Bulgarian Journal of Agricultural Science, 24 (Supplement 1) 2018, 47-51

BIOPHYSICAL COEFFICIENTS OF IRRIGATED SUDAN GRASS GROWN AS A SECOND CROP

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Abstract

BAZITOV, R., A. STOYANOVA and S. ENCHEV, 2018. Biophysical coefficients of irrigated Sudan grass grown as a second crop. *Bulg. J. Agric. Sci.*, 24 (Suppl. 1): 47–51

The experiment was conducted in the period 2014-2015 with sudan grass grown as a second crop, variety Endje 1 on the experimental field at the Agricultural Institute - Stara Zagora on the soil type of meadow-cinnamon. The variety was created at the Agricultural Institute - Shumen. Irrigation was performed gravitationally with seasonal flexible polyethylene pipelines. The following variants were tested: Variant 1. Non irrigation (Control); Variant 2. Optimal irrigation, 70-75% of WFD (100% irrigation rate); Variant 3. Irrigation as var. 2, but with removal of first watering; Variant 4. Irrigation as var. 2, but with removal of second watering; Variant 5. Irrigation as var. 2, but with the removal of third watering. Evapotranspiration (ET) for the vegetation period was established by water-based calculations under optimal irrigation for var. 2 for layer 0-80 cm. Based on experimental data, biophysical coefficients Z, R and K_b in sudan grass grown as a second irrigation crop in periods and years vary within certain limits and depend on specific weather conditions. In the years with insufficient rainfall and high pressure of meteorological elements, their values were low. During the growing periods the biophysical coefficients Z, R and K_b have different values which reach their maximum during the period of occurrence of the panicle, respectively: Z - 0.18, R - 0.43 and K_b - 0.84.

Key words: sudan grass; irrigation; evapotranspiration; biophysical coefficients

Introduction

The sudan grass (*Sorgum vulgare*, var. *sudanensis*) is a one-year feed culture. It is a natural hybrid of *Sorghum bicolor* and *S. arundinaceum* (Harlan and De Wet, 1972) and is mainly grown for green forage and silage production. For the first time in Bulgaria it was imported by private farmers for the region of Shumen (Stefanov and Stefanov, 2001). In spite of attempts for wider implementation in Bulgaria in recent years, this alternative to maize remains still underutilized as a result of the lack of knowledge of the qualities of modern varieties and technologies. Although sudan grass is not a traditional irrigation crop, the factor determining its yield as a second crop in our soil climatic conditions is moisture, which is achieved mainly by timely and proper irrigation. As a second crop under irrigation conditions, the yield of green sudan grass is not inferior to corn and even exceeds it by the amount of digestible protein per hectare.

For the area of Arizona and California, Knowles and Ottman (2015) found that sudan grass grown on heavy clay soils requires about 7-11 acre-inches of water a month, fed in 20-25 days from May to August and about 6 up to 8 inches of irrigation water if grown on fine texture soils. For the conditions of Serbia, Pejić et al. (2005) found that at 60-65% of FC the equivalence values reached 570 mm and the highest yield of green mass was 105,17 t/ha. According to Kikindonov et al. (2008), Kikindonov and Slanev (2011) in our country the sudan grass is mainly grown in North-Eastern Bulgaria, which is the reason for insufficient researches for the agro-technical requirements, incl. the irrigation needs of the crop.

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In their researches Slanev (2013) and Slanev and Enchev (2014) for the region of North-Eastern Bulgaria find that sudan grass under non-irrigating conditions maintains comparatively sustainable yields in the conditions of different agroclimatic years. Determination of evapotranspiration is an important condition for the design of an irrigation regime. It is a significant element in the water balance of the soil, which depends on the number of waterings, the period between waterings and the irrigation depths and irrigation rates.

The biological features of the crops and the specific weather conditions of the area in which they grow are of particular importance.

For the needs of meliorative practice, methods and formulas have been developed in many countries around the world. To clarify these formulas, it is necessary to experimentally determine the biophysical coefficients representing the ratio of evapotranspiration found experimentally to the elements of climate: temperature, deficiency of air humidity.

The aim of the present study was to establish the values of the biophysical coefficients Z, R, and K_b of the sudan grass variety Endje 1, grown as a second crop of silage for irrigation.

Material and methods

During the period 2014-2015 in the experimental field of the Agricultural Institute - Stara Zagora on the soil type meadow-cinnamon soil was experimented with sudan grass variety Endje 1, established at the Agricultural Institute - Shumen. The soil type is characterized by the following water and physical properties: FC - 26.57%, coefficient of wither (CW) - 18.19%, porosity - 47% and density - 1.45 kg/m^3. The experiment was based on the blocking method in four iterations, with a plot size of 25 m^2. The sudan grass is harvested during the development of occurrence of panicle - milk maturity. Irrigation is performed gravitationally with seasonal flexible polyethylene pipelines. The following options have been studied: Variant 1. Non irrigation (control); Variant 2. Optimal irrigation, 70-75% of WFD (100% irrigation rate); Variant 3. Irrigation as var. 2 but with removal of first watering; Variant 4. Irrigation as var. 2, but with removal of second watering; Variant 5. Irrigation as var. 2, but with the removal of third watering. Evapotranspiration (ET) for the vegetation period (germination) was determined by water-based calculations in optimally irrigated variant 2 for the layer 0-80 cm. In the initial stages of the crop development, 70% of the FC was maintained and, when it entered the period active growth with the growing needs of plants from water was maintained 75% of FC. On the basis of the results obtained for the development phase evapotranspiration, years and average for the optimum irrigation period, the values of the biophysical coefficients Z, R and K_b were calculated during development periods of the crop vegetation by the following formulas:

(1) $ET = z.\Sigma T^0$ formula of temperature sum of Delibaltov et al. (1969);

(2) $ET = R.\ \Sigma D$, Alpatiev's formula (1954);

(3) $ET = K_b\, p\ (0.46T^o + 8)$ formula of Blaney and Criddle (1962),

where: Z, R and K_b are biophysical coefficients expressing the evapotranspiration of a unit of meteorological factor; ET - the 10-day sum of the evapotranspiration, mm; ΣT^o - the ten-day sum of the mean daily air temperature, in ^{o}C; ΣD - the ten-day sum of the average daily airborne water saturation deficit in hPa; p - the average daily percentage of the annual sum of the daily hours.

Results and discussion

Sudan grass as a second crop develops under conditions different from those cultivated as the first crop. In spring sowing, the air temperature at the beginning of the vegetation is lower and then rises, while at the cultivation of the sudan grass as a second crop is opposite - at the beginning of the vegetation it is high and then gradually decreases. At the same time, the photoperiod duration decreases. Under these conditions, the sudan grass has a faster rate of growth and development, and the formation of panicle occurs about 25 days earlier than at hybrids grown as the first crop. Enchev's (2013) test results show that modern grain Sudan hybrids are a good precursor to barley.

Fig. 1 shows the sum of the precipitations by years and for the multi-year period.

The sum of rainfall during the growing season of the sudan grass during both experimental years is evenly distributed. For the trial year 2014, a total of three pots were realized - one in the second ten days of July and two in August. Typical for this year is that about 170 mm of precipitation has fallen in September, but they are of no agronomic significance, as the sudan grass during this period is in the period of the occurrence of panicle – milky maturity and being collected. The following year, 2015, we had to submit two watering this month, the first played and the role of pollen for germination. The last third watering was realized in August. Rainfall figures for the multiannual period are close in value to those for July 2014 and those for September 2015. The vegetation period of the rainfall, which includes the months July, August and September in terms of rainfall (P, %) is characterized as wet by wet 2014 (P = 2%). The same period of the following year is characterized as average dry from the average dry year 2015, (P = 54.7%).

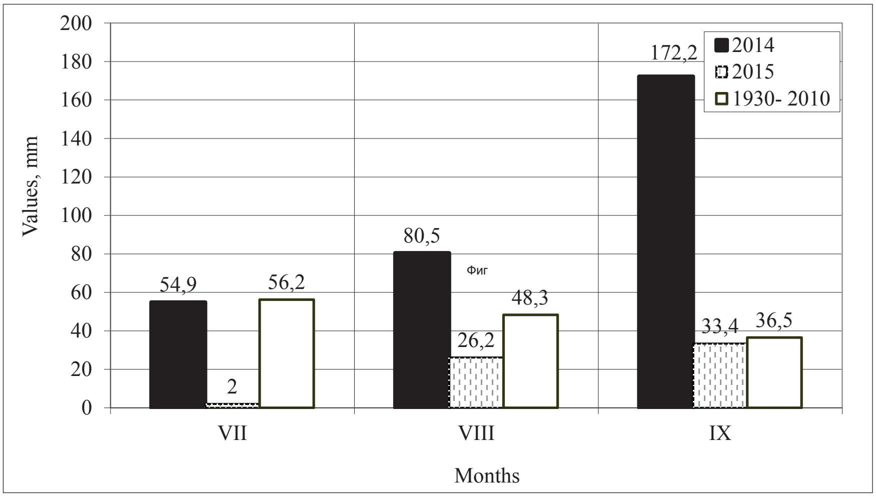

Figure 1. Sum of rainfalls, mm

Climate change, extreme deviations from agro-climatic norms require alternative crops for our agriculture. The sudan grass variety Endje 1 is one of the crops that under extreme climatic conditions manage to develop their potential for the accumulation of green and dry mass in extreme conditions (Kikidonov et al., 2015).

Evapotranspiration is a factor that greatly affects the irrigation regime. To develop the scientific basis for planning and management of the irrigation process as an element of sudan grass crop technology, it is necessary to determine the values of evapotranspiration. Basitov and Kikindonov (2016) have determined the size of the evapotranspiration by water-equation equations. The average daily values range from 2.1 to 4.5 mm depending on the amount of rainfall and the pressure of the weather elements over the years. Evapotranspiration of sudan grass while maintaining the 70-75% of the PPW, on average for the test period amounts to 247.05 mm, and the averages its value reaches its maximum in the phase occurrence of panicle – 4.5 mm per day. It is necessary to calibrate the formulas for calculating the evapotranspiration of meteorological characteristics by determining the values of the biophysical coefficients, depending on the sum of the average daily temperatures.

The study and modeling of irrigation regimes for the purpose of saving irrigated water can only be accomplished by refining water balance calculations and establishing the biophysical factors of the crop.

In order to meet the needs of multilingual practice in several countries of the world, methods and formulas have been developed to determine evapotranspiration by computational pathway. Based on established evapotranspiration data on developmental phases and years and on average over the study period, the values of the biophysical coefficients Z, R and K_b were calculated.

For the vegetation period of the sudan grass, the values of the coefficient Z determined by the formula of Delibaltov et al. (1969) reflecting the ratio between the evapotranspiration and the average daily temperature of the air, depend to a large extent on the growth and development of the sudan grass and vary depending on the biological development of the crop in the vegetation period. At the beginning, after sowing the plants to germinate its values are low, but with a tendency to increase. Average for the years, the highest values of the Z coefficient reached in the period: occurrence of panicle - 0.18. This is the period that coincides with the time of greatest strain on meteorological factors (August) (Fig. 2).

The values of the biophysical coefficient R, by periods and years, vary within certain limits and are determined by the deficiency of air humidity and water vapor. In years with low rainfall, such as 2015, the biophysical coefficient R has lower values than the other experimental year. The lowest values of R are obtained during the sowing season, average for the years - 0.23 and the highest, during the deformation period, respectively - 0.43 (Fig.3).

According to the formula of Blaine et al. (1962), taking into account the average daily percentage of the annual sum of the daily hours and T^{o} - the average daily air temperature for the ten days, the third biophysical coefficient was calculated - K_b. On average, for the studied years, the coefficient was established from 0.34 to 0.84, as the minimum values were recovered at the beginning of the vegetation. At the beginning of the active vegetation period, the biophysical coefficient K_b reached its maximum again in the period of brooming. The change in the values of the biophysical factors Z, R and K_b by years and periods is in line with changes in the values of the evapotranspiration during the vegetation period of the crop (Fig. 4).

The change of the biophysical coefficient values for the optimal years and the average for the study period are in line with the changes in the values of the evapotranspiration during the vegetation period of the sudan grass.

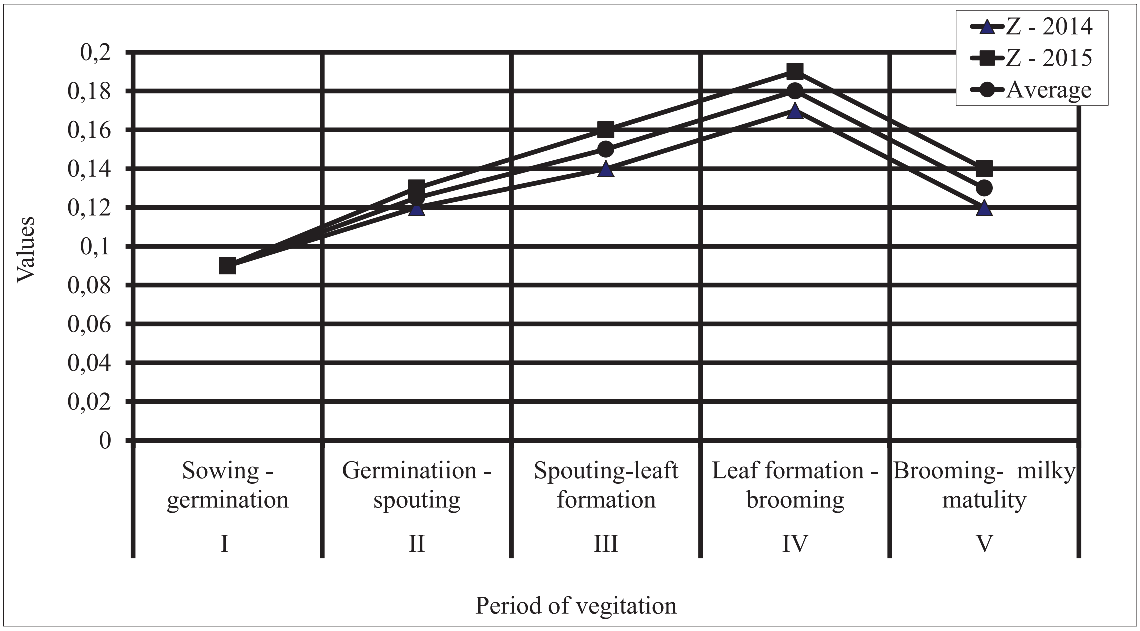

Figure 2. Values of biophysical coefficient Z by periods and years

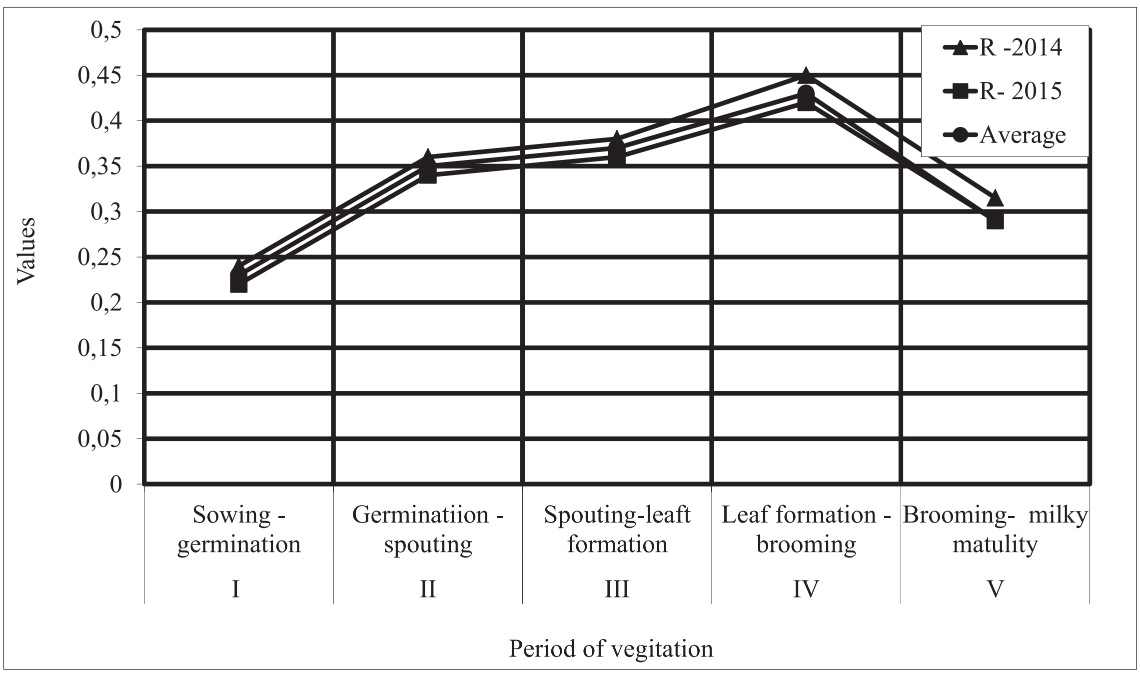

Figure 3. Values of biophysical coefficient R by periods and years

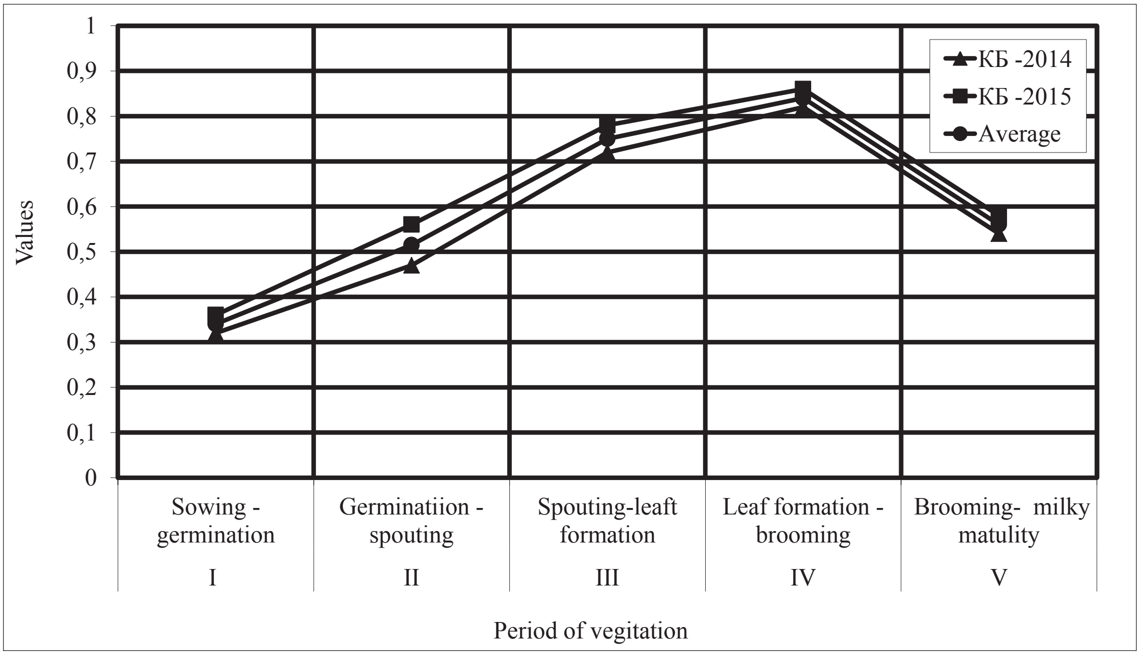

Figure 4. Values of biophysical coefficient K_b by periods and years

The established biophysical coefficients for the sudan grass, cultivated as a second crop under irrigation conditions, could serve to predict the design and operating irrigation regime for the conditions of Southern Bulgaria in further studies with annual feed crops.

Conclusions

Based on experimental data, biophysical coefficients Z, R and K_b in sudan grass grown as a second irrigation crop in periods and years vary within certain limits and depend on specific weather conditions.

In years with insufficient rainfall and high pressure of meteorological elements, their values are low.

During the growing periods of the crop, grown as a second irrigation crop, the biophysical coefficients Z, R and K_b have different values which reach their maximum during the period of the occurrence of panicle, respectively: Z – 0.18, R – 0.43 and K_b - 0.84.

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