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Productivity and feed quality of Sudan grass (*Sorghum sudanense* (Piper) Stapf.) and sweet sorghum forms

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Abstract. *During the period 2017-2018, the feed quality and productivity of three Sudan grass varieties – Endje 1, Vercors and Super Sweet, one stabilized Sudan grass population - SWT, local sweet sorghum - „Zaharna metla" population and the sweet sorghum cultivar "Shumensko sladko" were researched in Agricultural Institute – Shumen. Green mass (t/ha), dry matter (%) and dry mass production (%) as well as basic nutritional characteristics by the two swaths of the tested cultivars in brooming phase were controlled. It was found that the sweet sorghum cultivar "Shumensko sladko" gave the highest amount of green mass - 59.5 t/ha by two swaths, and the dry mass yield was the highest from the cultivar Endje 1 - 20.8 t/ha. In terms of chemical composition, the greatest variation was demonstrated in phosphorus content (0.369-0.696%, CV=27.3%), followed by crude fat (1.28-2.39%, CV=26.8%), Ca (0.889-1.572%, CV=21.8%), crude protein (6.05-9.00%, CV=14.6%), nitrogen free extracts (42.05-51.20%, CV=7.6%), crude fiber (32.64-39.26%, CV=6.1%) and mineral substances (8.17-9.61%, CV=5.9%). It can be summarized that all hybrids provide quality hay, however the Bulgarian cultivars Endje 1 and "Shumensko sladko" showed the best nutritional value - compared to Super Sweet, Vercors, SWT and "Zaharna metla".*

Keywords: chemical composition, evaluation, fodder crops, selection, yield

Introduction

The necessity of fresh feed in the early summer and the high quality of raw material makes mowing of Sudan grass and Sweet sorghum forms during the brooming phase preferred in agricultural practice. In the conditions of Europe and Bulgaria, when summer and autumn are the driest periods of the year, green feed shortages often occur (Donchev et al., 2016, Bazitov, 2020). The use of Sudan grass *(Sorghum sudanense* (Piper) Stapf.*)* and sweet sorghum *(Sorghum bicolor* var. Saccharatum H.*)* has made it possible to rationally feed animals with green mass by the end of October (Shehu et al., 1999; Slanev et al., 2015). Their production has been mainly used in the fresh state for grazing or for feeding cribs for animals. They can be ensiled and dried to feed animals during the winter months. In the earlier stages of their development, these crops are rich in nutrients and are ranked among the best annual feed plants in general nutrition (Kikindonov and Kikindonov, 2014).

Sudan grass has been popular with its great higher resistance to drought compared to many other crops, and in areas with higher temperatures and lower uneven rainfall it has given higher yields than corn (Lenobles and Feyt, 1983; Moyer et al., 2004, Kikindonov et al., 2008; Slanev and Enchev, 2014). Its implementation in Bulgaria would open greater opportunities for the development of sustainable agriculture schemes. Although many attempts have been made to implement it in Bulgaria, Sudan grass is still poorly represented as a forage crop (Kikindonov and Enchev, 2015; Bazitov and Kikindonov, 2016).

During the 1950s, Sudan grass was hybridized with other forms of sorghum to increase feed productivity. The Cytoplasmic male sterility (CMS) in sorghum greatly extended the possibilities of using sterile lines as maternal components and lines and varieties of Sudan grass as pollinators for the production of F_1 hybrids (House, 1995). The studies on the combining ability and correlation of the yield components with the specific agro-climatic conditions increased the breeding potential of a large genetic diversity of hybrids (Shon Yun et al., 1999).

The sweet forms of sorghum *(Sorghum bicolor* var. Saccharatum H) have excellent ability for biomass accumulation in extreme droughts and global warming. The vegetative mass of the sweet sorghum forms has an excellent feed value in the form of green mass, dried in hay or in the preparation of silage (Kalton, 1988). Production has been used for both feed and bio energy (Rooney, 2000; Donchev et al., 2018). The resulting sweet sorghum silage has lower digestibility than corn but has an equally positive effect on milk productivity (Tsukov, 1991).

Many of the common sweet sorghum forms are native populations resulting from natural and artificial selection (Bantalian et al., 2004). Contemporary origins also include hybrids of Sudan grass, technical sorghum and cereal forms. They have an expressed heterosis effect and an optimal combination of high productivity, possibility of

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multiple growths, high carbohydrate, protein and cellulose content and the ability to produce feed. Breeding with classical methods of hybridization has been connected with productivity, height, duration of vegetation, quality of raw material, and heterosis using cytoplasmic male sterility (Enchev et al., 2016).

Another major selection criterion has been the increase in nutritional value and quality of feed (Casler, 2001). The nutrient content of the green biomass and hay of Sudan grass and sweet sorghum forms has been influenced by the phenophase of crop development, periods of drought, soil pH, weeding and more (Zakonović et al., 1997; Moyer et al., 2004). Pell (2005) has established that abiotic stress was a prerequisite for increasing the content of hydrocyanic acid in the aboveground biomass of the Sudan grass. Studies by Sulungwe (2011) and Golubinova et al. (2016) indicated that the crude protein content decreased with vegetation progression and varied in terms of variety, date of sowing, mowing intensity and sowing density, while fiber levels increased, which is a prerequisite for decrease in nutritional value and digestibility of feed.

The aim of the study was to demonstrate the test results for feed productivity and quality of standard varieties of Sudan grass and Sweet Sorghum forms from the breeding program of Agricultural Institute – Shumen in the brooming phase.

Material and methods

The experiments for testing the productivity have been carried out during 2017-2018 on the test fields of Agricultural institute - Shumen, on leached chernozem in a long crop rotation of barley, corn, wheat, oats and beans, sugar beets with sugar beets as predecessor. The scheme of long plots with an area of 10.8 m^2 of harvested plot was used. Sowing was done at the end of April with 70 cm of line spacing and sowing norm of 50 000 plants/ha.

For the purpose of the study three Sudan grass varieties (Endje 1, Vercors and Super Sweet), one stabilized Sudan grass population - SWT, local sweet sorghum “Zaharna metla” and the sweet sorghum cultivar “Shumensko sladko” were tested in the brooming phase. The cultivar Endje 1 is a hybrid of two local populations of Sudan grass and sweet sorghum; SWT is a stabilized population after the hybridization of Sudan grass with technical sorghum; Super Sweet is a hybrid of Sweet sorghum forms with grain Sorghum; “Shumensko sladko” is a new sweet sorghum cultivar in Agricultural Institute - Shumen, recognized in 2020; “Zaharna metla” is a local population of sweet sorghum; Cultivar Sudan grass Vercors originated from France.

The cultivars Endje 1 and Super Sweet were used to form a group standard (for the comparative analyses of the results obtained) based on the mean values of the yield of green mass (t/ha), the dry matter percentage (%) and dry mass production (%) from both cultivars (Shanin, 1977).

Both hay makings were done when plants reached brooming phase. The yield of green mass, dry matter percentage and dry matter yield are measured in four repetitions. The dry matter is determined through drying at 70°C for 24 hours in two repetitions from the mixed sample.

In 2018, chemical composition analysis of Sudan grass varieties and sweet sorghum forms based on a total sample, formed by 10 plants from all repetitions of the individual variants was done. After crushing, 250 g of fresh mass was measured after drying from two swaths in brooming phase and analyzed for basic nutritional characteristics in the Feed nutrition laboratory of the Agricultural Institute – Shumen as follows: crude protein (CP), % of the dry matter of the feed by the classical Kjeldahl method, after determining the amount of nitrogen (N) by the formula: CP = N x 6.25; crude fiber - % of dry matter and crude fat – by Weende analysis; phosphorus (P), % of dry matter - by the vanadate-molybdate method of Gerike and Kumis (Sandev, 1979); calcium (Ca), % of dry matter - by complexometric method (Sandev, 1979).

A statistical processing was made according to Lidanski (1988) for determining yield in t/ha. An analysis of the variance was used to determine the significance of differences in productivity. Mathematical processing of the data was performed by software product ANOVA–1.

Results and discussion

The agro-meteorological conditions at the beginning of vegetation in 2017 were characterized as unfavorable (Table 1). The amount of precipitation is a determining factor in the production of fresh and dry biomass. In May, there was an uneven distribution of rainfall and drought combined with high temperatures. With a normal monthly rainfall of 64.0 mm, only 38.3 mm was reported for the year. All this inevitably worsened the active accumulation of biomass and had a negative impact on the total yield of the tested origins.

Despite the drought, the green and dry mass productivity test results in 2017 are indicative for the productive potential of the hybrids and varieties tested (Table 2). For the first swath, the green mass yield varied from 32.9 t/ha to 39.8 t/ha with 35.2 t/ha for the group standard. For the second swath good productive potential demonstrated the Sudan grass variety Vercors, which exceeded the group standard by 26.3%. Similar were the test data of the cultivar “Shumensko sladko”, whose yield exceeded the standard by 15.3%. The total green mass productivity of the first and second swaths was considerable - from 52.7 t/ha for Super Sweet to 63.9 t/ha for “Shumensko sladko”. It was noted that most of the tested origins exceed the group standard. The results obtained with respect to the total yield of dry mass per unit area retain the differentiation between the individual genotypes. The highest yield of dry biomass in the study period was formed by the Vercors and Super Sweet - 24.1 t/ha. They were proven to exceed the standard by 7.6%.

Table 1. Air temperature and rainfall in the region of Agricultural Institute-Shumen during 2017-2018

Years	Month	Rainfalls, mm					Air temperature, °C
		Decades					
		I	II	III	Amount	Norm	Mean
2017	IV	1.4	31.3	8.5	41.2	41.0	9.8
	V	21.3	6.4	10.6	38.3	64.0	15.5
	VI	59.6	19.6	-	79.2	75.0	21.3
	VII	65.5	1.8	29.5	96.8	60.0	21.6
	VIII	-	0.5	35.3	35.8	42.0	23.0
	IX	-	0.2	3.5	3.7	28.0	20.3
Total for the vegetation					371.3		
2018	IV	11.4	2.5	-	13.9	41.0	18.2
	V	26.6	41.6	2.8	71.0	64.0	17.8
	VI	12.0	1.0	55.4	68.4	75.0	20.8
	VII	12.3	27.8	100.5	140.6	60.0	23.0
	VIII	3.6	0.4	0.3	4.3	42.0	25.5
	IX	18.3	3.8	2.2	24.3	28.0	17.8
Total for the vegetation					322.5		

Table 2. Sudan grass and Sweet sorghum forms productivity in brooming phase, 2017

Variant	I swath			II swath			Total yield			
	Green mass, t/ha	Relative, %	Dry matter, %	Green mass, t/ha	Relative, %	Dry matter, %	Green mass, t/ha	Relative, %	Dry mass production, t/ha	Relative, %
Endje 1	36.8	104.5	25.0	22.7	108.6	50.0	59.5	106.1	20.6	92.0
SWT	36.8	104.5	34.3	20.7	99.0	44.4	57.5	102.5	21.8	97.3
Vercors	32.9	93.5	37.0	26.4	126.3	45.0	59.3	105.7	24.1	107.6
Super Sweet	33.6	95.5	45.4	19.1	91.4	46.3	52.7	93.9	24.1	107.6
Shumensko sladko	39.8	113.1	31.6	24.1	115.3	38.2	63.9	113.9	21.8	97.3
Zaharna metla	38.8	110.2	32.0	18.4	88.0	40.7	57.1	101.8	19.9	88.8
Group standard	35.2	100.0	35.2	20.9	100.0	48.2	56.1	100.0	22.4	100.0
GD 5%	4.70	13.4		3.35	16.0		4.19	7.5	1.81	8.1

*Dry mass production- the total dry mass is the sum of the dry mass of the two swaths, which is calculated by the percentage of dry matter from each swath.

During 2018, the trend of unfavorable climatic conditions in the critical development phase of Sudan grass and sweet sorghum forms continued. Again, an uneven distribution of rainfall and drought, accompanied by high temperatures were observed. In April, only 13.9 mm of rainfall fell during the sowing period at a normal monthly rate of 41.0 mm (Table 1). This led to a delay in germination and to some extent affected the relatively lower yields received this year. The dynamics of meteorological factors and its interaction with the genotype influenced the formation of differences in the productivity of the tested Sudan grass origins and sweet sorghum forms (Table 3). Data for the total yield from the two swaths indicated that among the selected materials bred at the Agricultural Institute – Shumen, Endje 1 and "Shumensko sladko" cultivars gave stable yields of green mass exceeding the group standard by 12.8% and 8.5%, respectively. The same was the case with the dry mass yield, an indicator where the excess especially for Endje 1 is palpable – with its 52.7 t/ha the dry mass yield it exceeded the group standard by 17.3%. The results for green and dry mater productivity dependence correspond with the data by Zamfir et al. (2001) and Kikindonov et al. (2013).

The average data from the two years' test of standard Sudan grass varieties, sweet sorghum forms and Sudan grass from the gene pool of Agricultural institute – Shumen, confirmed their high potential for accumulation of green and dry mass in unfavorable agro-meteorological conditions.

Table 4 indicates the average data for total green and dry mass yields from the comparative test of standard varieties, stabilized population and sugar forms. The first swaths are most productive and vary from 28.8 t/ha to 36.2 t/ha. The cultivar "Shumensko sladko" produced 36.2 t green mass per ha. In addition, the overall green mass yields are lower than in 2017. The data analysis on the total yield indicated that the highest yield of green mass obtained by two swaths in brooming phase was given by cultivar "Shumensko sladko", which exceeded the group standard by 12.2% or 59.5 t/ha.

Table 3. Sudan grass and Sweet sorghum forms productivity in the brooming phase, 2018

Variant	I swath			II swath			Total yield			
	Green mass, t/ha	Relative, %	Dry matter, %	Green mass, t/ha	Relative, %	Dry matter, %	Green mass, t/ha	Relative, %	Dry mass production, t/ha	Relative, %
Endje 1	33.8	110.5	29.2	23.4	116.4	47.5	57.2	112.8	21.0	117.3
SWT	20.7	67.6	28.3	17.3	86.1	39.7	38.0	75.0	12.7	70.9
Vercors	26.4	86.3	31.7	19.1	95.0	40.7	45.5	89.7	16.1	89.9
Super Sweet	27.3	89.2	28.3	16.8	83.6	41.9	44.1	87.0	14.8	106.5
Shumensko sladko	32.5	106.2	30.1	22.5	112.0	42.8	55.0	108.5	19.4	108.4
Zaharna metla	30.2	98.7	26.8	13.8	68.7	42.3	44.0	86.8	13.9	77.7
Group standard	30.6	100.0	34.8	20.1	100.0	44.9	50.7	100.0	17.9	100.0
GD 5%	5.25	17.2		3.03	15.1		3.52	6.9	2.23	12.3

*Dry mass production- the total dry mass is the sum of the dry mass of the two swaths, which is calculated by the percentage of dry matter from each swath.

Table 4. Average data for productivity of green and dry mass in Sudan grass and Sweet sorghum forms, 2017-2018

Variant	I swath			II swath			Total yield			
	Green mass, t/ha	Relative, %	Dry matter, %	Green mass, t/ha	Reletive, %	Dry matter, %	Green mass t/ha	Relative, %	Dry mass production, t/ha	Relative, %
Endje 1	35.3	107.3	27.1	23.1	112.1	48.8	58.4	109.2	20.8	104.0
SWT	28.8	87.5	31.3	19.0	92.2	42.1	47.8	89.3	17.0	85.0
Vercors	29.7	90.3	34.4	22.8	110.7	42.9	52.5	98.1	20.0	100.0
Super Sweet	30.5	92.7	36.9	18.0	87.4	44.1	48.5	90.7	19.2	96.0
Shumensko sladko	36.2	110.0	30.9	23.3	113.1	40.5	59.5	112.2	20.6	103.0
Zaharna metla	34.5	104.9	29.4	16.1	78.2	41.5	50.6	94,6	16.8	84.0
Group standard	32.9	100.0	32.0	20.6	100.0	46.5	53.5	100.0	20.0	100.0
GD 5%	4.65	14.1		3.13	15.2		3.84	7.2	1.22	6.1

*Dry mass production- the total dry mass is the sum of the dry mass of the two swaths, which is calculated by the percentage of dry matter from each swath.

The amount of the main chemical ingredients in the fodder crops determines their quality. The results of quantitative chemical analysis of the tested Sudan grass and local sweet sorghum varieties are presented in Table 5. The highest dry matter content of the studied forms was found in SWT (35.73%), and the lowest in Super Sweet (24.09%). The amount of organic matter varied from 22.03% in Super Sweet to 32.81% in SWT. The lowest crude protein content in the dry mass was found in the Endje 1 samples (6.05%) and the highest in Super Sweet samples - 9.00%. The dry matter, organic matter and crude protein content demonstrated moderate variability – CV=14.6-16.8%. Similar results for the content of crude protein and crude fat in Sudan grass were published by Slanev (2012).

The proportion of crude fiber was within a relatively narrow range (CV=6.1%) and varied from 32.64% for Endje 1 to 39.26% for the local population "Zaharna metla". The highest level of nitrogen free extracts was found in the forage from Endje 1 – 51.20% and the lowest in the forage from "Zaharna metla" – 42.05%, the parameter showed low variability – CV=7.6%. The mineral content in the tested varieties varied in narrowest borders compared to the other parameters – CV=5.9% (from 8.17%, SWT to 9.61%, Vercors).

Macroelements Ca and P play a very important role in the metabolism of plants (Silungwe, 2011). The content of Ca ranged from 0.899% for "Shumensko sladko" to 1.572% for Vercors. Ca values in aboveground origin biomass of the tested cultivars were above the recommended minimum value in cattle feed of 0.310% (McDowell, 1997). The content of P on average for all tested cultivars was 0.513%, with the highest content standing out for Endje 1 (0.696%), and the lowest content was that of SWT (0.369%). The deficiency of Ca and P in forage has a negative impact on the growth and reproduction characteristics of the farm animals (Soetan et al., 2010).

In summary, considering the aspects evaluated, all tested

hybrids provided quality hay, however the Bulgarian cultivars Endje 1 and "Shumensko sladko" showed better nutritional value compared to Super Sweet, Vercors, SWT and "Zaharna metla" cultivars.

Table 5. Chemical composition of Sudan grass varieties and sweet sorghum forms, 2018

Variant	Dry matter, %	Organic matter, %	CP, %	Crude fat, %	Crude fiber, %	NFE, %	Mineral substances, %	Ca, %	P, %
Endje 1	27.42	25.00	6.05	1.28	32.64	51.20	8.83	1.188	0.696
Vercors	34.46	31.15	6.79	2.21	36.77	44.63	9.61	1.572	0.423
SWT	35.73	32.81	7.00	1.29	36.36	47.16	8.17	1.248	0.369
Super Sweet	24.09	22.03	9.00	2.28	37.48	42.59	8.55	1.004	0.452
Zaharna metla	29.32	26.72	7.44	2.39	39.26	42.05	8.87	0.958	0.682
Shumensko sladko	24.69	22.38	8.42	2.30	35.60	43.66	9.36	0.899	0.453
Mean	29.28	26.68	7.45	1.96	36.35	45.22	8.90	1.144	0.513
CV, %	16.7	16.8	14.6	26.8	6.1	7.6	5.9	21.8	27.3

*NFE- nitrogen free extracts

Conclusion

The tested standard varieties, Sudan grass and Sweet sorghum forms (Endje 1 and "Shumensko sladko") from the breeding program of Agricultural institute – Shumen have shown their adaptive potential for high biomass yields during the brooming phase. In unfavorable climatic conditions, biomass yield from 46.8 to 59.5 t/ha was established, with 16.8-20.8% dry mass content. The tested origins have good nutritional properties of the biomass obtained in the phase of brooming, with crude protein content from 6.05 to 9.00%, crude fiber content from 32.64 to 39.26%. The content of Ca ranges from 0.899% for "Shumensko sladko" to 1.572% for Vercors and for P from 0.369% (SWT) to 0.696% (Endje 1). The Bulgarian cultivars Endje 1 and "Shumensko sladko" are superior in performance and plasticity to the standard varieties used in the practice.

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