РЕЗУЛТАТИ ОТ СЕЛЕКЦИЯТА НА СУДАНКА, СОРГО-СУДАНКОВИ ХИБРИДИ И ЗАХАРНО СОРГО ЗА ПРОДУКТИВНОСТ НА ЗЕЛЕНА МАСА
RESULTS OF BREEDING SUDANGRASS, SORGHUM-SUDANGRASS HYBRIDS AND SWEET SORGHUM FOR GREEN MASS PRODUCTIVITY

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Abstract

The increasing tendency of extreme deviations from the agro-climatic norms has enforced the search of alternative forage crops. Sorghum and sudangrass show high productive potential for the accumulation of green and dry mass under the conditions of water and temperature stress.

Effective breeding of segregating populations of F_2-F_5 progenies for the isolation of genotypes with improved productivity indices and for the enrichment of the gene-pool of pollinators for the creation of new sorghum x sudangrass hybrids has been realized. As a result the sudangrass variety *Endje* was bred and certified.

The influence of the genotype and the agro-climatic conditions on the productive potential of standard varieties such as *Verkor, Susu, Super Sweet, Endje* and *Yantar* was studied as well as on populations and sorghum x sudangrass hybrids, part of the breeding program of the Agricultural Institute – Shumen.

The great variety of grain and sweet sorghum forms, sudangrass and their hybrids of the breeding program of Agricultural Institute – Shumen widens the basis for selection of genotypes adapted to the actual conditions, allowing the harvest of green mass at different stages of the crop development during vegetation.

Key words: sorghum, sudangrass, hybrids, breeding, productivity.

INTRODUCTION

The increasing tendency of extreme deviations from the agro-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. 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 (Moyere et al., 2004; Lenobles, 1983). They are known for their better tolerance to drought than other annual summer grasses and are more yielding than corn in areas with higher temperatures and lower and uneven precipitation (Friboarg et al., 1995).

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 (Haecker, 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 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 (Sotomayor Rios et al., 1984; Shon Yun et al., 1999; 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).

Sorghum-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 two or more times at the flower stage for green chop, or one time at the late milk stage for silage production (Snyman and Youbert, 1996; Paknejad et al., 2001).

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 it attains actuality in South-Western Europe (Antocha, 1994; Kertikov, 2007; Uzun et al., 2009).

In the article are given results of Sudangrass, Sorghum-sudangrass hybrids and sugar sorghum forms breeding in the Agricultural Institute-Shumen during the last years. It has been assessed the influence of the genotype and the agro-climatic conditions on the productive potential of Standard varieties like Verkor, Susu, Super Sweet, Endje-1 and Yantar, populations and Sorghum x Sudangrass hybrids of the breeding program of Agricultural Institute – Shumen.

MATERIALS AND METHODS

This study was conducted at the Agricultural Institute-Shumen, located in North-Eastern Bulgaria, during the period 2000–2014.

In 2000 were obtained hybrids of the stabilized populations Sudan Sooner, Sudan Sweet, and Sudan Elit with 2 MS-lines of grain sorghum of the French company Euralis Semences: RS28/A – indicated with SAF_1, ZAF_1 and VAF_1, and RS22/A- indicated with SBF_1, ZBF_1 and VBF_1. In the period 2001 - 2006 seeds have been harvested from selected plants in F_2 - F_5 progenies of the hybrids SAF, ZAF and VAF. After their assessment in 2006 and 2007 through uniting of the best of them by dry matter content, green yield and dry matter yield, have been created the synthetic populations S-SP, Z-SP and V-SP.

The variety "Endje-1" is created in Agricultural Institute – Shumen by individual selection for productivity and diseases resistance from a cross of a local population of sweet sorghum (Northeastern Bulgaria origin) with a stabilized sudangrass population of Agricultural Institute - Shumen.

In the period of study have been created and tested sorghum-sudangrass hybrids of two selected sudangrass pollinators with ten MS lines of grain sorghum of the breeding program of AI. The pollinator SV is elite origin of typical sudangrass, while the SZ pollinator is a stabilized population after hybridization of sudangrass with sweet sorghum.

The long standing activity on breeding and technology of sudangrass, sorghum-sudangrass hybrids and sweet sorghum forms allow to summarize the results of the assessments of standard varieties and forms, bred in AI-Shumen, 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 lengthen the period of obtaining green mass as a fresh forage and for the silage and hay production.

The soil type of the experimental fields was a carbonate black-earth with good mechanical structure and weakly alkaline reaction of the soil solution. The used experimental design for the tests of the varieties and hybrids was a random complete block in 4 repetitions, and the long plots method with 2 repetitions was used for the tests of the selected individual progenies. The experimental plot was 10.8 m^2, in three 8m rows, the row spacing was 45 cm. The experimental plot of the selected individual progenies was 3.6 m^2, in 1 row. Seeds were sown at 20 kg/ha^{-1} seed rate, at 4-5 cm depth, in the period 25.04 – 05.05. The tested origins were harvested 3 times, two times at flower stage and once at late milk stage. The cutting was manual when the plants reached 50% of the height of the standards in the relevant development stage. Average sample was taken of each origin and each stage for determination of the dry matter content.

Data of the field experiments for productivity were treated by dispersion analysis for determination of the limiting values of the warranted differences – GD and the experiments accuracy, and for the analysis of the main action of the factors was used the method of Shanin for statistical treatment of the averaged results of multiannual experiments.

RESULTS AND DISCUSSION

They have been selected 100 F_2 progenies from the tested hybrids, which were tested for productivity and dry matter content from a single swath in flower stage. For check are included the Standard varieties Verkor, Susu and Super Sweet, as well as the hybrids SAF, ZAF and VAF.

From 5 progenies, exceeding the most yielding Standard Super Sweet, and from 3 progenies, exceeding in dry matter content the Standard Verkor, have been selected 64 F_{3-5} progenies. The average productivity of the progenies – 29.4 t/ha, is below that of the Group Standard - 35 t/ha and varies from 20 to 46 t/ha, with variation coefficient C_v% = 25.8%. The dry matter content varies from 22.9% to 86.4%, and the mean value of the F_5 progenies – 29.4%, exceeds the Standard value of 26.9%.

From the three progenies with higher than the most productive standard variety Verkor's productivity was formed a synthetic population Z-SP. The F_3 progenies with higher dry matter content than that of Susu were separated in two populations. In S-SP were included the progenies with the biggest dry matter content, and in V-SP – those with the highest productivity.

In 2008, in conditions of extreme drought and high temperatures, the Standard varieties, the pollinators, the sorghum-sudangrass hybrids and the newly formed synthetic populations were tested (Table 1). The productivity of the hybrids varies close to the Group Standard's values of 67 t/ha green yield and 22 t/ha dry yield, formed from two swaths in flower stage. Two of the hybrids – VAF_1 and VBF_1 exceed the Standard with proven differences. In late milk stage three of the hybrids significantly exceed the Standard's value of 49 t/ha. The dry matter content values vary from 44.0 to 52.0%.

After 5 cycles of individual selection have been differentiated three perspective synthetic populations with improved own productivity and dry matter content, which have a good potential for use as paternal components for the creation of new sorghum-sudangrass hybrids.

As a result of individual selection for productivity and disease resistance from a cross of local populations of sweet sorghum and sudangrass was bred the new sudangrass variety Endje-1, which is certified by the Bulgarian Patent Bureau (Certficate №10918/30.12.2010). In this way the long term lack of any breeding researches with the crop in Bulgaria was interrupted. Now we are on the road of intensive development of such researches in this sphere, characteristic for the worldwide science. (Antocha, 1994; Uzun et al., 2009).

Table 1. Productivity of Sorghum-sudangrass hybrids for green yield at flowering and late milk stage Group standard – Verkor, Susu, Super Sweet, 2008

Variant	Flowering stage (harvested twice)				Late milk stage		
	Green yield		Dry yield		Dry matter, %	Green yield	
	t/ha	Rel., %	t/ha	Rel., %		t/ha	Rel.,%
Group Standard	**67.3**	**100.0**	**22.0**	**100.0**	**48.7**	**51.4**	**100.0**
Verkor	75.1	111.7	23.5	106.8	45.8	41.3	80.3
Susu	69.3	103.0	24.1	109.5	47.9	53.0	103.0
Super Sweet	57.4	85.4	18.4	83.7	52.4	60.0	116.7
Sudan Sooner	40.4	60.0	16.9	76.8	46.8	33.9	65.9
Sudan sweet	50.4	74.9	17.2	78.4	50.0	44.5	86.4
Sudan Elite	59.6	88.7	18.7	84.9	46.8	42.3	82.2
SAF_1	68.7	102.2	22.7	103.1	45.2	46.7	90.8
SBF_1	68.5	101.9	23.0	104.6	44.0	47.4	92.2
ZAF_1	65.0	96.7	22.6	102.7	49.3	60.8	118.2
ZBF_1	64.1	95.3	22.3	101.3	44.0	61.1	118.8
VAF_1	74.8	111.2	24.8	112.7	50.6	45.1	87.7
VBF_1	88.9	132.2	29.6	134.6	49.3	58.8	112.7
S-SP	55.1	81.8	25.1	114.1	48.9	39.3	76.4
Z-SP	69.6	103.5	18.7	85.1	44.0	48.5	94.4
V-SP	67.0	99.7	20.0	91.1	48.1	48.2	93.6
GD 1%	11.0	16.4	3.72	17.3		5.29	10.3
P %	4.15		3.92			4.30	

In Table 2 are given the averaged data for productivity of the tested in 2009-2012 sorghum-sudangrass hybrids. The Standard varieties Sooner Sweet and Susu show themselves as highly productive in the three swaths. A part of the hybrids exceed the Standards in the variant of cutting in flower stage and have higher dry matter content. With the second cutting the tested hybrids fall back the Standards significantly in their green mass productivity, while regarding their dry matter content they are more qualitative. The total green mass productivity is also significant in flower stage – from 54.65 t/ha to 94.01 t/ha for the hybrids, and 80.48 t/ha for the Standard. The dry mass varies from 20.77 to 33.85 t/ha for the hybrids, and 27.37 t/ha for the Standard.

In milky-wax maturity stage the higher productive potential of the tested sorghum-sudangrass hybrids is manifested, as well as their hybrid vigor towards the sudangrass pollinators.

The long-standing activity on breeding and technology of sudangrass, sorghum-sudangrass hybrids and sweet sorghum forms allows us to summarize the results of the assessments of the Standard varieties and the forms bred in the Agricultural Institute – Shumen regarding their green and dry mass productivity. On Table 3 is represented the main action of the factors year of testing and genotype on the productivity during cuttings in broom and flower stages in the period 2010-2014. The productivity parameters of the tested origins vary in a wide range.

Table 2. Green mass productivity of Sudan grass and Sorghum x Sudan grass hybrids, 2009 – 2012

Variant	Total yield from 3 swaths in brooming		Total yield from 2 swaths in flowering		Yield in milky-wax maturity	
	Green mass t/ha	Dry mass t/ha	Green mass t/ka	Dry mass t/ha	Green mass t/ha	Dry matter %
Susu	**102.22**	**35.78**	**86.67**	**22.53**	**48.15**	**51.0**
Sooner Sweet	**85.56**	**22.24**	**51.85**	**11.93**	**39.26**	**46.0**
Sudangrass VE	**75.19**	**24.81**	**65.93**	**13.84**	**45.19**	**61.0**
SVA	102.59	28.73	51.85	17.63	42.96	56.0
SV7	95.56	23.89	65.93	17.14	42.96	58.0
SV8	102.59	33.86	55.93	16.22	24.07	52.0
SV9	90.37	28.92	82.59	26.43	41.85	52.0
SV10	107.41	29.00	60.37	19.32	60.00	62.0
SV11	81.85	21.28	42.96	12.89	39.26	47.0
SV12	95.56	27.71	77.41	24.00	45.19	58.0
SV13	87.78	21.07	54.81	18.09	34.81	52.0
SV14	122.96	43.04	56.67	18.70	41.85	57.0
SV15	106.67	35.20	60.74	18.22	39.63	55.0
Sudangrass ZE	**77.04**	**24.65**	**66.30**	**22.54**	**42.96**	**51.0**
SZA	95.56	23.89	65.93	17.14	42.96	58.0
SZ7	95.56	23.89	65.93	17.14	42.96	58.0
SZ8	115.93	39.41	86.67	24.27	51.11	58.0
SZ9	94.81	27.50	71.85	22.99	45.19	49.0
SZ0910	98.89	35.60	74.81	23.19	34.81	61.0
SZ0911	95.93	39.33	70.00	22.40	47.78	54.0
SZ0912	95.56	31.53	70.00	20.30	40.74	53.0
SZ0913	121.11	38.76	67.04	20.11	45.56	53.0
SZ0914	98.89	33.62	60.00	19.20	44.44	54.0
SZ0915	94.81	30.34	62.59	18.78	37.78	58.0
For the standard	87.78	29.01	69.26	17.23	43.71	48,5
GD - 1%	10.11	10.34	10.52	11.12	8.64	
P - %	2,48	2,76	3,33	3,85	2,32	

Table 3. Summarized results for productivity (t/ha) of sudangrass, sorghum-sudangrass hybrids and sweet sorghum forms in brooming and flowering maturity stages for the period 2010–2014

Variant	Total Yield of 3 swaths in brooming stage		Dry mass per day	Total yield of two swaths in flowering stage		Dry mass per day
	Green mass	Dry mass		Green mass	Dry mass	
Genotype						
Susu	78.8	24.7	0.20	78.3	24.1	0.24
Vercors	80.7	27.3	0.19	63.8	20.4	0.19
Sudangrass	81.5	23.7	0.16	74.1	24.2	0.17
SAxSV	93.2	31.7	0.20	84.1	29.4	0.23
SAxSZ	86.5	29.0	0.16	78.8	27.8	0.22
Endge-1	88.0	26.5	0.18	72.9	22.6	0.23
Yantar	77.9	24.0	0.15	77.4	24.8	0.20
Super Sweet	107.0	34.9	0.19	81.2	27.1	0.26
Year						
2010	85.9	23.3	0.18	82.7	22.0	0.17
2011	87.5	32.0	0.20	87.9	29.7	0.25
2012	81.1	32.2	0.17	74.8	27.7	0.21
2013	82.8	20.5	0.16	68.0	20.4	0.17
2014	93.4	30.5	0.20	84.4	33.5	0.25
Average	86.2	27.7	0.17	79.7	26.7	0.21
GD 1%	22.1	4.89		11.3	3.90	
P %	4.32			3.90		

The hybrid Super Sweet proves to be the highest yielding with total productivity of green and dry mass from three swaths respectively 107.0 and 34.9 t/ha. Yantar is with the lowest total green mass yield – 77.9 t/ha. The analysis of the factor year shows, that regardless of the differences in the agro-climatic conditions, the total green mass productivity for the period of study is similar for the tested origins. The situation with the dry mass productivity is not the same, as there are substantial differences.

The harvest of sorghum and sudangrass in flower stage brings to optimal combination of the quality and the volume of the green mass. The conditions of Northeastern Bulgaria allow two full-bodied swaths. The averaged data of 5-years tests of 8 origins show significant amplitude of variation for the first swath, for the second swath and for the total green mass yield. The differences of the dry mass yield are significantly less, as the dry mass being a resultant index shows the adaptive potential of the tested origins.

The forage and the sweet forms of sorghum, the sudangrass and sorghum-sudangrass hybrids are useful silage production when cut after grain milky maturity stage. 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 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.

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 accumulation of biomass 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.

Table 4. Summarized results for productivity (t/ha) of sudangrass, sorghum-sudangrass hybrids and sweet sorghum forms in milky-wax and grain technical maturity stages for the period 2010–2014

Variant	Yield in Milky-wax maturity stage		Dry mass per day	Yield in Technical maturity stage		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
Sudangrass	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
Endge	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	

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. The summarized data of testing the sweet sorghum forms, the sudangrass and their hybrids confirm their high potential for green and dry mass accumulation in differing agro-climatic conditions (Friboarg et al., 1995, Moyere et al., 2004). Studies in recent years in Bulgaria (Kertikov, 2007, Kikindonov et al., 2011; Slanev et al., 2011, Golubinova et al., 2015) confirm the perspective of this crop for the practice for the receipt of high green mass yields in the formation of stable forage balance.

CONCLUSIONS

1. Effective breeding of segregating populations of F_2-F_5 progenies for isolation of genotypes with improved productivity indices and enrichment of the gene-pool of pollinators for creation of new sorghum-sudangrass hybrids was realized. The average productivity of the progenies – 29.4 t/ha, is below that of the Group Standard - 35 t/ha and varies from 20 to 46 t/ha, with variation coefficient C_v% = 25.8%. The dry matter content varies from 22.9% to 86.4%, and the mean value of the F_5 progenies – 29.4%, exceeds the Standard value of 26.9%.

2. After 5 cycles of individual selection have been differentiated three perspective synthetic populations with improved own productivity and dry matter content, which have a good potential for use as paternal components for the creation of new sorghum-sudangrass hybrids.

3. As a result of individual selection for productivity and disease resistance from a cross of local populations of sweet sorghum and sudangrass was bred the new sudangrass variety Endje-1, which is certified by the Bulgarian Patent Bureau (Certficate №10918/30.12.2010).

4. The long-standing activity on breeding and technology of sudangrass, sorghum-sudangrass hybrids and sweet sorghum forms allows us to summarize the results of the assessments of the Standard

varieties Verkor, Susu, Super Sweet, Endzhe and Yantar and the forms bred in the Agricultural Institute – Shumen regarding their green and dry mass productivity in the period 2010–2014.

5. The productivity parameters of the tested origins vary in a wide range. The analysis of the factor year shows, that regardless of the differences in the agro-climatic conditions, the total green mass productivity for the period of study is similar for the tested origins. The situation with the dry mass productivity is not the same, as there are substantial differences.

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