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Evapotranspiration of a Hungarian rice variety, 'SZV Tünde' in large weighing lysimeter

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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

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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)

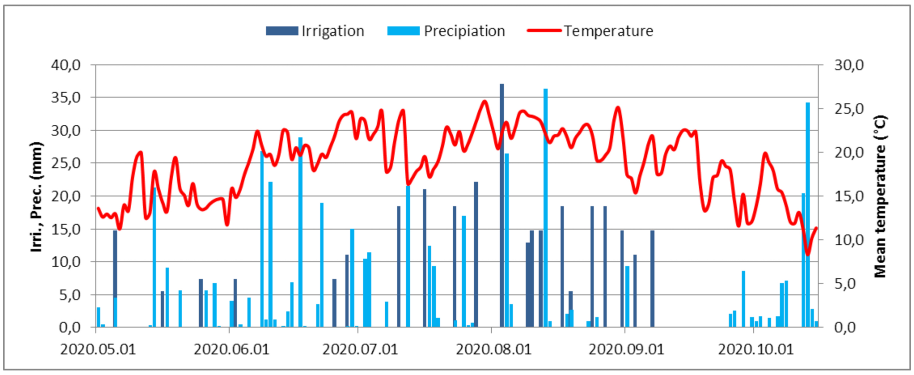

Figure 1: Data of daily mean temperature, precipitation and irrigation during the growing season of aerobic rice in 2020 (Szarvas, Hungary)

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-

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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	Duration*	Plant height	TKW**	L/W ratio ***	Blast resistance	Amylose
	year	days	cm	g			
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,

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315.6 mm of irrigation water was applied in 21 times from the sowing to 7^{th} of September. Harvest was done after fully ripening on the 9^{th} 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 5^{th} 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.

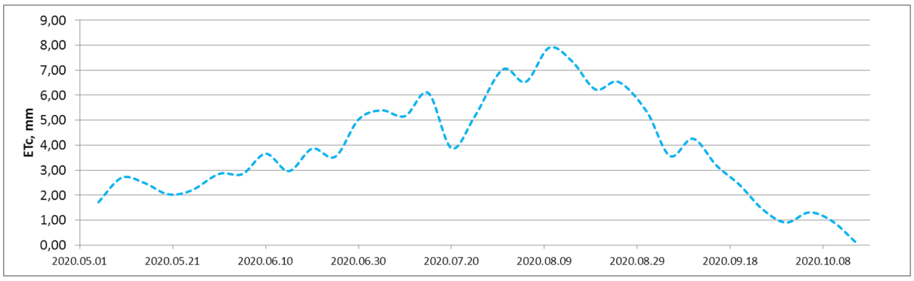

Figure 2: Five-day average crop evapotranspiration (ETc) of aerobic rice measured in large weighing lysimeter in 2020 (Szarvas, Hungary)

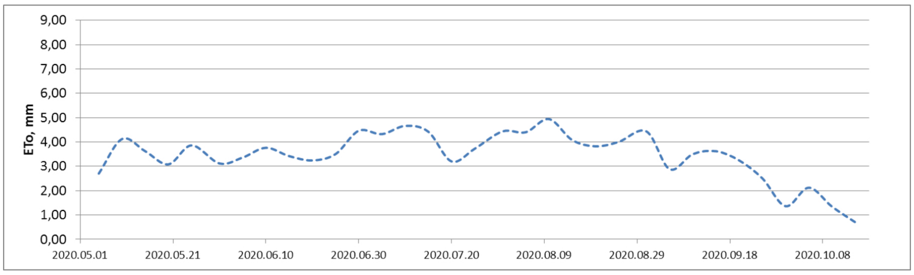

Figure 3: Five-day average site specific reference evapotranspiration (ETo) based on the meteorological data of the MATE ÖVKI Lysimeter Station (Szarvas, Hungary)

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