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Water use efficiency of energy willows determined in weighing lysimeters

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Summary

The agroecological conditions of Hungary, the rates of arable and afforested lands all enable that energy gained from biomass can be the dominant among renewable energy sources. In 2011 energy willows were planted in three weighable lysimeters at the lysimeter station of the Karcag Research Institute of RISF CAAES University of Debrecen. Energy plants are getting popular in Hungary nowadays and we know more and more about their growing conditions and demands. Nevertheless there are no sufficient data about the water regime of energy crops. The main goal of our research was to determine the water use and its efficiency of energy willow during the first few years after its plantation. Our results prove that weighing lysimeters are excellent tools for the quantification of the water balance of even woody crops. It was established that energy willows have quite high water demand even the first year after their plantation compared to the second year's water use due to their fast growth.

Schlagwörter: energy crops, water use efficiency

Introduction

Since the oil crisis taken place in the 1970ies woody energy plantations have been potential alternatives of fossil fuels. Mainly woody plantations planted specially for energy production are the most suitable serving raw material for the energy sector for several years or even decades. According to our recent knowledge energy willow is one the tree species that grows the fastest, both regarding length (3-3.5 cm per day) and weight, as it can be harvested even after the first vegetation year. Energy willow can be utilized for energy production very well as it has high caloric value (4,900 kcal/ kg). There is a high demand for energy willow on the biomass market which requires getting to know the demands, the optimal growing conditions and agrotechnical factors (soil, cultivation, plantation, protection, water regime) of this plant.

The production technology of woody plantations was elaborated in that period too is (SIRÉN et al. 1987). In Sweden the production of energy willow is fully mechanised, from plantation to harvest, and the technology has just slightly changed since the 1990ies (GUSTAFSSON et al. 2007). While in the 1990ies 18 thousand stem cuttings were planted per hectare, nowadays 13 thousand are characteristic. Conventionally plant nutrition was solved by means of artificial fertilizers, recently most of the farmers prefer thin manure mixed with wooden ash (DANFORS et al. 1998). Harvest is carried out every 3 years in the winter period, when the soil is frozen. Woody crops grown for energetic purpose generally tolerate extreme weather conditions. The most critical climatic condition is the temperature, the Hungarian circumstances are suitable from this point of view. Usually 500-600 mm of annual precipitation is needed for the even development of energy willow, but it can have quite high yields even drier years with 300-400 mm of rainfall. The even water supply is of great importance at the beginning growing phase after plantation as energy willow is more susceptible to drought in that period. From the second year of growth willow trees can utilise the moisture content of the deeper soil layers with a higher efficiency (GYURICZA 2010).

Material and methods

The experiment was carried out in 3 weighable lysimeters at the lysimeter station (*Figure 1*) of the Karcag Research Institute of the University of Debrecen in 2011 and 2012. Under the lysimeter units with plastic wall electronic scales can be found that can measure the changes of weight with the sensitivity of 0.1 kg (0.05 mm) in the measurement range of ±300 kg. The scales are connected to a data logger in pairs to measure and store the weight data every hour automatically. The data loggers have connection with a computer for data processing. The sizes of the units: surface area 2 m² depth 1 m. The lysimeters were filled with meadow chernozem soil.

Indicator plants

Variety Express of white willow (*Salix alba L.*) was used as an indicator plant, which originates from the breeding of an ancient native species. This variety has very good tolerance to the environment. The maximum biomass production of this variety can be reached in wet areas with low elevation. It is very suitable for plantation as an woody energy crop. The plantation was on 18th March in 2011. Four stem cuttings were planted into each lysimeter giving a density of 2 trees/m².

Irrigation

The two investigated years were extremely dry, during the investigated periods of 2011 and 2012 278.2 and 206.3 mm rainfall was detected in Karcag respectively, while the 50-year average for the April-November period is 408 mm. The

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Figure 1: **Energy willows in the weighable lysimeters at Karcag**

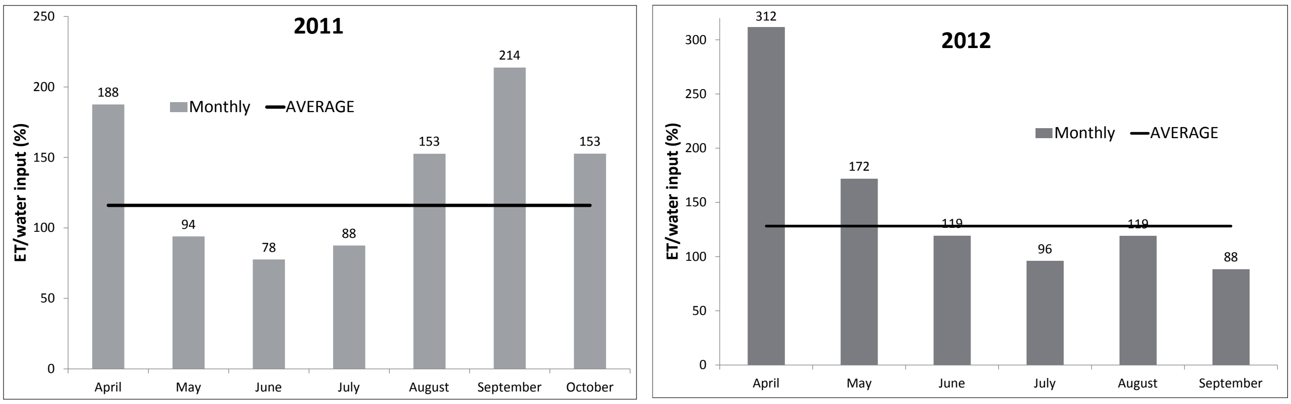

Figure 2: **The monthly and average rates of ET and water input in the lysimeters**

trees were irrigated not only because of the dryness of the years, though one of our reasons was to study the possibility of growing energy willows under dry climatic conditions. All 3 lysimeter units were irrigated with the same amount of water: from June to September 70 and 110 mm water was added respectively. In order to avoid extended evaporation losses, the irrigation water was used in spilt application of smaller doses.

Results and discussion

From the point of view of the selection of the growing area it is important to know the rate between the water input of the area and the water consumption of the trees. This rate gives information on the water balance of the soil, whether the water input can satisfy the water demand of the trees or the decrease of the soil moisture stocks can be expected in a certain period. Another aspect is if higher evapotranspiration values are manifested in higher yields making the water use efficiency of the trees better. Two indexes were calculated that can be the bases of further (e.g. economic) calculations:

- evapotranspiration per water input (%),
- dendromass per water input (mm/kg).

The rate between the water input and the average ET from the lysimeters are indicated in *Figure 2* for the investigated months of the two investigated years. When this value is under 100%, the trees has sufficient water supply, the water input covers the loss from the soil moisture content due to ET. The values above 100% show the extension of the water deficit of the soil.

In both years Aprils can be characterized with massive negative water balance and the worst water use efficiency. Nevertheless it can be mentioned that spring was extremely dry in both years (18.9 and 13.2 mm monthly precipitation). From May to July of the first year after the plantation the willow trees did not utilise all the soil moisture stocks resulting in positive water balances. From August to October 50-100% more water than the input was used by the trees parallel to their growing. Though there was no considerable difference in the water inputs, the data of the second year show – in harmony with the literature data of GYURICZA (2010) - that the willow trees can utilise the moisture content of the soil with a higher efficiency. In our case the average water use efficiency was 12% better in the second year.

After the forcedly early harvest of the willow trees the weight of the cut dendromass was measured in wet and then in dry state hence its water content could be calculated. The weight of the dry dendromass per 1m² (actually the yield) was determined. This value was the base of further calculations in order to determine the water use efficiency

Table 3: **Some yield and water use parameters of the willow trees for the investigated period (January-September 2012)**

Wet dendromass (kg/m^2)	Dry matter content (%)	Dry dendromass (kg/m^2)	ET (mm)	ET/dendromass index (mm//kg)
1.068	47.7	0.502	434	864.5

of the trees. Even the branches were harvested quite early, the average water content of them was 52.3%, which is very similar to the water content of the trees harvested in normal time (50-55% according to the literature). The yield, the dry dendromass was 5.02 t/ha, which also fits to the range of the average yield characteristic for dry areas (3.5-6.8 t/ha).

The index of *Table 3* shows the amount of evapotranspiration relevant to 1 kg of dry dendromass expressing how much water was used to build up 1 kg of dendromass of the willow trees during the investigated period.

According to our measurements and calculations the second year growth of the energy willow variety Express used 864.5 mm water to generate 1 kg of dry dendromass under the given agroecological circumstances (soil and weather).

Conclusions

This research aimed to provide data concerning the water use characteristics of energy willow as they are not complete in the literature, hence our results fill some gap in this respect. Our results prove that weighing lysimeters are excellent tools for the quantification of the water balance of even woody crops. We established that energy willows have quite high water demand even the first year after their plantation compared to the second year's water use due to their fast growth. For energy willow plantations it is suggested to choose such areas where the time distribution of natural precipitation is even as the growth of the trees can be moderated in case of long dry periods. Even irrigation is reasonable within the first year to ensure even growth. The water use efficiency index (ET/dendromass) is a good base for the comparison analyses of different years, tree species and varieties as well as growing areas.

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