sum	227						69					

of the design excess water was conducted for a return period of 5, 10, 50, and 100 years.

Results

The calculated water balance for the period from 1971 to 2021 for eight observation climatological stations is divided in order to obtain winter-spring excess water for the non-vegetation period and the vegetation period. The example presented in Table 2 shows the procedure for obtaining excess water. The amounts of excess water in the non-vegetation period for the observed period represented the empirical distribution, which was then "fitted" with 49 theoretical distributions used in this analysis for all values of soil water reserves (from 10 to 150 mm) and eight meteorological stations.

In order to examine the extent to which the group of observed frequencies coincides with the theoretical distribution, matching tests are performed between the theoretical distribution in the general population and the empirical frequency distribution in the sample extracted from that general population. The tests most commonly used to test the good fit between the theoretical and empirical frequency distribution in a sample are the Chi-square (χ^2) test, the Kolmogorov-Smirnov test, and the Anderson-Darling test, which were used in this paper as well.

The three first-ranked distributions that best correspond to the empirical distributions of excess water values in Vojvodina are the four-parameter Johnson SB distribution, the three-parameter Generalized Extreme-Value distribution (GEV), and the two-parameter normal distribution (Normal). The Generalized Extreme-Value distribution, although ranked second, was selected as the theoretical distribution for calculating the probability of the occurrence of corresponding excess water in the non-vegetation period, due to its application in hydrology and simpler calculation compared to Johnson's SB distribution (has fewer parameters). GEV distribution has great application in hydrology, especially in the analysis of extreme hydrological phenomena such as floods, high water levels, annual flows, annual precipitation amounts, etc. (Martins & Stedinger, 2000; Li & Chen, 1990).

Bearing in mind that the return period is directly related to the economic power of land users, realized yields and revenues, defining it is a technical problem chosen based on the economic criteria. Therefore, using three-parameter GEV distribution, excess water

Table 3: Five-year excess water in the non-vegetation period

Meteorological Station	Water reserves in the soil (mm) 10	50	100	150
	Excess water (mm)			
Beograd	258	218	163	103
Kikinda	190	150	93	30
Palić	199	159	103	44
Rimski Šančevi	225	185	130	69
Sombor	215	175	121	60
Sremska Mitrovica	211	171	117	57
Vršac	227	186	130	67
Zrenjanin	204	163	105	42

Table 4: Ten-year excess water in the non-vegetation period

Meteorological Station	Water reserves in the soil (mm) 10	50	100	150
	Excess water (mm)			
Beograd	293	253	201	143
Kikinda	219	178	124	53
Palić	231	191	137	71
Rimski Šančevi	255	215	163	102
Sombor	243	203	152	90
Sremska Mitrovica	233	193	142	83
Vršac	265	224	170	105
Zrenjanin	241	200	144	71

Table 5: Fifty-year excess water in the non-vegetation period

Meteorological Station	Water reserves in the soil (mm) 10	50	100	150
	Excess water (mm)			
Beograd	349	309	272	244
Kikinda	268	228	195	146
Palić	289	249	213	167
Rimski Šančevi	303	263	227	196
Sombor	288	248	209	177
Sremska Mitrovica	267	227	185	154
Vršac	334	295	259	226
Zrenjanin	312	274	242	191

was calculated separately for five-year, ten-year, fifty-year, and hundred-year return periods, for all analyzed meteorological stations, and for all values of soil water reserves

Table 6: Hundred-year excess water in the non-vegetation period

Meteorological Station	Water reserves in the soil (mm) 10	50	100	150
	Excess water (mm)			
Beograd	366	326	297	293
Kikinda	284	245	227	215
Palić	310	270	246	230
Rimski Šančevi	318	278	250	247
Sombor	302	262	230	224
Sremska Mitrovica	276	236	200	190
Vršac	358	321	297	299
Zrenjanin	339	303	288	280

in the analyzed area ranging from 10 to 150 mm. The results are shown in Tables 3, 4, 5, and 6.

Existing drainage systems are mainly sized to meet the needs of draining the design excess water in the non-vegetation period, 10% frequency or a 10 years return period, and for this excess water the operation of the aggregates in pumping stations is 35–40 days or 840–960 hours (Belić & Stojšić, 1985). This data is of key importance in sizing new or reconstructing and adapting existing drainage systems, because it indicates a tendency of an increased frequency of years with extreme values of excess water in the non-vegetation period and in the vegetation period.

Discussion

After water balancing in the forty-year period, statistical data processing was performed to determine the theoretical distribution of the probability of occurrence. The testing of theoretical and empirical distributions of excess water based on soil water reserve (from 10 to 150 mm) and eight meteorological stations was performed. The adopted three-parameter Generalized Extreme-Value distribution (GEV) was used to obtain relevant excess water for the probability of occurrence of 20%, 10%, 2%, and 1%, i.e. for return periods of 5, 10, 50, and 100 years. The obtained excess water ranged from 30–258 mm for a return period of 5 years, 53–293 mm for a return period of 10 years, 146–349 mm for a return period of 50 years, and 190–366 mm for a return period of 100 years. These results indicate that the zone of aeration can receive wide ranges of excess water of different frequency occurrences depending on the type of soil and its water-air characteristics.

The global analysis that has been conducted can serve as a basis, not only for detailed analyzes of increasing the efficiency of individual drainage systems but also for solving many other problems that overlap with the problem of creating, draining, and evacuating excess water. All this points to the fact, that a seemingly complex methodology can be easily applied in engineering practice to drainage systems that require increased efficiency.

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HORVÁTH Ákos, editor-in-chief

DSc (agricultural sciences), Chair of the Department of Aquaculture at the Institute of Aquaculture and Environment Protection of the Hungarian University of Agriculture and Life Sciences, member of the Committee on Animal Sciences of the Hungarian Academy of Sciences. Professional fields: aquaculture, fish reproduction, biology of fish gametes, cryopreservation, transplantation, population genetics of fish as well as aquatic toxicology.

Lucius Junius Moderatus Columella

(AD 4 – 70) is the most important writer on agriculture of the Roman empire. His De Re Rustica in twelve volumes has been completely preserved and forms an important source on agriculture. This book was translated to many languages and used as a basic work in agricultural education until the end of the 19th Century.