Comparative assessment and scientific support of seed breeding of the new variety Evgeniya of sudangrass

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Abstract. The article characterizes the advantages of sudangrass, presents its comparative assessment, and gives recommendations for the cultivation of a new variety Evgeniya for seeds. Implementation of the program for the development of forage production in Russia and other countries implies not only the creation of new varieties but also the promotion of their introduction. This study aims to test the new variety Evgeniya of sudangrass and refine the cultivation techniques for obtaining high-quality seeds in the Volga region. For a period of 2 years, we studied the new promising variety, new lines that were obtained during interspecific, intraspecific, and intervarietal crossings carried out in different years, and new varieties of sudangrass recommended for cultivation in the region. The Yubileinaya 20 and Zonalskaya 6 varieties of sudangrass were used as standards. Field studies were carried out in 2017-2019. It was found that the new variety Evgeniya was characterized by high values of economically valuable traits. The variety had several biometric and biological features, such as thin stems and high yields, so we studied the influence of sowing methods and seeding rates not only on yield but on seed quality. To obtain the maximum yield of high-quality seeds, Evgeniya sudangrass must be sown with a seeding rate of 0.6-0.7 mln. viable seeds per hectare and row spacing of 30 cm.

1 Introduction

World experience in the development of agriculture shows that the livestock industry has now the priority. Sudangrass is one of the most widespread cereals cultivated for forage due to its valua-ble biological properties, high productivity, and feeding qualities. Industrial production of sudan-grass is significantly developed in Western Europe, Kazakhstan, Ukraine, India, in the north and east of Africa, North and South America, Australia, in the southern and southeastern regions of the European part of Russia, in the Altai Territory, and the Far East. Sudangrass came from Sudan (Central Africa).

In the Lower Volga region (Russia) the most important issue in the development of agriculture is the creation of a solid forage base [1, 2]. The scientific studies and practical experience shows that the sudangrass is one of the most productive hay crops used in severely arid conditions [3, 4]. A distinctive feature of sudangrass is good after-growth after mowing or correct grazing on the root, provided with increased bushiness. So, highly nutritious green mass can be obtained throughout the summer and until the late autumn period [1, 2].

All herbivores eat sudangrass, so it is an important component in the green conveyor [5, 6]. Sudangrass can be planted multiple times during the growing season, so it is cost-effective for farmers. Sudangrass has a versatility of utilizations. It is equally suitable for the preparation of for-age, hay, silage, and haylage. Among grasses, sudangrass has the highest content of digestible pro-tein - the main nutrient, sugars, and ash. The sudangrass hay contains 9-10% of digestible protein. 1 kg of green mass contains 65-80 mg of carotene. 100 kg of sudangrass equals 17 f.u., and 100 kg of hay equals 52 f.u. The protein digestibility coefficient is 60.8%, for fat it is 45.7, for nitrogen-free extractives it is 73.4, for fiber this coefficient equals 69.1 [7]. Agricultural producers set a high value on the increased drought tolerance, productivity, and nutritional value of sudangrass [4].

Further introduction of sudangrass in the Lower Volga region depends on the creation of fun-damentally new varieties having high-yield and early mature, which are adapted to modern cultiva-tion technologies. The selection of sorghum crops, including sudangrass is focused on the use of the genetic function of the plant cytoplasm [8, 9, 10], heterosis [11, 12], the study of the concentration and modification of kafirins [13]; protein modulation [14]; expression of apomictic potentials [15]; genetic modification as a tool to increase nutritional value [16, 17, 18].

Resource-saving cultivation technologies that are used in the farms of the region enable to overcome the factors that hinder the wider spread of sudangrass. However, it should be noted that the composition of sudangrass varieties in the region requires constant improvement [2].

Table 1. Thickness and other characteristics of the stem pith, the height of varieties of plants and breeding lines of sudangrass, 2017-2018.

Variety, line	Days from germination to		Stem pith	Plant height, cm		Stem thickness, cm	
	Emergence	Blooming		In 30 days	At full ripeness	At the bottom	At the top
Yubileynaya 20 (st)	34	37	dry	106.1	162.4	0.8	0.5
Zonalskaya 6 (st)	35	38	juicy	101.3	155.2	0.7	0.3
Mechta Povolzh'ya	34	39	dry	90.8	165.2	0.6	0.3
Spartanka	32	36	juicy	118.3	160.1	0.6	0.3
Evgeniya	42	49	juicy	119.1	197.4	0.7	0.4
KSI 2209	32	39	semi-juicy	117.9	168.1	0.6	0.3
MEV-27/2015	40	48	juicy	115.1	186.4	0.7	0.4
MEV-31/2015	42	48	juicy	116.4	180.6	0.7	0.4
F fact.	12.556*	31.124*	–	14.543*	7.454*	2.148*	4.549*
HCP_{05}	1.10	1.12	–	3.12	5.30	0.03	0.01
*$F_{fact.} \geq F_{teor.}$ (hereinafter)							

Thus, it is relevant to create and introduce new varieties of sudangrass, which have high adap-tive capacity in the conditions of the arid Lower Volga region [2]. The introduction of new varieties depends on scientifically validated seed production.

This works aims at competitive testing of the new variety Evgeniya of sudangrass and the re-finement of cultivation techniques for obtaining high-quality seeds in the Volga region.

2 Material and methods

For field and laboratory experiments, we used the technique of B.A. Dospekhov [19]. According to the methodology of the laboratory of sorghum of the N.I. Vavilov All-Russian Institute of Plant Genetic Resources, the area of the studied plot in the competitive variety testing was 5.0 m^2 with four replicates. The development of sudangrass plants during the growing season was monitored and controlled according to the method of F.M. Kuperman [20]. The analysis and characterization of the traits were carried out in accordance with the methodology of the State Commission for Selection Achievements Test and Protection (Gossortcommission) and the "Wide unified classifier of traits of sorghum" [21]. The Agros 2.09 software was used to statistically process the experimental data by the analysis-of-variance method.

For a period of 2 years, studied were the new variety Evgeniya of sudangrass, breeding lines that were obtained during interspecific, intraspecific, and intervarietal crossings (supervisor E.V. Morozov), and promising varieties of sudangrass.

The recognized varieties Yubileinaya 20 and Zonalskaya 6 of sudangrass were used as standards.

Evgeniya sudangrass. Patent holders are Russian Research and Design Institute of Sorghum and Corn and Saratov State Vavilov Agrarian University. Authors of the variety are Vertikova E.A., Zhuzhukin V.I., Morozov E.V., Semin D.S., Subbotin A.G., Gorbunov V.S., Garshin A.Yu., Kibalnik O.P., Kukoleva S.S., Starchak V.I. (Patent for selection achievement No. 9740).

Evgeniya variety is resistant to lodging, has high yield, especially when mowing in the sweeping phase, and profitability of seed production. The foliage and thin stems ensure the production of high-quality green mass, including hay, silage, and haylage (according to Gossortcommission).

All groups of cattle eat green mass, haylage, and hay. Evgeniya sudangrass contains 0.24 feed units, 2.08 MJ of metabolizable energy per kilogram of green forage. One kilogram of hay contains 0.53 feed units, including 118 g of crude protein, 72 g of digestible protein (5.1 g of lysine), 18 g of crude fat, 411 g of nitrogen-free extractives, 6.8 MJ of metabolizable energy. Evgeniya sudangrass has been zoned in region 9 since 2018 (patent No. 9740) (according to Gossortcommission).

Field research was carried out in the Engels district of the Saratov region in 2017-2018. Production tests were carried out at the farm of Individual Entrepreneur "Akhmerov Rashid Ravilovich" (Tatishchevsky district of the Saratov region) in 2019. The tests aimed to reproduce the new variety Evgeniya and to clarify the technological process of growing varieties for productivity and seed quality. The following three sowing methods were studied:

1. Continuous sowing with row spacing of 15 cm. The seeding rates were 0.8, 0.9, 1.0, and 1.1 million viable seeds per 1 ha;
2. Continuous sowing with row spacing of 30 cm. The seeding rates were 0.5, 0.6, 0.7, and 0.8 million viable seeds per 1 ha;
3. Wide-row method with row spacing of 70 cm. The seeding rates were 0.2, 0.3, 0.4, and 0.5 million viable seeds per 1 ha.

Weather conditions during the years of research were contrasting. The variability of deviations from the mean annual temperature and precipitation was observed. Fairly favorable agrometeorological conditions for the cultivation of sudangrass were noted in 2019. In 2018, the plants were significantly affected by drought. In general, the growing season of 2017 was characterized as favorable, but in September there was an excessive amount of precipitation.

Table 2. Assessment of morphological traits of varieties and breeding lines of sudangrass, 2017-2018.

Variety, line	Length of the panicle internode, cm	Dimensions of the largest leaf, cm		Inflorescence size, cm	
		length	width	length	width
Yubileynaya 20 (st)	9.2	45.1	3.2	28.1	23.1
Zonalskaya 6 (st)	6.1	46.2	2.1	28.2	14.3
Mechta Povolzh'ya	17.1	38.5	2.3	34.1	17.0
Spartanka	12.1	38.7	2.8	27.3	21.1
Evgeniya	17.6	47.9	2.4	36.6	22.2
KSI 2209	13.5	39.4	3.0	28.6	21.4
MEV-27/2015	17.1	48.3	2.5	36.3	22.8
MEV-31/2015	18.1	47.5	2.4	34.4	21.3
F fact.	4.832*	9.172*	NS	11.476*	8.431*
HCP_{05}	4.05	3.15	–	3.12	2.25

3 Results and discussion

The first cut of sudangrass was carried out at the stage of the beginning of emergence of the studied plants since the biomass at this stage is characterized by high nutritional value and greater digestibility for animals. The germination-emergence period for the studied varieties of sudangrass ranged from 32 days for Spartanka to 42 days for Evgeniya. For Mechta Povolzh'ya sudangrass the studied trait was 20 - 34 days, which was statistically significant at the level of trait for the dry-stem Yubileinaya standard, Table 1.

For Spartanka variety the emergence phase occurred statistically significantly earlier than for Yubileynaya 20 (by 5.9%) and Zonalskaya 6 (by 8.6%). The duration of the germination-emergence phase for Evgeniya was statistically significantly longer by 17.9% on average than for the standards (Table 1). Among the breeding lines, the KSI 2209 was the most early-maturing.

Spartanka variety did not differ significantly from the Yubileinaya 20 in terms of the duration of the germination-blooming phase, but this indicator was significantly lower than for the Zonalskaya 6 by an average of 5.3%. The Evgeniya variety proved to be the most slow- maturing, since this phase started on the 49th day, which is significantly lower on average by 28.9% than that of the standard varieties.

In terms of characteristics of the plant stem pith, varieties Yubileinaya 20 and Mechta Povolzh'ya were assessed as dry-stemmed; Zonal 6, Spartanka and Evgeniya were assessed as juicy-stemmed. The breeding lines MEV-27/2015 and MEV-31/2015 had a juicy stem, the line KSI 2209 had a semi-juicy stem.

In the conditions of the Lower Volga region, the intensity of the initial growth of plants is of particular agrotechnical importance. Rapid development of sudangrass plants can effectively suppress the growth of weeds, which allows early inter-spacing cultivation [4]. This indicator is an indirect characteristic of the breeding material resistance to cold.

Sudangrass is characterized by the intensity of plant development at the initial stages of the growing season as compared with other types of sorghum.

A comparative study of sudangrass varieties showed that the 30-days heights were outstanding for Spartanka (118.3 cm) and Evgeniya (119.1 cm). Spartanka statistically significantly exceeded the juicy-stemmed standard by 16.8% and by 11.5% the dry-stemmed standard Yubileynaya 20 (Table 1). Evgeniya significantly exceeded the dry-stemmed Yubileynaya 20 by 12.3% and the juicy-stemmed Zonalskaya 6 by 17.6% (Table 1).

In terms of plant height in the phase of full ripeness, Evgeniya variety was the only one having a statistically exceeding value of standard by 24.4% on average. This trait for Mechta Povolzh'ya was not statistically different from that for the Yubileynaya 20 standard. Spartanka also did not have significant differences in plant height in the phase of full seed ripeness as compared with the Zonalskaya 6 standard (Table 1). This trait for breeding lines KSI 2209, MEV-27/2015, MEV-31/2015 significantly exceeded that of standards by an average of 14.5%.

The stem thickness for the variety Mechta Povolzh'ya was statistically significantly less both in the upper and lower parts compared to Yubileynaya 20. It has a positive effect on the eatability of the dry-stemmed sudangrass variety by animals.

The juicy-stemmed varieties have thinner stems. Evgeniya sudangrass occupies an intermediate position between the studied varieties in terms of this trait (Table 1).

The length of the panicle internode in the studied plants varied from 12.1 to 18.1 cm (Table 2). All studied varieties and lines significantly exceeded the best-regionalized varieties by 1.5-2 times in terms of this trait (Table 2).

The length of the largest leaf for Evgeniya and MEV-31/2015 breeding line plants did not differ significantly from the standards. The MEV-27/2015 line exceeded variety Yubileynaya 20 in terms of this trait by an average of 6.0%. Varieties Mechta Povolzh'ya and Spartanka had a statistically significant value of the trait lower than the standards (Table 2).

There were no statistically significant differences in the width of the largest leaf between the standards and the studied varieties (Table 2).

Table 3. Productivity of sudangrass varieties and breeding lines when mowing during the emergence phase, 2017-2018.

Variety, line	Plant foliage (first cut),%	Biomass yield, t/ha				Yield of dry matter, t/ha			
		1st cut	2nd cut	3rd cut	Total (three cuts)	1st cut	2nd cut	3rd cut	Total (three cuts)
Yubileynaya 20 (st)	20.8	6.2	5.5	3.2	14.9	2.0	2.0	0.9	4.9
Zonalskaya 6 (st)	25.2	6.3	5.5	3.1	14.9	1.1	1.6	0.8	3.5
Mechta Povolzh'ya	33.3	4.2	6.8	3.0	14.0	1.0	2.2	0.8	4.0
Spartanka	36.8	5.1	4.7	2.2	12.0	0.9	1.4	0.6	2.9
Evgeniya	23.0	8.1	7.3	4.4	19.8	4.4	2.3	1.0	7.7
KSI 2209	35.4	5.3	5.7	3.2	14.2	1.5	1.9	1.6	4.0
MEV-27/2015	23.5	8.0	6.8	4.0	18.8	4.0	2.5	1.8	8.3
MEV-31/2015	22.6	7.9	7.1	3.9	18.9	4.1	3.1	2.0	9.2
F fact.		3.1*	5.2*	2.1*	6.4*	3.2*	5.1*	3.4*	7.3*
HCP_{05}	–	0.38	0.18	0.11	0.32	0.09	0.07	0.03	0.23

Table 4. Productivity of sudangrass varieties and breeding lines at full ripeness, 2017-2018.

Variety, line	Bushiness, pcs		Yield, t/ha	
	Total	Productive	Green mass	Grain
Yubileynaya 20 (st)	3.0	2.6	12.4	2.44
Zonalskaya 6 (st)	1.6	1.3	12.5	2.24
Mechta Povolzh'ya	3.4	2.6	13.4	2.60
Spartanka	2.0	1.6	13.9	2.85
Evgeniya	2.4	2.1	15.7	3.60
KSI 2209	2.2	1.9	14.8	3.50
MEV-27/2015	2.2	1.9	15.3	3.30
MEV-31/2015	2.1	1.9	15.1	3.10
F fact.	2.623*	7.259*	11.743*	6.532*
HCP_{05}	0.41	0.20	0.78	0.07

Varieties-standards had approximately the same inflorescence length, 28.1 cm for Yubileynaya 20 and 28.2 cm for Zonalskaya 6. Variety Mechta Povolzh'ya significantly exceeded the dry-stemmed standard in terms of this trait by 21.4%. Spartanka sudangrass did not have significant differences in inflorescence length as compared to Zonalskaya 6. Variety Evgeniya and breeding lines MEV-27/2015 and MEV-31/2015 statistically significantly exceeded varieties Yubileynaya 20 and Zonalskaya 6 by 32.2%.on average

Variety Mechta Povolzh'ya had an inflorescence width by 26.4% less than the Yubileynaya 20 standard. Variety Spartanka exceeded the Zonalskaya 6 standard in terms of the studied trait. Evgeniya variety exceeded the Zonalskaya standard by an average of 55.2% 6, but did not differ significantly from variety Yubileynaya 20 (Table 2).

The productivity of sudangrass varieties decreased from the first to the third cut. The biomass yield averaged 6.4 t/ha at the first cut, 5.3 t/ha at the second cut, and 3.5 t/ha at the third cut (Table 3).

The biomass yield for 3 cuts in total varied from 12.0 to 19.8 t/ha on average for two years. Variety Mechta Povolzh'ya had a total biomass yield by 6.0% less than variety-standard Yubileynaya 20 and variety Zonalskaya 6.

This trait for Spartanka was by 19.5% lower than for the standards Zonalskaya 6 and Yubileynaya 20. Variety Evgeniya statistically significantly exceeded the varieties-standards by 32.9% on average. The same tendency was noted when comparing the dry matter yield. The studied breeding lines had a significant excess over the standards in terms of biomass yield in total by an average of 24.6% (Table 3). Total dry matter yield per hectare for Evgeniya exceeded that for Yubileynaya 20 by 69.4%, and more than twice for Zonalskaya 6 (Table 3). The total and productive bushiness of sudangrass at the end of the growing season varied from 1.6 to 3.4 pcs., and from 1.3 to 2.6 pcs., respectively (Table 3). The foliage of the sudangrass varieties was 17-38%.

The yield of green mass for the studied varieties of sudangrass at full ripeness of seeds was 13.4-15.7 t/ha (Table 4).

Variety Evgeniya statistically significantly exceeded the Yubileynaya 20 standard by 26.6% and the Zonalskaya 6 standard by 25.6%. For Mechta Povolzh'ya the studied trait was significantly higher by 8.1% than that for standard Yubileynaya 20. The yield of green mass for Spartanka was higher than for Zonalskaya 6 by 11.2% on average for two years.

The variability of the grain yield trait for the studied varieties and lines was 2.60-3.60 t/ha. All studied promising varieties and new breeding lines of sudangrass exceeded the best zoned varieties-standards by 0.36-1.36 t/ha (Table 4).

The success of the introduction of a new variety in agricultural production depends on seed production and scientifically validated recommendations for its cultivation. The main elements of agrotechnical measures for growing a new variety are the correct

Table 5. Productivity and quality of seeds for Evgeniya sudangrass as a function of sowing meth-ods and seeding rates, 2019.

Row spacing, cm	Seeding rate mln. pcs./ha	Grain yield, t/ha	Grain yield		Weight of 1000 grains, g	Laboratory seed germination, %	Seed moisture, %
			t/ha	**%**			
15	0.8	3.4	2.1	61.8	25.2	91.2	14.2
	0.9	3.1	1.9	61.3	24.4	90.5	14.0
	1.0	3.0	1.7	56.7	23.6	90.0	13.4
	1.1	2.7	1.5	55.6	22.9	80.6	13.1
30	0.5	3.2	2.3	71.9	26.3	92.0	14.8
	0.6	3.7	2.6	70.3	26.1	91.5	14.3
	0.7	3.4	2.3	67.6	25.5	91.2	14.0
	0.8	3.1	2.0	64.5	24.4	90.8	13.7
70	0.2	2.6	2.0	76.9	27.2	93.5	17.6
	0.3	2.9	2.2	75.9	27.0	93.4	17.3
	0.4	3.2	2.3	71.9	26.6	93.0	16.8
	0.5	3.0	2.2	73.3	26.4	92.3	16.1
Ffact.		18.31*	34.94*		65.78*		
HCP_{05}		0.22	0.12		0.14		

selection of the optimal number of plants placement per unit area and the methods of sowing. The criterion for assessing the agricultural techniques used is grain yield.

Due to the fact that Evgeniya sudangrass has a number of biometric and biological features, such as thin stems and high yields, we studied the impact of sowing methods and seeding rates not only on yield but also on seed quality (Table 5).

The productive bushiness of sudangrass varied in the range from 1.0 to 2.3 pieces per a plant. With an increase in the seeding rate of seeds, the weight of grain from one panicle also decreased approximately by two times.

The maximum grain yield for Evgeniya sudangrass (3.7 t/ha) was obtained with a seeding rate of 0.6 million viable seeds per hectare and row spacing of 30 cm. This indicator statistically significantly exceeded the yield for all other variants of the experiment. The high yield of grain of the studied variety (3.4 t/ha) was registered when sowing with a seeding rate of 0.8 mln. seeds per 1 ha and row spacing of 15 cm, as well as with a seeding rate of 0.7 mln. seeds per 1 ha and row spacing of 30 cm (Table 5).

The maximum yield of seeds (2.6 t/ha) was obtained when sowing with a seeding rate of 0.6 mln. viable seeds per 1 ha and row spacing of 30 cm. Sowing with row spacing of 15 cm and 70 cm resulted in lower seed yield by 0.2-0.4 tons.

The results of production tests proved that the seeding rates and sowing methods directly affect the main quality characteristics of the obtained grains of Evgeniya sudangrass.

The variability of laboratory germination of seeds of Evgeniya sudangrass was on average 92.3-93.5% for crops with a seeding rate of 0.2-0.5 mln. viable seeds per 1 ha and row spacing of 70 cm. For the experiment with 0.8-1.1 mln. viable seeds per 1 ha and row spacing of 15 cm, it was 80.6-91.2%. It is noted that the seeds obtained in this way have lower weight of 1000 grains by 1.2-4.3 g and, as a result, the seed yield from each ton decreases by 8.1-20.7%.

The production tests showed that an increase in the seeding rate results in a decrease in grain moisture before harvesting. The variability of this trait averaged 16.1-17.6% when sowing with a seeding rate of 0.2-0.5 mln. seeds per 1 ha and row spacing of 70 cm and 13.1-14.2% when sowing with a seeding rate of 0.8-1.1 mln. seeds per 1 ha and row spacing of 15 cm.

4 Conclusion

The competitive variety test showed that the studied new variety Evgeniya of sudangrass was characterized by high values of economically valuable traits. In has shorter growing season, than the early-ripening variety Spartanka. In terms of 30-days plant height, Evgeniya significantly exceeded varieties-standards by 14.95% on average, but did not significantly differ from Spartanka (118.3 cm). The plant height in the phase of full ripeness for Evgeniya exceeded that for varieties-standards by 24.4% on average. In terms of the yield of green mass in total for three cuts Evgeniya exceeded varieties-standards by 32.9%, in terms of grain yield it exceeded varieties-standards by 54.1%.

As a result of competitive testing, the selection lines MEV - 27/2015 and MEV - 31/2015 of sudangrass were transferred to the State variety testing and in 2019 patents for selection achieve-ments were obtained (Patent for selection achievement № 10648 and Patent for selection achieve-ment № 10650, respectively).

As a result of production tests, it was established that to obtain high quality grains of Evgeniya sudangrass, it is recommended to sow it with a seeding rate of 0.6-0.7 million viable seeds per one hectare and row spacing of 30 cm.

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