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Study of Productive Capacities for Production of Forage, Crude Protein and Chemical Composition in Sorghum (*Sorghum vulgare* P.) Hybrids

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Abstract

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The objective was to study the productive capacities for production of forage, crude protein and chemical composition in sorghum (*Sorghum vulgare* P.) hybrids.

The trials were laid out in Second experimental field in the 2002 – 2004 periods without irrigation, on a soil type of slightly leached chernozem with neutral soil reaction. Spring oat was used as a preceding crop.

Sorghum hybrids for silage production were studied with the following representatives: Super Sweet –10 from USA; Yantar from Russia; Super Sile – 20 from USA; Sooner Sweet from USA and SS-II from USA. Averaged results of the following characteristics of the hybrids were used as controls. Sowing rate 35 000 g.s./da at 45 cm interrow spacing and 7 cm intrarow spacing; Fertilizing rate – $Đ_5N_{13}$; Stage of harvesting – milky-wax ripeness.

It was found from the study that: The tested hybrids formed two maturity groups: early and medium early. The medium early group including the hybrids SS-II and Sooner Sweet had the greatest stem height and the share combination of components (leaves:stems:heads) in yield structure was the most favourable.

Hybrid SS-II had the highest productivity of green mass (10645 kg/da), dry mass (3466 kg/da) and crude protein (245.3 kg/da) followed by hybrid Sooner Sweet regarding dry mass yield and hybrid Super Sweet-10 regarding crude protein yield.

Key words: sorghum for green mass, productivity, quality, structural analysis

Introduction

Due to its remarkable drought resistance and high plasticity, sorghum for forage production is grown in many countries. High green mass yields can be obtained from it with appropriate set of varieties and hybrids and proper agri-cultural practices (Gramatikov et al., 2002; Dukic et al., 2003). In the last years, due to lasting arid conditions in both our country and most of world and limited possibilities for irrigation, the studies on that problem became exceptionally topical. (Grama-tikov, 1997; Krastev et al., 2002; Kikin-donov et al., 2005; Tanchev, 1999; Swith and Frederiksen, 2000). Therefore comparative field trials were carried out with a set of sorghum varieties and hybrids for green mass production.

The objective was to study the productive capacities for production of forage, crude protein and chemical composition in sorghum *(Sorghum vulgare* P.) hybrids.

Material and Methods

The trials were laid out in Second experimental field in the 2002 – 2004 pe-riod without irrigation, on a soil type of slightly leached chernozem with neutral soil reaction. Spring oat was used as a prece-ding crop.

Sorghum hybrids for silage production were studied with the following representatives: Super Sweet –10 from USA; Yantar from Russia; Super Sile –20 from USA; Sooner Sweet from USA and SS-II from USA.

Averaged results of the following characteristics of the hybrids were used as controls. Sowing rate 35 000 g.s./da at 45 cm interrow spacing and 7 cm intrarow spacing; Fertilizing rate – $Ð_5N_{13}$; Stage of harvesting – milky-wax ripeness.

The trial was laid out by the chessboard method with four replications and harvest plot size of 20 m^2. Agricultural practices were applied according to biological and agricultural requirements of sorghum, as well as depending on agrometeorological conditions during the growing season.

The following characteristics were observed: phenology of development and growing season by days for each hybrid, stem number per m^2, stem height in cm, yield structure – leaves, stems, heads – in percentage ratios from green and dry mass by years and on average for the study period in kg/da, crude protein in kg/da, dry matter content in green mass in %, content of crude protein (CP), crude fiber (CF), calcium (Ca) and phosphorus (P) in % of dry matter. Mathematical statistical processing of the results of dry mass yields was performed by the method of variance analysis (Shanin, 1977).

Results and Discussion

The years of study significantly differed in main agroclimatic factors (air temperature and atmospheric precipi-tation) during the period (April-September) of growth and development of sorghum (Figure 1). The year 2004 was the most unfavourable in a meteorological respect with a clearly outlined dry period from May to September and total precipitation amount of 168.1 mm/m^2. In the other expe-rimental years, the precipitation amount was comparatively greater (279.0 mm/m^2 in 2004 and 238.5 mm/m^2 in 2001), but relatively intensive and economically insignificant. As a whole, the growing seasons were characterized by high su-mmer temperatures, hot days, therefore the study was exceptionally valuable.

Depending on soil and climatic conditions, on average for the study period, the

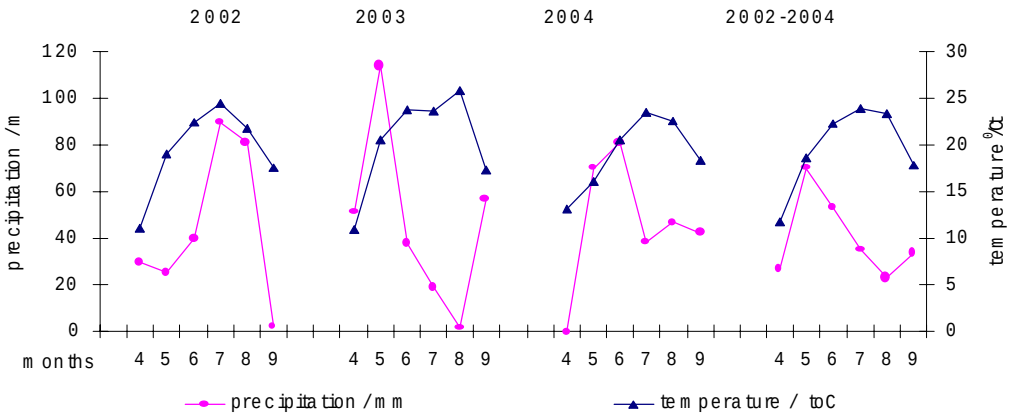

Fig. 1. Climatogram by years and on average for the studied period

sorghum sowing was conducted from 12.04 to 21.04, usually under insufficient water supply of surface (3-5 cm) soil layer. Therefore the crop emergence was slow and long. The beginning occurred after 7-8 days and the full emergence after 13-16 days, i.e. from 25.04 to 07.05. In order to develop, sorghum requires relatively high temperatures (25-28^{i} Ñ), that were missing in late April and early May. For that reason, its initial development was slow. It reached the 3-4 leaf phenological stage after 20-22 days from the date of its full emergence. Further growth and development were quite intensive and after 21-27 growing days, sorghum reached the early flowering stage. Depending on agro climatic conditions in the different years of study, sorghum reached cutting ripeness (milky-wax ripeness) in the period from 18.06 to 27.07, i.e. the climatic factor exerted a strong influence on its development.

It is evident from the analysis of the results in Table 1 by years of study that the silage hybrids differed in duration of growing season and reached cutting ripeness, namely milky-wax ripeness, at different time. In the first year, it varied from 75 days for hybrid Super Sweet –10 to 92 days for hybrid SS-II. In the second one, it was from 79 days for hybrid Yantar to 93 days for hybrid SS-II, whereas in the third year, the period was much longer, namely from 100 days for hybrid Yantar to 106 days for hybrid Super Sile – 20. In this instance, the hybrids Super Sweet – 10, Yantar and Super Sile – 20 appeared to be from the early group, whereas Sooner Sweet and SS-II formed a group of medium early hybrids.

The stem number per unit area recorded in 2002 was equal or close to the necessary plant number corresponding to the sowing rate, i.e. there was no tillering, the stems were single. However in 2003, the recorded stem number per unit area was two times or two times and a half greater than the seed number in the sowing rate. There was a high degree of tillering, the coefficient reaching to 2.5. In the third experimental year, great tillering was also recorded, the coefficient reaching to 2.5.

In the first year, the average plant height being an indirect indicator of productivity of forage mass varied from 128.3

Table 1
Structural analisis of sorghum hibrids for forage production by years

Hybrids	Dates of harvesting	Number of growing days	Stem number m^2	Stem height cm	% participation of components		
					stems	leaves	heads
2002							
Super Sweet10	08.07.	75	35	161	67.9	23.2	8.9
Yantar	10.07.	77	33	149	66.6	24.6	8.8
Super Sile20	15.07.	83	34	124	61.6	28.1	10.3
Sooner Sweet	24.07.	92	32	179	61.8	17.0	21.2
SS-II	24.07.	92	34	189	61.0	16.9	22.1
SE (P=0.05)			2.3	9.4			
2003							
Super Sweet10	16.07.	87	63	191	69.7	21.2	9.1
Yantar	08.07.	79	42	167	73.3	17.1	9.6
Super Sile20	14.07.	85	96	206	72.2	17.3	10.5
Sooner Sweet	21.07.	92	69	233	69.2	12.6	18.2
SS-II	22.07.	93	90	229	69.1	14.1	16.8
SE (P=0.05)			3.1	10.2			
2004							
Super Sweet10	27.07.	106	65	203	66.5	22.4	11.1
Yantar	21.07.	100	53	200	66.6	21.6	11.8
Super Sile20	27.07.	106	84	198	68.8	23.1	8.1
Sooner Sweet	26.07.	105	73	220	69.4	20.7	8.9
SS-II	26.07.	105	86	221	64.8	17.3	17.9
SE (P=0.05)			3.5	11.4			
Average for the 2002 - 2004 period							
Super Sweet10	08-27.07.	75 - 106	54	185	68.1	22.4	9.5
Yantar	08-21.07.	77 - 100	43	172	68.9	21.1	10.0
Super Sile20	14-27.07.	83 - 106	71	176	67.5	22.8	9.7
Sooner Sweet	21-26.07.	92 - 105	58	211	66.8	16.8	16.4
SS-II	22-26.07.	92 - 105	73	213	65.0	16.1	18.9
Average		84 - 104	60	191	67.3	19.8	12.9

cm in hybrid Super Sile – 20 tî 189.4 ñm in SS-II. Hybrid Sooner Sweet ranked second with 179.3 ñm plant heights. In the second year, it varied from 167 cm for hybrid Yantar to 229 cm for SS-II. Sooner Sweet ranked second again with 233 cm height. In the third year, the tendency of the preceding years remained, namely 167 cm for hybrid Yantar to 229 cm for SS-II, hybrid Sooner Sweet ranking second again with 233 cm plant height.

Output quality is determined to a great degree from percentage ratio of yield components, namely stem: leaf: head ratio. During the study period, it was most favourable in hybrid SS-II followed by that

in Sooner Sweet. They had lower stem participation and higher head participation, i.e. grain in total yield formation. In the rest, the leaf participation was predominant, as compared to that of the heads.

With regard to the obtained yields of green mass (Table 2), by years, as well as on average for the study period, there were several productivity groups. The first group included hybrid SS-II having shown the highest results. Depending on the characteristic agrometeorological condi-tions in the study years, its yields varied within the range of 5730 kg/da green mass in 2002 to 14400 kg/da in 2003. It was noteworthy that the percentage of abso-lutely dry matter of the same hybrid was also the highest, i.e. 31.42 tî 34.79 %. The hybrid Super Sweet-10 belonging to the first group also had a high green mass yield. It ranked second in this indicator with yields varying from 4950 kg/da to 11500 kg/da or on average for the study period - 8983 kg/da. However in this hybrid, the dry matter percentage was relatively the lowest, being equal to 27.47 % on average for the period. The hybrids Super Sile-20 and Sooner Sweet formed the second group according to green mass productivity. Variety Yantar was the lowest yielding by years (from 3845 kg/da to 7360 kg/da), as well as on average for the period. However it was noteworthy that in this variety, the dry matter percentage in green mass was relatively high (29.14%), as compared to the hybrids of the second productivity group.

The results of the dry mass yields in the same table show that there was slight displacement in the gradation by productivity according to this characte-ristic. Naturally, that was due to the different dry matter content in the different sorghum hybrids at the moment of their harvesting. In 2002, hybrid SS-II had a lea-ding place according to this characteristic with a dry matter yield equal to 1803 kg/da, i.e. 50.3% higher yield than the average for the hybrids (control) and with very good mathematical significance of the yield differences. Hybrid SS-II also had the most intensive dry mass accumulation per growing day - 19.60 kg per unit area, followed by hybrid Super Sweet-10 ranking second according to accumulation intensity – 14.89 kg/da per day.

During the mentioned year, except for variety Yantar, the other three hybrids also had a high dry mass yield, but their results were lower than the averaged result of the hybrids with mathematical significance. In 2003, hybrid SS-II was again the highest yielding, but hybrid Sooner Sweet also was such one. Hybrid Super Sweet-10 also had good performance, but the differences in the yield, as compared to that of the control had no mathematical significance. In the third study year, two groups were outlined – that of the high-productive hybrids (SS-II, Super Sweet-10 and Sooner Sweet); their differences in dry mass yields, as compared to the control, had positive significance.

The other hybrids formed a second group with very good negative significance of the differences in the dry mass yields, as compared to the control. The results in the table show that on average for the study period, hybrid SS-II had the highest productivity. It reached an average dry mass yield equal to 3466 kg/da at daily intensity of dry mass accumulation reaching to 36.26 kg/da. The hybrids Sooner Sweet and Super Sweet-10 had dry mass yields close to that of the control variant. Variety Yantar and hybrid Super Sile – 20 showed lower productivity.

Interesting are the results (Table 3)

Table 2

Forage productivity of sorghum hybrids by years and on average for the studied period

2002

Hybrids	Yields, kg/da				
	Green mass	% dry matter	Dry mass	% of average	Dry mass per day
Super Sweet10	4950	22.57	1117 ^{0}	93.2	14.89
Yantar	3845	53.56	906 ^{000}	75.6	11.77
Super Sile20	4115	24.72	1017 ^{000}	84.8	12.25
Sooner Sweet	4025	28.63	1152 ^{0}	96.1	12.52
SS-II	5730	31.46	1803 $^{+++}$	150.3	19.60
Average	4533	-	1199	100.0	-

$GD_{5\%}$ = 90.6 kg/da; $GD_{1\%}$ = 124.4 kg/da; $GD_{01\%}$ = 170.2 kg/da;

2003

Super Sweet10	11500	29.73	3419 $^{-}$	99.3	39.30
Yantar	7203	28.47	2051 ^{000}	59.6	25.96
Super Sile20	10850	28.99	3144 ^{000}	91.3	37.46
Sooner Sweet	10343	34.78	3597 $^{+++}$	104.4	39.10
SS-II	14400	34.79	5010 $^{+++}$	145.5	53.87
Average	10859	-	3444	100.0	-

$GD_{5\%}$ = 62.4 kg/da; $GD_{1\%}$ = 85.7 kg/da; $GD_{01\%}$ = 117.2 kg/da;

2004

Super Sweet10	10500	30.12	3163 $^{+++}$	107.0	29.83
Yantar	7360	28.09	2067 ^{000}	69.9	20.67
Super Sile20	9680	29.18	2825 ^{000}	96.5	26.65
Sooner Sweet	10060	30.04	3022 $^{+}$	102.2	28.78
SS-II	11806	31.42	3709 $^{+++}$	125.4	35.32
Average	9881	-	2957	100.0	-

$GD_{5\%}$ = 54.9 kg/da; $GD_{1\%}$ = 75.4 kg/da; $GD_{01\%}$ = 103.2 kg/da;

Average for the 2002 - 2004 period

Super Sweet10	8983	27.47	2468	98.5	28.00
Yantar	6136	29.14	1788	71.4	19.47
Super Sile20	8215	27.63	2270	90.6	25.45
Sooner Sweet	8143	31.15	2537	101.2	26.80
SS-II	10645	32.56	3466	138.3	36.26
Average	8424	-	2506	100.0	-

Table 3
Chemical composition of the structural components in sorghum hybrids for forage production, % of dry matter

Hybrids	Components	Content of:			
		CP	CF	Ca	P
Super Sweet10	Leaves	16.30	23.94	0.645	0.239
	Stems	7.24	27.57	0.403	0.142
	Heads	10.91	24.28	0.192	0.242
Yantar	Leaves	16.23	21.27	0.462	0.249
	Stems	7.49	24.96	0.468	0.150
	Heads	12.42	24.67	0.178	0.293
Super Sile20	Leaves	14.50	25.02	0.484	0.227
	Stems	7.05	24.42	0.343	0.146
	Heads	11.70	23.47	0.159	0.273
Sooner Sweet	Leaves	13.79	23.90	0.784	0.204
	Stems	3.89	26.27	0.340	0.068
	Heads	11.08	12.36	0.219	0.272
SS-II	Leaves	14.61	22.02	0.695	0.224
	Stems	4.09	27.06	0.333	0.114
	Heads	10.86	12.70	0.099	0.277

concerning the chemical composition of structural components, as well as the content of different nutrients in the hybrids. Variety Yantar and hybrid Super Sweet-10 having relatively lower dry mass productivity, had the highest content of crude protein (CP) in leaves. At the same time variety Yantar had the lowest content of crude fiber (CF). The hybrid Sooner Sweet having high productivity of dry mass had the lowest percentage content of CP and the highest one of CF, i.e. there was inverse relation between yield and quality. The percentage content of CP in the stems in case of lower dry mass yields, namely in variety Yantar, Super Sile – 20 and Super Sweet-10, varied from 7.05 to 7.49 %, whereas in case of high yields, it was relatively quite lower – 3.89 to 4.09 %. The CP content in heads was almost the same in all studied hybrids. However the CF content was quite higher in the hybrids with high CP content in leaves (23.47 tî 24.67 %), whereas in hybrids Soo-ner Sweet and SS-II, the CF content in heads was relatively low (12.36 to 12.70 %). Hybrid SS-II was distinguished for high content of calcium (Ca) in stems, leaves and heads, whereas the components of hybrid Super Sweet-10 had quite low content. There were no significant differences in the percentage phosphorus (P) content of the components between the different hybrids.

With regard to the obtained crude protein yields (Table 4) as a function ex-pressing the dry mass yield and percentage content of CP in dry mass, two groups were

Table 4
Crude protein yields from the structural components and sorghum hybrids for forage production, kg/da

Hybrids	Structural components			Total	% of average
	leaves	stems	heads		
Super Sweet10	90.1	110.4	25.5	226.0	110.2
Yantar	61.2	92.3	22.2	175.7	85.7
Super Sile20	75.1	108.0	25.7	208.8	101.8
Sooner Sweet	58.7	65.9	46.1	170.7	83.2
SS-II	81.5	92.1	71.1	245.3	119.6
Average	73.3	93.7	38.1	205.1	100.0
SE (P=0.05)	5.7	7.3	2.9		

clearly outlined. The first one had higher CP yields than the average yield of the hybrids (control) and the second one had lower yields than that of the control. The first group included the hybrids SS-II, Super Sweet-10 and Super Sile – 20 with CP yields ranging from 226.0 tî 245.3 kg/da, i.e. 1.8 tî 19.6 % higher than that of the control. The other two were, as follows: hybrid Sooner Sweet having a relatively high dry mass yield showed a quite low yield of crude protein – 16.8 % below the average yield for the hybrids and variety Yantar, 14.3 % lower yield than the control. Hybrid SS-II was distinguished for the highest CP yield. It exceeded by 19.6 % the average yield from the tested hybrids.

Conclusions

The tested hybrids formed two maturity groups: early and medium early.

The medium early group including the hybrids SS-II and Sooner Sweet had the greatest stem height**,** the share combination of components (leaves:stems:heads) in yield structure being the most favourable.

Hybrid SS-II had the highest productivity of green mass (10645 kg/da), dry mass (3466 kg/da) and crude protein (245.3 kg/da) followed by Sooner Sweet regarding dry mass yield and Super Sweet-10 regarding crude protein yield.

References

Dukic, D., R. Stanisvljevic, I. Stoianovic, J. Milenkovic, R. Petrovic and O. Aleksic, 2003. Yield, quality and energy fodder sorghum and Sudan grass. *Grassland Science in Europe,* **8**: 326-329 (Sb).

Gramatikov, B., 1997. Comparative study of different sorghum hybrids cultivated as second crop grain and silage. *Plant Science*, (3-4): 49-51 (Bg).

Gramatikov, B., B. Zarkov, D and D. Tanchev, 2002. Sorghum- an alternative crop for dry conditions. *Jubilee Scientific Session, Sadovo*, **1**: 102-105 (Bg).

Kikindonov, Ts., S. Krastev and K. Slanev, 2005. Testing of varieties, hybrids and in-

dividual crosses of grain sorghum. *Plant Science*, (3): 212-218 (Bg).

Krastev, S., Ts. Kikindonov, G. Kikindonov, 2002. Development of initial material for breeding of grain sorghum. *Jubilee Scientific Session, Sadovo*, **1**: 186-189 (Bg).

Shanin, Y., 1977. Field Trial Methods. Sofia, *BAS*. (Bg).

Swith, W. and R. Frederiksen, 2000. Sorghum - origin, history. *Technology and production*, *John Wiley & Sons*. Texas University, pp. 334.(USA)

Tanchev, D., 1999. Study of productivity of grain sorghum hybrids. *Plant Science*, (2): 207-209 (Bg).

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