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Effect of irrigation rate on Sudan grass yield, grown as a second crop

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Abstract. *The aim of the present study was to establish the effect of irrigation rate on the yield of Sudan grass variety Engje-1, grown as a second crop for silage on meadow-cinnamon soil for the region of Southern Bulgaria. For this purpose, an experiment with Sudan grass variety Endje-1 on the experimental field of the Agricultural Institute - Stara Zagora, after its predecessor barley, was conducted. The Sudan grass was harvested in the brooming stage. Five variants were explored: Variant 1 - without irrigation (control); Variant 2 - with optimal irrigation, 75-80% of field capacity (FC); Variant 3 - irrigation as Var.2 but with removal of the first watering; Variant 4 - irrigation as Var.2 but with removal of the second watering; Variant 5 - irrigation as Var.2, but with removal of the third watering. It was found that the efficiency of 1m^3 of irrigation water was the highest at the optimum variant (Var.2), where 5.36 kg of dry mass (DM) were produced by 1 m^3 of water. With the removal of the second irrigation (Var.4), the yield on the dry mass decreased by 6.4% compared to the optimal variant (Var.2), and with the removal of the first irrigation (Var.3) the losses on the dry mass reached, 12.3%, respectively. The highest values of this indicator were obtained by varying the second irigation (Var.4) - 7.53 kgDM/m^3 water. The coefficient of efficiency of the irrigation rate, representing the ratio between the increase of the yield (in comparison with the version without irrigation - Var.1), and the size of the realized irrigation norm had the highest value in the version without second irrigation (Var.4) and the lowest values for the version without first irrigation (Var.3).*

Keywords: coefficient of efficiency, dry biomass, irrigation water, precipitations, yield

Introduction

Sudan grass *(Sorghum sudanense (Piper) Stapf.)* is an annual forage crop and a natural hybrid of *S. bicolor* and *S. arundinaceum* (Harlan and De Wet, 1972). Sudan grass and its hybrid forms are mainly used for grazing, hay and silage due to their high production potential and valuable economic qualities, especially in drought conditions (Moyer et al., 2004). In Bulgaria, studies about Sudan grass have been carried out mainly in Northeastern Bulgaria under non-irrigation conditions (Kikindonov and Slanev, 2011; Kikindonov et al., 2013). For the same region, Slanev (2013) and Slanev and Enchev (2014) found that Sudan grass maintained relatively stable yields in years with different agro-climatic characteristics.

Sudan grass has been popular with its greater resistance to drought differing to many other crops, and in areas with higher temperatures and lower uneven rainfall. It has given higher yields than corn (Moyer et al., 2004). Pejić et al. (2012) in a field experiment with Sudan grass on the calcareous chernozem in Vojvodina, Republic of Serbia, established that the efficiency of irrigation water use varies from 2.8 to 3.7 kg/m^3 with an average value of 3.2 kg/m^3. For the Arizona and California regions in the United States, Knowles and Ottman (2015) found that Sudan grass, grown on heavy clay soils, required about 7-11 acre-inches of irrigation water per month from May to August and about 6 up to 8 inches of irrigation water if grown on fine textured soils. Taha et al. (2019) reported for the region of Egypt that the highest values of water use efficiency are 8.08 and 8.88 kg m^{-3}, obtained by irrigation with 125% ETo, respectively in the 1st and 2nd year. The lowest values of water efficiency (7.45 and 7.77 kg m^{-3}) were obtained at 75% ETo. This result is due to reduced water availability and field fertilizer distribution below 75% ETo. Ismail et al. (2017) also found that declining water use increases the water efficiency of Sudan grass under irrigation. Ismail et al. (2018) in an experiment with Sudan grass (*Sorghum sudanensis L.*) cv. California Gold and pearl millet *(Pennisetum glaucum L.)* with three irrigation methods, found that irrigation water use efficiency was the best under sub-surface drip (SSD) followed by including surface drip (SD) and sprinkler irrigation (SPI), respectively. Irrigation water use efficiency of 100% and 75% were significantly similar in both investigated crops. Al-Solaimani et al. (2017) state that by increasing the frequency of irrigation the yield of fodder from Sudan grass can be improved.

In Bulgaria, the studies on Sudan grass, which is an alternative of the maize crop, are insufficient for the Southern Bulgaria region, where agro-meteorological conditions are different from those in Northern Bulgaria and irrigation is necessary for the simultaneous emergence and achievement of high yields, especially when it is grown as a second crop (Bazitov and Kikindonov, 2016; Bazitov et al., 2017). Although it is not a traditionally irrigated crop, the factor that largely determines its yield in our soil and climatic conditions is soil

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moisture. Therefore, care must be taken to maintain optimum soil moisture, which is achieved by timely and proper irrigation (Zhivkov, 1995; Matev, 2001; Davidov, 2003; Davidov and Stoyanova, 2010). In the country there is little and insufficient research on the agro-technical requirements and irrigation of Sudan grass grown as a second crop (Bazitov and Kikindonov, 2016). The aim of the study was to determine the effect of irrigation rate of Sudan grass, grown as a second crop, under the agro-climatic conditions in Southern Bulgaria by applying an interrupted irrigation regime with a watering removal.

Material and methods

The experiment with Sudan grass (*Sorghum sudanense (Piper) Stapf.*) was conducted on the experimental field of the Agricultural institute - Stara Zagora on a meadow-cinnamon soil, after its predecessor barley during the period 2014-2016. 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 was harvested in the blooming stage. The preparation of the soil for the sowing of the Sudan grass was carried out by double disking and the sowing - in the optimal agro-technical term for the region. Phosphorus fertilizer at a rate of 80 kg/ha was imported before the main tillage. Nitrogen fertilizer was applied manually during the growing season at a rate of 90 kg/ha. The air temperature and the precipitation on the experimental field are measured and collected in database in the Agricultural Institute - Stara Zagora.

Five variants were explored:

Variant 1 - without irrigation (control);

Variant 2 - with optimal irrigation, 75-80% of field capacity (FC);

Variant 3 - irrigation as Var.2 but with removal of the first watering;

Variant 4 - irrigation as Var.2 but with removal of the second watering;

Variant 5 - irrigation as Var.2, but with removal of the third watering.

The irrigation water was distributed into the irrigation grooves by means of perforated pipes with hoses mounted thereon to direct the irrigation jets into the respective grooves. The dynamics of soil moisture for the purpose of determining the irrigation rate was monitored by sampling soil for the layer 0-80 cm in the case of optimally irrigated Variant 2. The irrigation rate was achieved when soil moisture dropped to 75-80% of the field capacity (FC). Irrigation variants have been tested under natural soil conditions with no fertilization and optimal fertilization. During the vegetation of the Sudan grass, three waterings were applied with optimal irrigation in Variant 2. In this study, we look at the results under optimal fertilization conditions. The effect of the application of different irrigation regimes could be expressed by the coefficient of efficiency of irrigation rate (K), which represented the ratio between the increase in yield (relative to the variant without irrigation) and the magnitude of the realized irrigation rate. The dry biomass quantity (DM), in percentage (%) of weight of the green biomass (kg) was determined by the method of drying the green biomass at 70°C temperature for 24 hours. The effect of irrigation water was expressed in kgDM/m^3 water. This is the amount of dry biomass (kg) obtained from 1 m^3 of irrigation water.

Mathematical processing of the data was performed by software product ANOVA– 1.

Results and discussion

The productivity of Sudan grass depends on both agro-technical activities and meteorological conditions during the year. The watering time is regulated in accordance with the available moisture at the time of soil sampling, which depends on the temperature and the amount of precipitation. In the cultivation of Sudan grass, as a second irrigation crop for the formation of high and stable yields, the amount of precipitation that fell during the months of active vegetation (VII-VIII) is of great importance. In our experiment, the distribution of precipitation during the growing season of Sudan grass was uneven over the three experimental years (Table 1). Regarding the probability of precipitation (P, %), the months of July and August, which had the most significant contribution to the formation of Sudan grass yield in 2014 were average wet months - with 33.0% and 20.0% of the precipitation required, respectively. For the second year (2015), July was dry (89.8%) and August - average dry month (62.4%). In the last experimental year (2016), July and August were dry, 95% and 90.1%, respectively. The same months of the transitional 50-year period in terms of precipitation probability are characterized as moderately humid, July by 25.4% and August by 37.20%, respectively. The soil moisture after sowing the Sudan grass during all three experimental years was sufficient for its even growth. During the vegetation period of the Sudan grass for the experimental years, three irrigations were applied at the optimally irrigated Variant 2 - 100% (irrigation rate). Irrigation was implemented with 80 mm irrigation rate when soil moisture drops to 75-80% of the field capacity (FC).

Table 1. Precipitation amount by months and years of the Sudan grass

Years	Months						Period of active vegetation
	June, mm	July, mm	P, %	August, mm	P, %	September, mm	July-August, mm
2014	36.5	48.4	33	62.5	20.0	146.5	110.9
2015	125.8	34.9	89.8	26.0	62.4	33.4	60.9
2016	50.8	3.0	95	14.5	90.1	11.7	17.5
1963 -2013	60.1	55.3	25.4	48.6	37.6	52.8	103.9

*P- probability of precipitation (%)

Temperature was the other major factor that influenced the development of Sudan grass during the growing season and the amount of its yield. The average daily temperatures during its vegetation in July and August was higher by about 1.5-2°C in comparison with June and September (Figure 1).

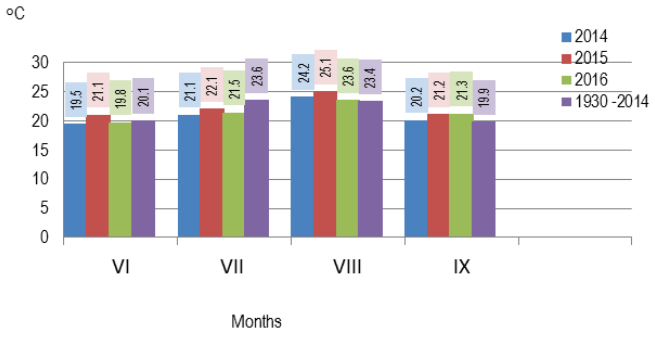

Figure 1. Sum of average daily air temperature during vegetation period (°C)

In determining the effect of irrigation of Sudan grass by varying the yield of dry mass relative to the non-irrigated variant, it was found that in optimal irrigation (Var.2) the yield increased by 24.2% (Table 2). When the variants were irrigated together with Var.2, but with the removal of first, second or third watering, the largest increase in the amount of yield compared to the non-irrigated variant (Var.1) was in Variant 4 (with the abolition of the second irrigation) - 16.3%. In case of the variants with removal of the first and second irrigation (Var.3 and Var.4), and with removal of the third watering (Var.5), the yield increased by 8.9, 16.3 and 15.4%, respectively, compared to the control variant (Var.1).

Table 2. Efficiency of the use of water for Sudan grass for 2014-2016

Variants of experience	Irrigation norm (M), m^3/ha	Yield dry mass, kg/ha	+ / - Yield in kg/ha compared to Var.1	+ / - Yield in % compared to Var.1	+ / - Yield in % compared to Var.2	Productivity of 1 m^3 of water, kg/m^3	Coefficient of Efficiency of irrigation rate (K)
Var.1. No irrigation (control)	-	10360	-	100	80.5	-	-
Var.2. Optimal irrigation	2400	12870	2510	124.2	100.0	5.36	1.04
Var.3. Irrigation as Var.2 but with removal of the first watering	1600	11290	930	108.9	87.7	7.05	0.54
Var.4. Irrigation as Var.2 but with removal of the second watering	1600	12050	1690	116.3	93.6	7.53	1.05
Var.5. Irrigation as Var.2, but with removal of the third watering	1600	11960	1600	115.4	92.9	7.47	1.00
Great differences (GD) - 5% = 42.2 kg/ha; 1% = 57.8 kg/ ha; 0.1% = 78.4 kg/ha							

*Var. – variant; + / – yield in kg/ha - increase or decrease in yield compared to the respective variant; *DM - dry mass - 1 m^3 of water in kg.

When comparing the yields obtained in the individual variants with the yield obtained from the optimally irrigated variant (Var.2), it was found that the lowest reduction of the yield from dry mass of Sudan grass was realised in the variant with removal of the second irrigation (Var.4) - 6.4%, respectively. In the variants with removal of the first and third irrigation (Var.3 and Var.5) the dry mass yield decreased by 12.3% and 7.1%, respectively. The highest decrease in the yield - 19.5% was observed when growing Sudan grass without irrigation (Var.1). The analysis of the results for the indicator of the productivity of 1 m^3 irrigation water showed that with the decrease in the number of irrigations, the efficiency of water use increased. An average of one cubic meter (1m^3) of water was used for production of 5.36 to 7.53 kg dry mass per vegetation period. The highest values of this indicator were obtained in Var.4 - 7.53 kg of dry mass (DM) by 1 m^3 irigated water – kgDM/m^3. Second was the variant with removal of the third irrigation Var.5 - 7.47 kgDM/m^3, respectively. When removing the first irrigation (Var.3), the efficiency of 1m^3 of irrigation water of the Sudan grass reached 7.05 kgDM/m^3. Lastly, the optimal irrigated option was Var.2, which produced 5.36 kg of dry mass from each cubic meter of water.

The other indicator that determines the increase in yield in irrigated variants compared to the variant without irrigation is coefficient of efficiency of the irrigation rate (K). This coefficient in the variant with the removal of the second irrigation (Var.4) is 1.05, which means that each cubic meter of water provides an additional yield of dry biomass of 1.05 kg. In the optimal irrigation – Var.2, the values of the efficiency coefficient of the irrigation rate are 1.04, being almost identical to those of Var.4 (with removal of the second watering). In the variants with removal of the first and third watering (Var.3 and Var.5)

the values of the coefficients were 0.54 and 1.00, respectively.

The results for the efficiency of using the irrigation water of the Sudan grass, which is grown as a second crop for the conditions of southern Bulgaria (5.36 kg DM per cubic meter), are lower than those for the conditions of Egypt, which are 8.88 kg per cubic meter (Taha et al., 2019). The difference is 3.52 kg per cubic meter. Our results are higher by 2.16 kg DM per cubic meter than those obtained for the conditions of Serbia – 3.20 kg per cubic meter (Pejić et al., 2012). These divergent results are most likely due to the different soil and climatic conditions, different irrigation methods and fertilization level under which the relevant studies were conducted.

Conclusion

It was found that during the study period (2014-2016), at the optimum variant of irrigation of Sudan grass – Variant 2 (2400 m^3/ha), an average yield of 12870 kg/ha dry biomass was obtained, which was 24.2% higher than the yield obtained from the variant without irrigation (Variant 1). With the removal of the second watering (Var.4), the yield of the dry mass decreased by 6.4% compared to the optimal variant (Var.2); with the removal the first watering (Var.3) the losses on the dry biomass reached 12.3%. The productivity of 1 m^3 of irrigation water under the optimum watering variant was 5.36 kg dry mass/m^3 water. The highest values of this indicator were obtained in Variant 4 with removing of the second watering - 7.53 kgDM/m^3. The effect of irrigation on the Sudan grass, expressed by the coefficient of efficiency of the irrigation rate (K) was the highest with the removing of the second watering (Var. 4), where from 1 m^3 of water 1.05 additional yield of dry biomass was obtained, compared to the other variants (Variants 1, 2, 3 and 5).

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