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Water use efficiency of *Miscanthus giganteus* under different irrigation doses

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Summary

The main goal of the research was to determine the water balance and its elements for *Miscanthus giganteus* in the case of different irrigation doses in an experiment set in three weighing lysimeters in the lysimeter station of Karcag Research Institute, Hungary. The lysimeters were irrigated with different doses of water: 10, 15, 20 l/week (5.88, 8.82, 11.76 mm), respectively from May to August in 2018. Beyond the height of the plant and the water balance and its components, water use efficiency index was calculated from the rate of total water input and evapotranspiration in order to characterize the differences among the irrigation treatments. We established that in each month of the investigated period the larger was the water input the highest was the evapotranspiration. The same correlation was characteristic to the height of the plants. The water use efficiency index was more favourable (lower) in the case of the higher irrigation doses.

Keywords: weighing lysimeters, water balance, evapotranspiration

Introduction

Water is essential for crop production as nutrients can be taken up by plants in water soluble forms and it is a basic material of photosynthesis too (Láng 2007). Plants need water during the whole vegetation period. The main source of water is the natural precipitation stored in the upper layers of the soil and gets available by plants. Nevertheless the spatial and temporal distribution and the amount of natural precipitation can be hectic (increasing winter-, decreasing summer precipitation, heavy rainfalls vs. long droughty periods) (Ledér 2016). One of the alternatives of the possibilities to decrease the weather risks in agriculture and ensure more effective food production is irrigation that can make agricultural production safer and more intensive.

Miscanthus giganteus is a perennial grass with high biomass potential, low nutrient demand, good frost tolerance and carbon assimilation capacity (Fogarassy 2001). It can be grown for a long time in the same plot, the duration of a plantation can be 15-25 years. It is not sensitive to the soil properties, its yield is mainly determined by the water supply and the temperature (Percze 2010). It is harvested once a year, in early spring, when its moisture content is low hence it has favourable calorific value.

The 2009/28/EU directive appropriates the increase of the rate of renewable energy up to 20% in communal energy consumption of the EU countries by 2020 in order to support the broader dissemination of renewable energy. In Hungary 14.65% green energy ratio of the total is the goal to be achieved by 2020 (Fodor 2013). In order to reach this goal, not only woody energy crops but herbaceous crops – among them *Miscanthus giganteus* – are of great importance.

Material and Methods

The main goal of the research was to determine the water balance and its elements for *Miscanthus giganteus* in the case of different irrigation doses (water supply). For that, 3 weighing lysimeters in the lysimeter station of Karcag Research Institute, Institutes for Agricultural Research and Educational Farm, University of Debrecen were used (*Figure 1*). The surface area of the lysimeters is 1.7 m² and their depth is 1 m. The measurement frequency was 10 minutes; the accuracy of the weighing system is 0.1 kg (equivalent water height: 0.06 mm). Seepage water was frequently collected at a bottom outlet and quantified. The amount of precipitation was measured by a rain gauge at the meteorological station. The 3 investigated lysimeters were irrigated with different doses of water: 10, 15, 20 l/week (5.88, 8.82, 11.76 mm), respectively. The investigation period lasted from May 2018 to August 2018.

The basis for quantifying precipitation (P) and evapotranspiration (ET) was a simple water balance equation with the measured quantities on the left-hand side and the (yet unknown) boundary fluxes between soil and atmosphere on the right-hand side (Eq. 1).

$$\Delta W + SW = P + I - ET \quad (1)$$

(ΔW = change of profile water content, SW = seepage water at lysimeter outlet, P = precipitation on the lysimeter, I = irrigation on the lysimeter, ET = evapotranspiration from the lysimeter; all dimensions are mm).

The Water Use Efficiency Index (WUEI) was calculated from the rate of Total Water Input (TWI) and evapotranspiration (ET): ET/WUEI*100 (%). This index shows whether the water balance was negative or positive, in other words if the water supply was sufficient (100% or below) for the crop, or insufficient meaning that the crop decreased the moisture stocks of the soil (Zsembeli et al. 2011).

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Figure 1. ***Miscanthus giganteus*** **in the lysimeters in May, June, July, and August of 2018.**

Table 1. **Water use of** *Miscanthus giganteus* **with different irrigation doses in May, 2018.**

Irrigation (mm)	Precipitation (mm)	TWI (mm)	Seepage water (mm)	ET (mm)	Water balance (mm)	WUEI (%)
23.53	44.90	68.43	0.00	188.25	-119.82	275.1
35.29	44.90	80.19	0.00	192.37	-112.18	239.9
47.06	44.90	91.96	0.92	201.62	-110.59	219.3

Table 2. **Water use of *Miscanthus giganteus* with different irrigation doses in June, 2018.**

Irrigation (mm)	Precipitation (mm)	TWI (mm)	Seepage water (mm)	ET (mm)	Water balance (mm)	WUEI (%)
23.53	55.00	78.53	0.00	98.76	-20.24	125.8
35.29	55.00	90.29	0.00	117.00	-26.71	129.6
47.06	55.00	102.06	0.00	127.59	-25.53	125.0

Table 3. **Water use of *Miscanthus giganteus* with different irrigation doses in July, 2018.**

Irrigation (mm)	Precipitation (mm)	TWI (mm)	Seepage water (mm)	ET (mm)	Water balance (mm)	WUEI (%)
29.41	57.30	86.71	0.00	90.89	-4.18	104.8
44.12	57.30	101.42	0.00	105.06	-3.65	103.6
58.82	57.30	116.12	0.00	119.65	-3.53	103.0

Results and Discussion

In this paper the monthly water use and its efficiency of *Miscanthus giganteus* for the period of May-August of 2018 is reported in the cases of the 3 different irrigation doses. This experiment started in 2017; the first harvest was in April, 2018.

The height of the reeds exceeded 1.5 m by the beginning of May; the plants getting the smaller amount of irrigation water were the shortest. Strongly negative water balance was characteristic to all the three lysimeters (*Table 1*). The highest ET values of the whole investigation period were calculated for this month, the difference among the treatments was not significant (2 and 7%). WUEIs were above 200%, all the water input was transpirated by the reeds, even considerable amount of water was taken up from the original moisture content of the soil of the lysimeters. The larger was the water input the better was the water use efficiency of the reeds. The high water use was manifested in the growth of the plants too, by the end of May the average height was above 2 m.

In June – similarly to May – the highest ET was characteristic to the lysimeter with the highest water input, though the differences among the treatments were more considerable: 29% more water was transpirated from the lysimeter getting the highest dose of irrigation then the one with the lowest dose (*Table 2*). The WUEIs were above 100%, still negative water balance was characteristic to all treatments, though the differences were not significant.

In July the tendencies of water use were similar to the previous months, 31% more water was transpirated from the lysimeter getting the highest dose of irrigation then the one with the lowest dose (*Table 3*). The WUEIs were just above 100%, almost all the amount of ET was covered by the natural precipitation and irrigation. The height of the reeds did not change a lot in that month, the growth was only a few centimetres, and still the reeds getting the lowest TWI were the shortest.

Table 4. **Water use of *Miscanthus giganteus* with different irrigation doses in August, 2018.**

Irrigation (mm)	Precipitation (mm)	TWI (mm)	Seepage water (mm)	ET (mm)	Water balance (mm)	WUEI (%)
17.65	72.20	89.85	0.00	82.85	7.00	92.2
26.47	72.20	98.67	0.00	92.73	5.94	94.0
35.29	72.20	107.49	0.00	105.61	1.88	98.2

Though ET from the lysimeters was not less intensive, in August positive water balances were characteristic; in our opinion the highest amount of rainfall of the investigated period contributed to it (*Table 4*). The drying of the reeds started, though they had no water deficiency.

Conclusions

On the base of the regular measurements of the water balance and its components of *Miscanthus giganteus* with different irrigation doses, we established that in each month of the investigated period the larger was the water input (10, 15, 20 l/week) the highest was the ET (469, 508, 556 mm/4months, respectively). The same correlation was characteristic to the height of the plants. In the WUEIs we found significant differences in the first and the last month of the investigation period, in total the WUEI was more favourable (lower) in the case of the higher irrigation doses (142.42%, 136.86%, 132.77% with the increasing doses). More accurate information on water use efficiency of *Miscanthus giganteus* will be available after the harvest of the reeds as we will be able to determine the total biomass in the function of ET. That index describes how much plant biomass was built up by using 1 mm of water through evapotranspiration during the investigated period.

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