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RESEARCH ARTICLE

ASSESSMENT OF THE EFFECTIVENESS OF BIOMASS ACCUMULATION IN SUDANGRASS, SORGHUM x SUDANGRASS HYBRIDS AND SWEET SORGHUM FORMS

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ABSTRACT

The increasing tendency of deviations from the agro-climatic norms forces the search of alternative forage crops. The great variety of grain and sweet sorghum forms, sudangrass and their hybrids of the breeding program of Agricultural Institute – Shumen is a good basis for selection of adapted to the actual conditions genotypes, allowing harvest of green mass in different stages of the crops' development during vegetation. The many years studies – breeding and technological, of the sudangrass, sorghum x sudangrass hybrids and sweet sorghum forms allows summarizing the field test results of Standard varieties and materials bred in the Institute for productivity of green and dry mass. It has been studied the genotype and the agro-climatic conditions' influence on the productive potential of Standard varieties, populations and sorghum x sudangrass hybrids. Assessment is made for the effectiveness of harvesting the tested origins in four stages of development – brooming, flowering, milky-wax and technological maturity of seeds. The application of different schemes of harvesting diversifies the sources of green mass as rich forage for production of silage, haylage and hay.

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INTRODUCTION

The tendency of extreme deviations from the climatic norms forces the search of alternative forage crops. Sorghum and sudangrass show high productive potential for accumulation of green and dry mass in the conditions of water and temperature stress (Serafimov and Golubinova, 2015). The great variety of grain and sweet sorghum forms, sudangrass and their hybrids widens the basis for selection of adopted to the actual conditions genotypes, allowing harvest of green mass in different stages of the crops' development during vegetation. These features update their application for minimizing the risk and the stabilization of the forage balance in the practice (Kikindonov *et al*., 2008, 2011; Slanev *et al*., 2011). Sudangrass forages are grown extensively to provide supplementary forage for animals as pasture, greenchop, silage and hay (Lenobles and Feyt, 1983; Moyer *et al*., 2004). They are known for their better tolerance to drought compared to other annual summer grasses and are more yielding than corn in areas with higher temperatures and lower and uneven vegetation rainfalls (Fribourg, 1995).

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The sudangrass (*Sorghum sudanense* (Piper) Stapf) is a natural interspecies hybrid of *S. bicolor* and *S. arundinaceum* (Harlan and Wet, 1972). It is introduced in 1900's in the USA from Ethiopia and Sudan, and in 1930's its introduction in Russia and Eastern Europe begins (Hacker, 1992). A survey of breeders of sudan type *Sorghum ssp* by Kalton (1988) showed that selections made were primarily for total yield, leafness, digestibility, regrowth capacity, diseases resistance and low prussic acid content. Since 1950's Sudangrass has been hybridized with other Sorghum ssp to increase forage productivity. The development of the CMS-system in sorghum widens dramatically the possibilities of use of sorghum MS-lines as maternal component and lines and varieties of sudangrass as pollinators for obtainment of F_1 hybrids (House, 1995). The studies of the combining ability and the correlations of yield components with the concrete agro-climatic conditions multiply the selection potential of great genetic diversity of sorghum hybrids (Paknejad *et al*., 2001). Two types of sudangrass hybrids are currently grown in the world. The true sudangrass hybrids of sudangrass MS-lines and restorers resemble the common sudangrass in growth and quality characteristics however they tend to be taller, have an intermediate stem diameter and are higher yielding than sudangrass. These hybrids recover rapidly after harvest and are very productive (Beurlein *et al*., 1968; Serafimov and

Golubinova, 2015). Sorghum x sudangrass hybrids (*S.bicolor* (L) Moench x *S. sudanense* (Piper) Stapf), are more vigorous and taller than sudangrass, have larger stems and coarser leaves, and give higher forage yield when harvested twice or more times at the flower stage for green chop, or once at the late milk stage for silage production (Snyman and Youbert, 1996). The hybrids of sudangrass show their high productivity potential in optimum conditions of cultivation, but owe their wide spreading to their high adaptability and resistance to extreme droughts, high temperatures and salt resistance, that's why they attain actuality in South-Western Europe (Antocha, 1994; Kertikov, 2007; Uzun *et al*., 2009).

The demand of the sweet sorghum (Sorghum bicolor var. Saccharatum H.) as a forage and energy crop also increases because of the favorable ratio of saccharose and monosaccharides like fructose and glucose. It is well known in the temperate climate areas as one of the crops with the highest effectiveness of biomass accumulation in the conditions of extreme droughts and global warming. Apart from the old pure forms of local populations and varieties the modern sweet sorghum forms include various hybrids with sudangrass, technical sorghum and grain sorghum. They are with strongly expressed hybrid vigor and optimum combination of high productivity, multiple regrowth, content of carbohydrates, proteins and cellulose and are used for forage production. As a result of our long term studies in the breeding and technology of sudangrass, sorghum x sudangrass hybrids and sweet sorghum forms we could make a summarized assessment of standard varieties and bred in our Institute forms for their green and dry mass productivity. The application of different schemes of harvesting in brooming, flowering, milky-wax and technical maturity of seeds stages varies the sources of green mass for the silage, haylage and hay production.

MATERIAL AND METHODS

Tested material

The following Standard varieties have been used in our study: sudangrass variety Vercor, sorghum x sudangrass hybrid Susu, sweet sorghum forms – the direct varietiy Yantar and the hybrid Super Sweet, stabilized sudangrass populations SVE, hybrids of sudangrass and sweet sorghum SZE (Endje) and stabilized populations SAV and SAZ from hybridization of sudangrass and sweet sorghum with grain sorghum MS line SA.

Agro-technical measures

The field experiments are sown after sugar beet predecessor in a 6-crop rotation of vetch and oats mix, beet, sorghum, barley, corn, wheat. An autumn plowing at 35 cm is applied, followed by two cultivations before sowing. The weed control is performed by hilling and 2.4D treatment. If necessary in case of aphids attack treatment with insecticide is applied.

Experimental design

The sowing is made at the end of April – beginning of May, when the soil temperature reaches over 10-12ºC, at 45 cm distance between the rows in 2010-2012 and 75 cm between the rows – in 2013-2014. The sowing norm is 30 kg/ha, which, depending on the seeds absolute weight and germination forms a density of sowing of 110 to 130 plants per m^2. The scheme of the tests is fractional plots, 3 rows for origin with 4 replications for each variant, 10.8 m^2 area of the experimental plot. In order to avoid the influence of the neighbor row for yield determination statistically treated is only the weight of the inner row, i.e. the area of the harvest plot is 3.6 m^2. Manual cutting is made when 50% of plants reach the relevant stage of development. A mean sample is taken from each stage of each origin for determination of the dry matter content.

Statistical treatment of the results

Data of the productivity field tests were treated by dispersion analysis for the limiting values of the proved differences – GD and the experimental exactness – P%. The method of Lidanski (1988) for statistical treatment of the mean of long standing tests' results is used for analysis of the major influence of the factors.

RESULTS AND DISCUSSION

The period of study ranges over five years, differing significantly between each other and with the climatic norm regarding the volume and the distribution of the rainfalls and temperatures during the vegetation. 2010 could be characterized as a good year for the development of sorghum and sudangrass. The total rainfalls sum is high, the rains fallen in May and June together with the low temperatures are unfavorable for the germination and the initial development of the crops. The conditions in July, August and September compensated the initial delay and up to 15th of September were realized productive green mass and technical maturity grain grow ups. The spring of 2011 was continuous and cool. The air temperature reached 15ºC after 15th of May, which forced a late sowing on 12-15.05. The low temperature sum determines the delay in the development of thermophilic crop like sorghum, which confirms what Dorgevic *et al*. (1992) have noted in their studies. The rainfalls are unevenly distributed during the vegetation, which describes the year as an unfavorable. The stable weather allowed postponing the cuttings and the harvesting till the end of September, and that compensated to certain extent the unfavorable agro-climatic factors. The conditions in 2012 were extremely unfavorable – cool and prolonged spring, followed by a record-braking for the last decade drought. Despite the well-timed sowing (25-27.04) the comparatively low temperatures in May delayed the initial development of sorghum and sudangrass. The following continued extreme drought strongly affected the productivity of cuttings for green mass in flowering stage and in milky-wax stage. The worst was the affect of the drought on the second and third swaths in broom stage and on the second swath in flowering stage. 2013 was a comparatively normal year for the development of the studied crops. The average monthly temperatures and the vegetation rainfalls sum do not differ significantly from the norm, but the distribution of rainfalls was uneven. The conditions in 2014 were especially unfavorable for timely implementing of the agro-technological measures. The rainfalls exceed three times the norm.

Table 1. Duration of vegetation, sum of rainfalls and temperatures for cultivation of Sudangrass, sorhum x Sudangrass hybrids and sweet sorghum forms, experimental fields of AI-Shumen, 2010-2014

Variant	Years				
	2010	**2011**	**2012**	**2013**	**2014**
Dates of sowing	**28.04**	**12.05**	**27.04**	**24.04**	**05.05**
Duration of vegetation, days after sowing					
I swath in broom stage	70	60	60	65	55
II swath in broom stage	35	30	37	33	36
IIIswath in broom stage	30	40	47	35	42
I swath in flowering stage	85	75	73	79	82
II swath in flowering stage	45	45	58	45	52
Milky-wax maturity stage	110	100	93	106	130
Technical maturity stage	135	130	141	131	143
Sum of rainfalls, ml					
I swath in broom stage	250	75	108	163	355
II swath in broom stage	41	49	22	45	103
III swath in broom stage	38	46	42	42	70
I swath in flowering stage	285	82	112	147	370
II swath in flowering stage	43	68	47	42	107
Milky-wax maturity stage	301	143	102	178	490
Technical maturity stage	328	168	162	195	536
Temperature sum, ºC					
I swath in broom stage	1182	954	1202	1068	1160
II swath in broom stage	793	796	807	795	820
IIIswath in broom stage	661	863	801	762	620
I swath in flowering stage	1499	1058	1462	1288	1270
II swath in flowering stage	1116	1554	1162	1188	1120
Milky-wax maturity stage	2233	1863	2130	2087	2501
Technical maturity stage	2929	2613	2790	2683	2708

Table 2. Summarized results for productivity of Sudangrass, sorghum x sudangrass hybrids and sweet sorghum forms in brooming stage, 2010-2014

Variant	Productivity, t/ha					
	I swath green mass	**II swath green mass**	**III swath green mass**	**Total Yield**		**Dry mass per day**
				Green mass	**Dry mass**	
Genotype						
Susu	34.0	26.3	18.5	78.8	24.7	0.20
Vercors	32.8	19.5	20.3	80.7	27.3	0.19
SVE	34.7	26.5	20.4	81.5	23.7	0.16
SAxSV	41.3	31.6	20.5	93.2	31.7	0.20
SAxSZ	39.3	27.2	19.8	86.5	29.0	0.16
SZE(Endje)	35.5	31.4	21.3	88.0	26.5	0.18
Yantar	34.2	28.0	17.7	77.9	24.0	0.15
Super Sweet	39.5	41.0	26.6	107.0	34.9	0.19
Year						
2010	38.1	31.8	15.6	85.9	23.3	0.18
2011	33.8	28.1	25.6	87.5	32.0	0.20
2012	35.7	31.0	14.4	81.1	32.2	0.17
2013	22.5	35.3	25.0	82.8	20.5	0.16
2014	21.6	37.9	34.4	93.4	30.5	0.20
Average	**30.3**	**32.8**	**23.0**	**86.2**	**27.7**	**0.17**
GD 1%	13.7	11.5	6.08	22.1	4.89	
P %	4.37	4.01	4.72	4.32		

Table 3. Summarized results for productivity of Sudangrass, sorghum x Sudangrass hybrids and sweet sorghum forms in flowering stage, 2010-2014

Variant	Productivity, t/ha				
	I swath green mass	**II swath green mass**	**Total Yield**		**Averaged dry mass per day**
			Green mass	**Dry mass**	
Genotype					
Susu	46.9	31.4	78.3	24.1	0.24
Vercors	36.0	27.8	63.8	20.4	0.19
SVE	41.8	32.3	74.1	24.2	0.17
SAxSV	50.7	33.4	84.1	29.4	0.23
SAxSZ	48.8	30.0	78.8	27.8	0.22
SZE(Endje)	45.2	27.7	72.9	22.6	0.23
Yantar	49.7	27.7	77.4	24.8	0.20
Super Sweet	45.7	35.5	81.2	27.1	0.26
Year					
2010	49.7	33.0	82.7	22.0	0.17
2011	46.5	41.4	87.9	29.7	0.25
2012	45.6	29.9	74.8	27.7	0.21
2013	40.4	27.6	68.0	20.4	0.17
2014	48.6	36.3	84.4	33.5	0.25
Average	**46.1**	**33.5**	**79.7**	**26.7**	**0.21**
GD 1%	7.22	8.12	11.3	3.90	
P %	4.31	4.69	3.90		

Table 4. Summarized results for productivity of Sudangrass, sorghum x Sudangrass hybrids and sweet sorghum forms in milky-wax and technological maturity of grain, 2010-2014

Variant	Milky-wax maturity		Dry mass per day	Technical maturity		Dry mass per day
	Green mass	**Dry mass**		**Green mass**	**Dry mass**	
			Genotype			
Susu	71.7	40.0	0.32	67.3	47.7	0.36
Vercors	58.0	31.2	0.22	52.0	38.7	0.30
SVE	63.0	37.8	0.21	59.7	45.3	0.34
SAxSV	75.9	43.3	0.80	69.8	49.2	0.37
SAxSZ	78.8	45.2	0.35	73.2	55.0	0.42
SZE(Endje)	73.7	40.3	0.28	67.7	50.2	0.38
Yantar	71.2	35.7	0.33	64.2	42.3	0.31
Super Sweet	74.3	40.7	0.31	69.3	46.7	0.36
			Year			
2010	75.8	49.1	0.36	66.6	52.1	0.36
2011	65.7	30.6	0.30	62.3	41.4	0.34
2012	41.4	21.6	0.24	40.0	34.5	0.34
2013	51.4	29.3	0.27	57.1	42.1	0.32
2014	72.4	41.0	0.31	74.8	38.1	0.30
Average	**61.3**	**34.3**	**0.39**	**60.2**	**41.6**	**0.32**
GD 1%	8.22	4.95		9.87	7.94	
P %	3.81	3.42		4.76	4.88	

In May and September – the months which are overloaded with agro-technical operations for timely sowing and harvesting (Samuil, 2007), the rainfalls were record-braking. This brought to delay of the sowing and the normal development of the crops and to strong development of weeds in the experimental fields. The open winter favors the multiplication and the development of the field mouse population, which caused great local damages in the crops.

Data of the vegetation duration, the sums of rainfalls and temperatures during the separate years are given in Table 1. The marked extreme deviations from the climatic norms brought to strong variation in the temp of development and the accumulation of green and dry mass of the tested origins in the different stages of development. The main effect of the factors year of test and genotype on the productivity from cutting in broom stage for the period 2010-2014 is given on Table 2. The productivity parameters vary in a wide range. The hybrid Super Sweet proves to be with the highest productivity, with total yield from three swaths of green and dry mass respectively 107.0 and 34.9 t/ha. The variety Yantar is with the lowest total yield of green mass – 77.9 t/ha. The analysis of the year of test factor shows that despite the agro-climatic differences during the whole period of study similar yields of green mass are obtained. The case is different with the dry mass productivity, where significant differences are observed. Similar results have been reported by other researchers (Lloveras *et al*., 2006). The harvesting of sorghum and sudangrass in flowering stage brings to optimal combination of the quality (Serafimov and Golubinova, 2015) and the volume of the green mass. In the conditions of Northeastern Bulgaria two swaths of full value are possible. The analysis of the main effect of the genotype of the tested origins and the conditions during the years of testing are given in Table 3. The averaged data of 5 years tests of 8 origins show significant extent of variation for the first swath, the second swath and for the total green mass yield. Significantly lower are the differences in the dry mass yield, which being a resultant quantity shows the adaptive potential of the tested origins. The differences in the summarized results of the test increase with the later development.

The forage and the sweet forms of sorghum, the sudangrass and sorghum x sudangrass hybrids are useful for silage production when cut after grain milky maturity stage (Moyer *et al*., 2004). The preservation of the fresh condition of the plants after the physiological maturing of the seeds in wax maturity gives possibility of harvesting high quality raw material for continuous silage even in extremely dry years. The results in Table 4 for the main action of the factors confirm the influence of the genotype and the conditions on the productivity with high degree of proof. The advantage of the sweet sorghum and the hybrid forms regarding the yield of green and dry mass for silage is significant for the stage from milky to technical maturity of the grain. The most indicative is the influence of the agro-climatic conditions in the comparison between the favorable 2013, the dry 2012 and the extremely wet 2011 and 2014. The vegetation rainfalls have the biggest effect on the productivity of the Sudangrass and its hybrids. The development of Sorghum and Sudangrass is strongly affected by the vegetation temperature sum. The significant differences in the agro-climatic factors of the years of our study allow reliable assessment of the productive potential and the adaptability of the sorghum-sudangrass hybrids in conditions of extreme deviations from the norm. Data of the obtained dry mass per day as a resultant index are exact assessment of the tested origins and the system of harvest for the most effective biomass accumulation during the vegetation. Despite the bigger in volume total green mass yields by cutting in broom and flower stages, the total growth and the intensity of dry mass accumulation per day is increased with the later cuttings.

The summarized data of testing the sweet sorghum forms, the sudangrass and their hybrids of the gene pool of AI-Shumen in the conditions of Northeastern Bulgaria confirm their high potential for green and dry mass accumulation in differing agro-climatic conditions.

In general, we could outline the following conclusions

The genotype and the agro-climatic conditions directly affect the productive potential of the tested varieties, populations and sorghum x sudangrass hybrids, and efficiency of harvesting the studied origins in four development stages – brooming, flowering, seeds milky-wax and technical maturity. The variety of grain and sweet forms of sorghum, sudangrass and their hybrids is good basis for effective selection of adopted to the actual conditions genotypes and harvesting green mass in a wide range of plants development.

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