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Water use efficiency of maize and different sorghum hybrids under lysimeter conditions

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Summary

In 2009 maize and sorghum was studied in a weighable lysimeter experiment in order to determine the water use efficiency of these two plants as farmers often have the dilemma if maize can be substituted by sorghum even with benefit (e.g. better water use efficiency) under the soil- and climatic conditions of the Great Hungarian Plain. This question is arisen even with a greater emphasis under irrigated conditions, especially as the safety of plant production can be ensured only by irrigation in droughty periods. One maize and one sorghum hybrid in three replications were applied as indicator crops for the comparison. In 2010 three different sorghum hybrids were studied under irrigated and non-irrigated conditions. For both years water balances for different time frames were calculated involving the determination of each component of them. On the base of the different yield- and water balance parameters indexes characterising the water use efficiency of the crops were also calculated. It could be concluded that in a normal, dry year sorghum consumed 10 percent more water than maize under irrigated conditions. In the wet year somewhat lower evapotranspiration, but very much better water use efficiency characterized the 3 investigated sorghum hybrids.

Keywords: irrigation, water use efficiency, maize, sorghum, lysimeter

Introduction

The control of the water regime of the soil will be of great importance in the food production worldwide (LÁNG et al. 1983, VÁRALLYAY 1978). This will be one of the strategic question of the maintenance of soil fertility and the increase of crop yields. It can be predicted with no risk that water will become the main limiting factor of crop production in the future, especially taking the effects of the global climatic change into consideration. In Hungary farmers also want to accommodate to the changing conditions. There is long tradition of the efforts focus on saving water in agricultural use of water to ensure the safety of yield with as little amount of water as possible. On large areas of the Great Hungarian Plain irrigation can be used only conditionally (strictly taking its environmental impacts as secondary salinization, soil degradation, etc into consideration) due to the special ecological and soil conditions. Basically two approaches, water saving soil cultivation and the application of crops with higher water use efficiency) can be the solution of this problem, depending on the intensity of the production. Although maize can be grown successfully if its plant nutrition is rational (SÁVÁRI and GYŐRI 1998) on the better soils of the Great Hungarian Plain, nowadays sorghum has great a perspective as a potential substitution of maize as a fodder as well as an energy crop (BLASKÓ et al. 2008, KOVÁCS et al. 2009). Nevertheless there are no sufficient, scientifically established and quantified data comparing the water use efficiency of maize and sorghum.

Materials and methods

In 2009 an experiment was set at lysimeter station of the Karcag Research Institute in order to compare the water balance of sorghum and maize. One sorghum (*Sucrosorgo*) and one maize hybrid (*PR37F73*) were studied in three replications in the six weighable lysimeters of the institute. We continued the experiment in 2010 with the comparison of three sorghum hybrids (*Albita, Berény* and *Sucrosorgo*) in two replications. During the examination periods (June–September) the same amount of irrigation water was used for each lysimeter unit. The units were irrigated in smaller doses in order to avoid the high passive evaporation lost from the soil surface in 2009, but due to the extremely rainy year of 2010 (with the record amount of 889.1 mm annual precipitation) only a little irrigation water was applied before the very wet summer started.

Results and discussion

Water balances for different time frames (seasonal, monthly, daily) were calculated involving the determination of each components of them. The water balances calculated for the whole examination periods (June–September) of 2009 and 2010 are shown in *Figures 1-2*, respectively. As all the components of the water balance are indicated, it is well visible that the indicator crops had different outputs even the water inputs (natural precipitation and irrigation) were the same within the investigated years. In 2009 among the outputs, the difference in the amount of deep percolation water (drain water) has nothing to do with the plants and its very small quantity is not determining the difference experienced in the water regime of the crops. Much more dominant role has the evapotranspiration (ET) making the water balance of the crops different. If we consider the 4 months of the investigated period, the average daily amount of ET is above 4 mm. This value can be considered realistic taking the relevant meteorological conditions (warm

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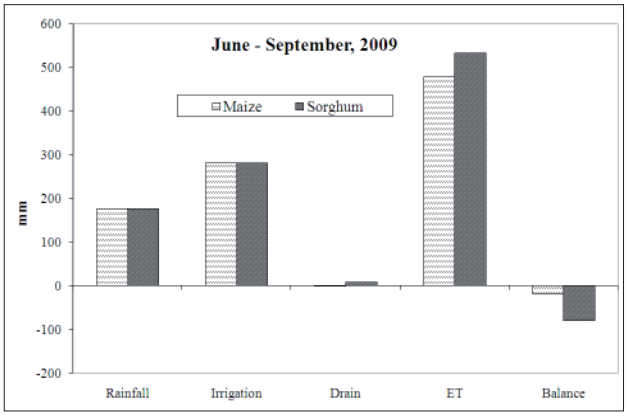

Figure 1: **The water balances of maize and sorghum in 2009**

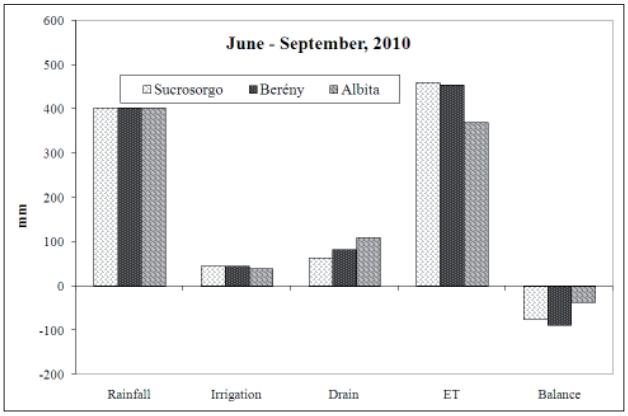

Figure 2: **The water balances of the sorghum hybrids in 2010**

Table 1: **Water use parameters of the indicator crops in the lysimeters**

	Maize 2009	Sucrosorgo 2009	Sucrosorgo 2010	Berény 2010	Albita 2010
Precipitation (mm)	175.9	175.9	402.8	402.8	402.8
Irrigation (mm)	280	280	45	45	40
Total water input (mm)	455.9	455.9	447.8	447.8	442.8
ET (mm)	478.5	533.13	459.9	454.4	369.7
ET/water input (%)	105	117	103	101	83

summer) and the optimum-like water supply into account. As a summary it can be concluded that sorghum had approximately 10% higher water consumption than maize had even all the agrotechnical conditions were the same. In 2010 very wet summer was characteristic, the fallen 400 mm of precipitation made irrigation unnecessary. Due to the high air humidity during the often rain events the ET values were relatively low.

Some water use parameters of maize and sorghum of the investigated periods are shown in *Table 1*. The evapotranspiration in the function of the total water input 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 fund of the soil. In 2009 the water balances were negative, 5% of the water transpirated by maize originated from the soil moisture fund, while 17% in the case of sorghum. This result is in harmony with the literature data stating the soil drying capability of sorghum. In 2010 two sorghum hybrids had slightly negative water balance, while one hybrid showed positive balance, only 83 percent of the total water input was used for evapotranspiration. It must be mentioned that the hybrid *Albita* is a grain sorghum, while *Berény* and *Sucrosorgo* are sweet sorghum hybrids with much higher green mass.

In order to assess the effect of water input (irrigation) on the water balance of maize and sorghum further, the yield data were also used (*Table 2*). We measured the total biomass for all indicator crops, the corn-cob mass was determined for maize, while for sorghum the sugar content was measured. Naturally the biomass yields of the two crops cannot be compared directly, but they were used as the base of further

Table 2: **Water use efficiency indexes in the function of yields in 2009**

Index	Maize	Sorghum
Total biomass (g/m²)	3300	5100
Biomass/ET (g/mm)	6.9	9.6
Corn-cob mass (g)	2700	-
Sugar content (%)	-	18.9
Sugar yield (g/m²)	-	964
Corn+cob mass/ET (g/mm)	5.64	-
Sugar yield/ET (g/mm)	-	1.8

calculations for determining the water use efficiency. As we experienced different values of ET, the question arose if the water use efficiencies of the two crops are different as well. In other words, some economic calculations can answer the question whether the bigger biomass or yield can compensate the higher input originating from the higher water consumption. As the hydrological approach of this question some indexes characterising the water use efficiency of the crops were calculated. These indexes can be the bases of further economic calculations.

The total biomass production of maize and sorghum in the function of ET describes how much plant biomass was built up by using 1 mm of water through evapotranspiration during the investigated period. The results of 2009 show a relatively higher water consumption of maize as it consumed less water in total, but approximately 30% more for producing the same amount of biomass. This difference obviously originates from the higher biomass production of sorghum, but also means a better water use efficiency of it.

In *Table 3* the water use efficiency indexes calculated for the yields of the sorghum hybrids in 2010 are shown. These

Table 3: **Water use efficiency indexes in the function of yields of sorghum in 2010**

Index	Sucrosorgo	Berény	Albita
Total biomass (g/m²)	8900	7000	3400
Biomass/ET (g/mm)	19.4	15.4	9.2
Sugar content (%)	15	17	11.5
Sugar yield (g/m²)	1335	1190	391
Sugar yield/ET (g/mm)	2.9	2.6	1.1

values can be compared to other results gained under similar conditions and also to the results of other years. Hybrid *Sucrosorgo* was studied both years. There was considerable difference in the total biomass yield as the water supply was much satisfactory in the wet year of 2010 (positive water balance). The other two sorghum hybrids had lower biomass production, which was expected in the case of *Albita*, the grain sorghum hybrid. *Berény*, the other sweet sorghum hybrid had the highest sugar content, but still generated lower total amount of sugar due to its lower biomass yield. *Albita*, the grain sorghum hybrid generated 20-30% less sugar than the sweet ones, and although consumed 20% less water, still it needed the highest amount of water to generate 1 g of sugar.

Conclusions

Weighable lysimeters are very suitable tools for the determination of the water balance of the soil providing the possibility of the precise calculation of evapotranspiration, especially as the differences can be precisely quantified. On the base of the different yield- and water balance parameters indexes characterising the water use efficiency of maize and sorghum were calculated. It could be concluded that sorghum consumed 10 per cent more water under irrigated conditions and its daily duration of transpiration is longer. Comparing the different sorghum hybrids it could be established that the higher biomass production of sweet sorghum hybrids goes hand in hand with the higher water demand, but better water use efficiency. The examined sweet sorghum hybrids (*Sucrosorgo* and *Berény*) pay better for the sufficient water supply, while the grain sorghum hybrid (*Albita*) probably shows better water use efficiency in dry years providing potential substitution of maize as a fodder crop.

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