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Evapotranspiration in Sudan grass second culture grown under non – irrigated and optimal irrigated conditions

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Abstract: *The aim of the present study was to establish the evapotranspiration of Sudan grass variety Engje-1, grown as a second crop for silage on meadow-cinnamon soil for the region of Southern Bulgaria under irrigation conditions and without irrigation. For this purpose, an experiment with Sudan variety Endje-1 was conducted in the experimental field of the Agricultural Institute - Stara Zagora on soil type meadow-cinnamon soil, after its predecessor barley. The Sudan grass is harvested in the brooming stage. Two variants were explored: Variant 1 - without irrigation (control) and Variant 2 - with optimal irrigation, 70-75% of field capacity (FC). Evapotranspiration of Sudan grass grown as a second crop under non-irrigated conditions, depending on the nature of the year, ranges from 168.7 mm to 183.7 mm. Under conditions of irrigation, the largest share in the formation of the water consumption is occupied by the irrigation norm - 87.1% on average (from 86.3 to 90.8%). Under irrigated conditions, the relative participation of the initial water reserve in the formation of evapotranspiration significantly decreases.*

Keywords: field capacity, irrigation norm, irrigation depth, precipitations, water balance, water consumption

Introduction

Water scarcity and an increase in demand are predicted in the near future (Popova et al., 2018) The greatest impression of this water stress is forecast on field crops (Alghabari et al., 2016). It is expected that in irrigated agriculture, forage crops will face severe drought stress as their vegetative growth is totally dependent on moisture availability. In the future, a greater upcoming challenge will be to increase forage production with decreased irrigation supply. Implementation of various irrigation strategies with improved water productivity may be one of the options to mitigate drought stress (Beis and Patakas, 2015). The decreasing supply of irrigation water has increased its cost, thus, to remain viable, dairy farmers need to adopt new strategies to improve the water productivity of both irrigated and rainfed agriculture.

For Bulgarian soil and climatic conditions, the factor that determines the yield of Sudan grass as a second crop is moisture, which is achieved mainly through timely and proper irrigation. For the Arizona and California regions, Knowles and Ottman (2015) found that Sudan grass, grown on heavy clay soils, requires about 7-11 acres of water per month, fed every 20-25 days from May to August, and about 6 up to 8 inches of irrigation water if grown on fine textured soils. For the conditions of Serbia, Pejić et al. (2005) found that at 60-65% of field capacity (FC) the values of evapotranspiration (ET) reach 570 mm and the highest yield of green mass is obtained - 105.17 t/ha. The obtained results are similar to the studies for Sudan grass grown as a second crop for the region of Southern Bulgaria (Bazitov et al., 2017, 2018). Al-Suhaibani (2006) found expanding irrigation interval on Sudan grass from 3 to 7 and 11 days decreased the potential yield from 143.6 to 123 and 85.3 t/ha, respectively. During a three year field study with Sudan grass in the Imperial Valley, California, Grismer and Bali (2001) established that the average applied water depth and estimated consumptive use evapotranspiration (ET) during the project were 1019 and 935 mm. By using a deficit irrigation approach, the same amount of applied water attained 17% higher biomass accumulation and 14% greater cropwater productivity (Samiret al., 2017). In their research Slanev and Enchev (2014) for the region of Northeastern Bulgaria found that Sudan grass maintains relatively stable yields in different agro-climatic years. The determination of evapotranspiration is important for the preparation of a project irrigation regime for field crops (Stoyanova et al., 2008; Matev and Petrova, 2011, 2012). Evapotranspiration of any crop (including that of Sudan grass) is a major cost element in the water balance of the active soil layer and one of the main factors determining the parameters of the irrigation regime (Bazitov and Kikindonov, 2016). The intensity of ET directly affects the duration of the irrigation period, and hence the number of irrigations and the size of the irrigation rate. The aim of the present study is to establish the evapotranspiration of Sudan grass variety grown as a second crop for silage on meadow-cinnamon soil for the region of Southern Bulgaria under irrigation conditions and without irrigation.

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Material and methods

During the period 2014-2016 in the experimental field of the Agricultural Institute - Stara Zagora an experiment with Sudan grass variety Endje-1 was conducted on soil type meadow-cinnamon soil, after its predecessor barley. The soil type is characterized by the following water-physical properties: field capacity (FC) - 26.57%, wilting coefficient - 18.19%, porosity - 47% and bulk density - 1.45 kg/m^3. The experiment was based on the block method in four replications, with the size of the harvest plots of 25 m^2. The Sudan grass is harvested in the brooming stage. Irrigation is carried out by gravity with seasonal flexible polyethylene pipes. Two variants were explored: Variant 1 - without irrigation (control) and Variant 2 - with optimal irrigation, 70-75% of FC. Evapotranspiration (ET) for the vegetation period (germination - tasseling) is established by water balance calculations at optimally irrigated Variant 2 for the layer 0-80 cm according to the formula:

$ET = W_1 – W_2 + N + m$, mm

Where: W_1 - water balance at the beginning of the study period, mm;

W_2 - water balance at the end of the study period, mm;

N - amount of precipitation that fell in the studied period, mm;

m - irrigation rate, mm.

In the initial stages of the Sudan grass development, 70% of the FC was maintained, and when it entered the period of active growth with increasing needs of the plants for water, 75% of the FC was maintained. During the vegetation period of the Sudan grass, three irrigations were realized in variant 2 with an irrigation rate of 80 mm, in order to maintain 70-75% of FC. Mathematical processing of the data was performed by software product ANOVA–1.

Results and discussion

The evapotranspiration (ET) of the Sudan grass depends to a large extent both on the meteorological conditions during the experimental years and on the irrigation mode applied in the individual variants. The values of the total ET of the layer 0-80 cm for non-irrigated and irrigated patches are presented by years and average for the period in Table 1. On average for the three years of the study, irrigation increases the water consumption of Sudan grass by 43.8-68.6%, with the largest increase in ET in 2015, when there was the greatest tension of meteorological factors: temperature and humidity deficit. However, as absolute values, the values of the total ET are in sync with the specific meteorological conditions. Sudan grass as a second crop develops under different conditions than that grown as a first crop. While in spring sowing the air temperature at the beginning of the vegetation is lower and then rises, in the cultivation of Sudan grass as a second crop it is the opposite - at the beginning of the vegetation it is high, then gradually decreases. At the same time, the duration of the photoperiod decreases. Under these conditions, Sudan grass has a faster rate of growth and development and tasseling occurs about 25 days earlier than hybrids grown as a first crop. When grown in open areas, the ET of the Sudan grass which is grown as a second crop, is formed mainly by the vegetation rainfall, the initial water supply (accumulated after harvesting the predecessor) and the irrigation rate (if the crop is grown under irrigated conditions). The data concerning the formation of the water flow of the Sudan grass in the layer 0-80 cm on average for the three years of the experiment are presented in Figures 1, 2, 3 and 4, and by years - in Table 2.

Table 1. Total evapotranspiration (ET) of Sudan grass by years and average 2014-2016

Years	Variants	ET, mm	No - irrigated		Irrigated	
			± (mm)	%	± (mm)	%
2014	without irrigation	183.7	0.0	100	- 80.6	69.5
	irrigated	264.3	80.6	143.8	0.0	100.0
2015	without irrigation	173.7	0.0	100	-110.1	61.2
	irrigated	283,8	110.1	168.6	0.0	100
2016	without irrigation	168.3	0.0	100	-109.5	60.5
	irrigated	277.8	109.5	165.0	0.0	100
Average	without irrigation	175.2	0.0	100	-100.1	60.6
	irrigated	275.3	100.1	159.1	0.0	100.0

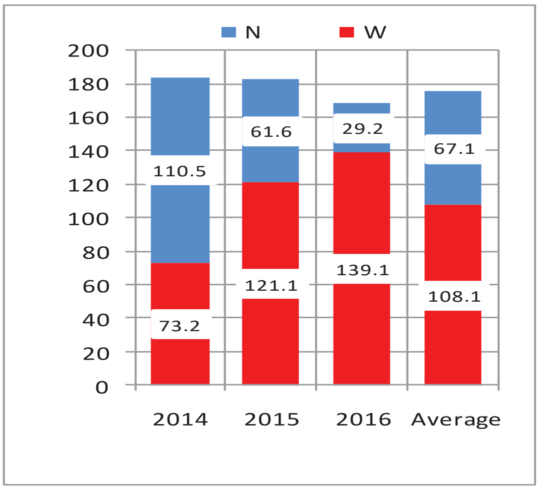
Figures 1 and 2 show the formation of ET in absolute values, under non-irrigated and irrigated conditions, respectively, and the second two - its formation in relative values (%). Regardless of the growing conditions, the main part of ET of Sudan grass second crop in the experimental years is provided mainly by the initial water balance of the soil during the vegetation of the crop (Table 2).

In non-irrigated Sudan grass, the main part of its ET is formed by the remaining water quantity in the active soil layer, or so on initial water supply and the amount of precipitation used during the vegetation period (Figure 1). In the case of irrigated Sudan grass, the irrigation rate increases the absolute values of the total ET, as part of it participates in its formation at the expense of the usable precipitation and the available stock of moisture in the soil (Figure 2). Under non-irrigated conditions, the vegetation precipitation provides on average for the period, 38.30% of ET for the layer 0-80 cm, and the remaining 61.70% are at the expense of moisture reserves accumulated in the soil after harvesting the predecessor (Figure 3). Under conditions of irrigation, the main share in the formation of the water consumption of the Sudan grass falls on the irrigation norm - average for the years of research 87.1% - Figure 4.

Table 2. Involvement of water supply, precipitations and irrigation depth in the formation of evapotranspiration (ET) to Sudan grass in the soil layer 0-80 cm

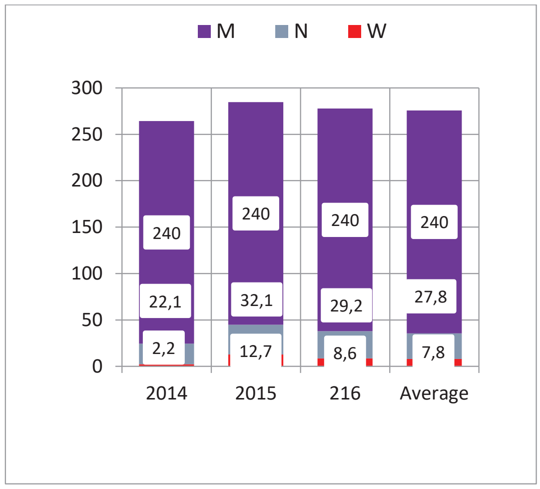
Component	Without irrigation		Irrigated		Without irrigation		Irrigated	
	mm	%	mm	%	mm	%	mm	%
	2014				2015			
ΣET	183.7	100.0	264.3	100.0	173.7	100.0	283.8	100.0
W	73.2	39.8	2.2	0.8	112.1	64.5	12.7	4.3
N	110.5	60.2	22.1	8.4	61.6	35.5	32.1	11.3
M	-	-	240.0	90.8	-	-	240.0	84.4
	2016				Average 2014 – 2016			
ΣET	168.3	100.0	277.8	100.0	175.2	100.0	275.3	100.0
W	139.1	82.7	8.6	3.1	108.1	61.7	7.8	2.8
N	29.2	17.3	29.2	10.5	67.1	38.3	27.8	10.1
M	-	-	240.0	86.3	-	0.0	240.0	87.1

ΣET- total evapotranspiration, mm
W- water supply, mm
M- irrigation depth, mm
N- precipitations during vegetation period, mm



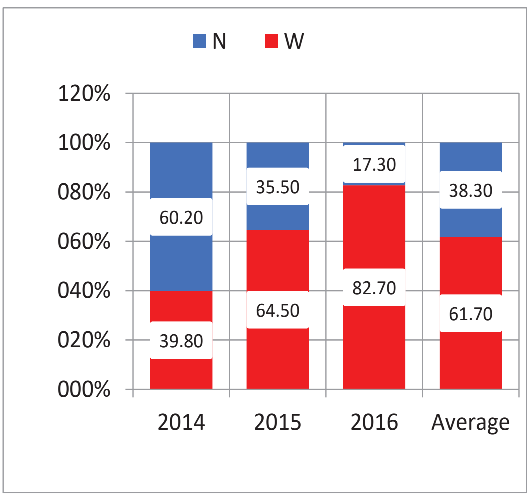
N- precipitations during vegetation period, mm
W- water supply, mm

Figure 1. Evapotranspiration (mm) in the soil layer 0-80 cm without irrigation



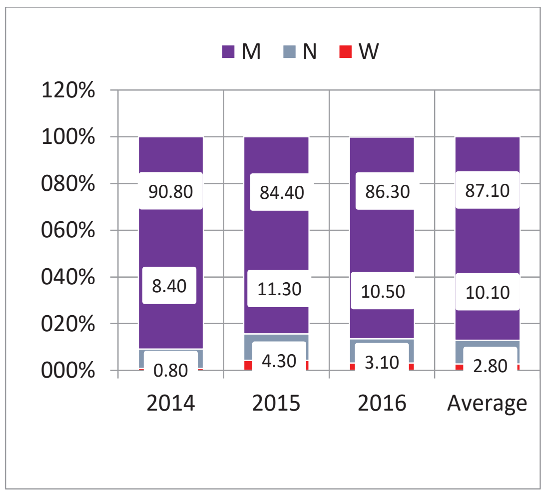
M- irrigation depth, mm
N- precipitations during vegetation period, mm
W- water supply, mm

Figure 2. Evapotranspiration (mm) in the soil layer 0-80 cm under optimum irrigation



N- precipitations during vegetation period, mm
W- water supply, mm

Figure 3. Relative evapotranspiration (%) in the soil layer 0-80 cm without irrigation



M- irrigation depth, mm
N- precipitations during vegetation period, mm
W- water supply, mm

Figure 4. Relative evapotranspiration (%) in the soil layer 0-80 cm under optimum irrigation

For the purposes of irrigation, in addition to the total ET, the ET during the different periods of the development of the crop, expressed by its average daily course, is of special importance. The data by years are presented on Figures 5, 6 and 7, respectively, under non-irrigated and irrigated conditions, respectively. Under non-irrigated conditions during all three experimental years, regardless of the meteorological differences, the course of ET depends on the water supply of the soil and the precipitation used during the Sudan grass vegetation. ET in the initial stages of culture development is low, but the moisture supply was sufficient for its normal course. Regardless of the amount of precipitation in the variants with natural humidification, the average daily values of ET do not exceed 2.9 mm (the third decade of August - 2014). Until the beginning of the irrigation period, the ET in both variants is almost the same, after which in the irrigated variant the values increase sharply, thanks to the favorable humidity conditions created by the irrigation. The maximum in irrigated Sudan grass is reported in the third decade of August 2015 - 4.6 mm, after which it gradually begins to decrease and towards the end of the growing season reaches values close to those at the beginning of the growing season.

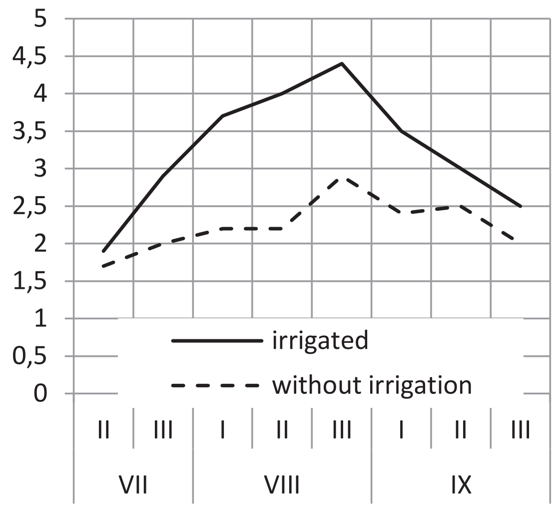


Figure 5. Daily evapotranspiration during 2014

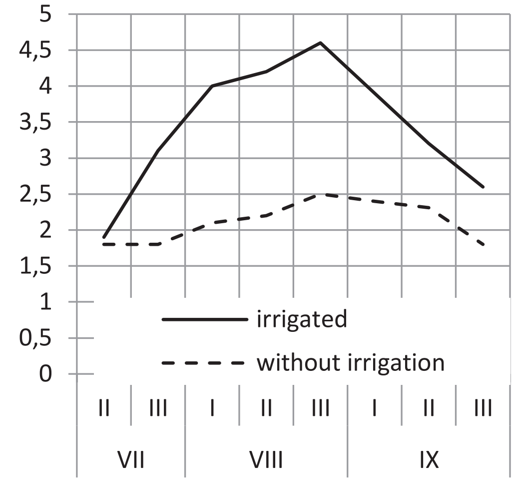


Figure 6. Daily evapotranspiration during 2015

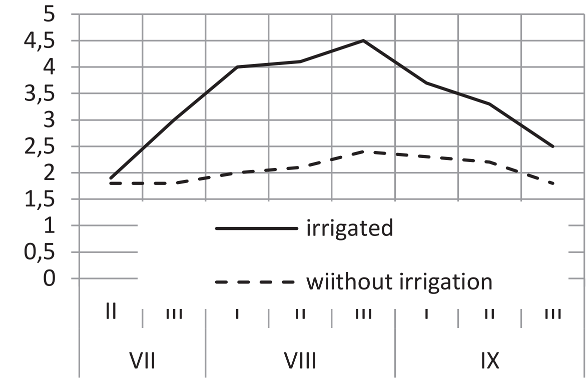


Figure 7. Daily evapotranspiration during 2016

The results obtained for the evapotranspiration of Sudan grass, grown as a second crop, correspond to those obtained by Pejić et al. (2015) for the conditions of Serbia. This is due to the close amounts of precipitation and irrigation rates used in both countries. In this regard, Knowles and Ottman (2015) underlined that it is important to avoid the moisture stress of Sudan grass since stress can cause accumulation of nitrate-nitrogen and/or production of prussic acid in forages that can be toxic to livestock.

Table 3. Evapotranspiration (ET) productivity for Sudan grass

Variants	ET, mm	Yield dry biomass, kg/ha	Productivtity of ET		ET, mm	Yield dry biomass, kg/ha	Productivtity of ET	
			1 - Yield (kg/ha) per 1 mm of ET	2 - ET (mm) to obtain yield of 1 kg/ha			1 - Yield (kg/ha) per 1 mm of ET	2 - ET (mm) to obtain yield of 1 kg/ha
			2014				2015	
1. Without irrigation	183.7	9800	0.018	53.34	173.7	11250	0.015	64.76
2. Irrigated	264.3	12030	0.021	45.51	283.8	14050	0.020	49.50
		2016				Averege 2014 - 2016		
1. Without irrigation	168.3	10020	0.017	59.53	175.2	10360	0.017	59.13
2. Irrigated	277.8	12550	0.022	45.17	275.3	12870	0.021	46.74

1- Yield (kg/ha) per 1 mm of ET
2- ET (mm) for yield of 1 kg/ha

Data on the productivity of evapotranspiration in Sudan grass, expressed in the two ways described for the three experimental years and on average for the experimental period are given in Table 3. The water use efficiency (WUE) can be presented in two reciprocal ways: 1) the yield (kg/ha) per 1 mm of ET and 2) ET (mm) to obtain yield of 1 kg/ha. Sudan grass as a second crop can be considered to use the available water in the soil relatively rationally, both in optimal irrigation and in conditions of soil drought. On average for the three experimental years for the production of 1 kg of dry biomass yield under non-irrigated conditions 59.13 mm of water are used, and under irrigated conditions – 46.74 mm, respectively. For each 1 mm of consumed water, under non-irrigated conditions, an average of 0.017 kg/ha bio dry mass is obtained and 0.022 kg/ha dry biomass under optimal irrigation, respectively.

Conclusion

It was found that evapotranspiration (ET) of Sudan grass grown as a second crop under non-irrigated conditions, depending on the nature of the year, and ranges from 168.7 mm to 183.7 mm. Under non-irrigated conditions, the reserves of moisture accumulated during and after harvesting the predecessor provide an average of 61.7% for the soil layer 0-80 cm, and the remaining 38.3% are at the expense of usable vegetative precipitation. In the conditions of irrigation the largest share in the formation of water consumption is occupied by the irrigation norm – an average of 87.1% (from 86.3 to 90.8%), and the relative share of the initial water reserve in the formation of ET significantly decreases. In non-irrigated conditions, the maximum of the average daily values of ET depends on the meteorological conditions and reaches 2.9 mm; with optimal irrigation, water consumption is the most intense during the third decade of August, after which it gradually begins to decrease and towards the end of the vegetation period reaches values close to those at the beginning of the vegetation period. To obtain 1 kg of yield under non-irrigated conditions, an average of 59.13 mm of water is used, and under irrigated conditions – 46.74 mm, respectively; with 1 mm of water used, under non-irrigated conditions, an average of 0.017 kg /ha dry biomass is obtained, and under optimal irrigation - 0.022 kg/ha dry biomass, respectively.

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