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DEVELOPMENT OF SUDANESE GRASS CULTIVARS WITH CULTIVATION TECHNOLOGY FOR SEED PURPOSE

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SUMMARY

The presented research sought to investigate the new types of Sudanese grass (*Sorghum* × *drummondii*) from the global gene pool for developing new cultivars with high productivity and economically valuable traits. In breeding of Sudanese grass, the main task was to develop the drought-resistant, highly productive cultivars with good product quality, adapted to the soil and climatic conditions of Kazakhstan. The latest manuscript summarizes the results of many years of research on the local collection and the exotic material of the Sudan grass. Samples selected as valuable starting material for breeding depended on economically important traits, including precocity, seed productivity, plant height, grain quality, and lodging resistance. Based on the research on precocity, the two cultivars Kiz 25 and Kiz 34, placed in the competitive nursery, had their full ripeness phase starting two days earlier (28.09) compared with the standard cultivar Aylana-2017, which reached full ripeness on 30.09. In the competitive nursery of variety testing, the highest grain yield resulted in the Sudan grass cultivars Kiz 4 and Kiz 25. By harvest time, the yield (2.21 t/ha) obtained during the full ripeness phase of grains was higher than the harvest made at the wax ripeness phase (2.27 t/ha).

Keywords: Sudanese grass (*Sorghum* × *drummondii*), local collection, selection, competitive variety testing, seed cultivation technology, yield

Key findings: In the development of drought-resistant and highly productive cultivars of Sudanese grass (*Sorghum* × *drummondii*), 80 out of 100 samples emerged viable, and based on precocity data, the cultivars Kiz 25 and Kiz 34 reached allocation in the competitive nursery. The Sudan grass cultivars Kiz 4 and Kiz 25 were distinct, with higher grain yield.

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INTRODUCTION

The Sudan grass (*Sorghum* × *drummondii* [Steud.] Millsp. & Chas) is a valuable forage crop, which is crucial for arid regions. Sudanese grass is a promising forage crop for economic and soil-climatic conditions in the northeast of Kazakhstan. The biological characteristics of the grass fully satisfy the forage production schemes of the region and can provide an opportunity to stabilize feed manufacture in the region in the required amount. Sudanese grass is a universal forage crop. It can be applicable in many use schemes, removing the culture in the optimal phases of technological ripeness (Zhanatkyzy *et al.,* 2023).

For using Sudanese grass in the feed production system, greater prospects were valid with many advantages, including soil-climatic plasticity and high toxicity. Sudanese grass serves to produce hay, haylage, and silage, as well as, fed directly as green mass (Kukoleva, 2022; Kukoleva *et al.,* 2022).

For each soil-climatic zone, selecting the most productive forage crops developed new cultivars, determining the ways for their most effective use. The resourceful use of Sudan grass has complementation with ecological plasticity, which makes it possible to cultivate it on almost all types of soils, including solonetz and desert soils (Antimonov *et al.,* 2018; Karabayev *et al.,* 2024). Expanding the range of new feed crops that meet specific requirements and using them along with traditional ones is an essential reserve for increasing feed production and improving their quality. One ton green mass of Sudanese grass contains 0.23 k.u. and up to 16%–18% protein, while 1 k.u. is about 100 g of digestible protein (Chamurliev *et al.,* 2023).

In arid areas, Sudanese grass makes good use of precipitation from the second half of the warm period and forms a large volume of green mass. By consuming 1 mm of moisture, Sudanese grass creates 25.2 kg of dry matter, compared with winter rye and barley, which produce 6.3 and 14.7 kg, respectively (Malinovskii*,* 1984). Frequently recurring droughts in the Southern territories (every 1–2 years) necessitate the search for crops least suffering from the negative phenomenon and give relatively stable yields with high-quality products. The potential of sorghum grass still needs full realization. The world collection of Sudanese grass makes it possible to develop cultivars and hybrids with higher yields and quality indicators, adapting to environmental conditions (Ermolina *et al.,* 2016).

Currently, many countries have developed the hybrids of sorghum and Sudanese grass (Hayday, Tonka, Aneto, Greengo, Sugargraze II, Master BMR, and Forage King), which have become an important feed resource for livestock due to their drought resistance and undemanding nature of soil fertility, as well as, high biomass productivity. The most valuable economic quality of Sudanese grass is its high ability to regrow after mowing and proper grazing (Erdal*,* 2020). Under favorable conditions, its growth during a day can reach 5–10 cm. Sudanese grass crops are not subject to trampling, and therefore, it can be successful as a pasture crop. Nowadays, many requirements persist from cultivars, such as, compliance with soil and climatic conditions, resistance to diseases and pests, adaptability to mechanical cultivation, as well as, the influence of seeding rates and sowing methods (Kovalenko*,* 1982).

Therefore, it is necessary to see the different aspects of the technology for cultivating Sudanese grass genotypes without irrigation and study the sowing methods and harvesting times in different phases of development and when best to harvest for seeds. Climate change, water shortage, and drought require ways to grow water-efficient crops. Their large-scale introduction into production is the most effective solution to all problems (Kolos*,* 1979). In this regard, the presented study thought it necessary to develop drought-resistant and high-yielding genotypes of Sudanese grass and develop their cultivation technology.

MATERIALS AND METHODS

The object of the latest research was the cultivars of Sudanese grass (*Sorghum* ×

drummondii), obtained from the domestic and world collections. A comprehensive assessment of the Sudanese grass genotypes employed the following methods, i.e., "Methodology of State Variety Testing of Agricultural Crops" (Skokbaev*,* 2002), "Guidelines for the study of collection samples of corn, sorghum, and cereal crops" (Kolos*,* 1979), and "Methodology of field experience" (Methodological guidelines, 1968). In breeding work on Sudanese grass, the study material came from the following resources: Agroplasma Institute, Russia; POSGRR, Kazakhstan; local breeding cultivars, synthetics, especially valuable and promising hybrids and cultivars, as well as, source material from the Institute of Genetics, Physiology, and Plant Protection, Academy of Sciences, Moldova. The creation of a working collection materialized among the contrast lines (the local and world collection of VIR). In the work of selecting, developing, and improving source material, visual selection proceeded. Field experiments relied on the complete scheme of the selection process. A collection of 80 cultivars of Sudanese grass resulted from viable types. Source material comprising 20 samples bore picking for further selection in Sudanese grass (Alabushev, 2017).

The following observations helped evaluate the Sudanese grass collection based on the morphological and economically valuable traits. These are growing season (number of days from germination to panicle maturation), plant height (cm), panicle length (cm), seed yield (t/ha), tillering coefficient, the onset of the main phases of development, and considering the disease susceptibility. The Sudanese grass standard cultivar Ailana-2017 served as control for comparison and assessment.

The conduct of two field experiments studied the cultivating technology components of the Sudanese grass for seeds, comprising a) testing methods of sowing Sudanese grass without watering, with a row spacing of 70 cm (control) and with a row spacing of 45 cm; b) study of the timing of harvesting Sudanese grass when cultivated for seeds without watering: the phase of full ripeness treated as control in comparison to the waxy ripeness phase. The experiments had three replicates, and each plot size was 21 sq. m.

Research on the source material of Sudanese grass and the technology of cultivation for seeds happened in South-East Kazakhstan at the stationary site of the Kazakh Research Institute of Agriculture and Plant Growing (KazRIAPG), Almaty Region, Kazakhstan. The experiments seat on the foothill zone on light chestnut soils, with the mechanical composition of medium loamy soils, and the thickness of the humus horizon (50 cm) had humus content from 2.7% to 3.0%.

RESULTS AND DISCUSSION

In the research, attention centered on the purpose and objectives of the study, as well as, the soil and climatic conditions where the experimental work transpired. Hence, determining the germination of Sudanese grass cultivars in the local and exotic collections was the first step. From the collection, identifying the viability of 100 samples resulted in 80 samples as viable (Table 1). Breeding research aimed to develop the cultivars of Sudanese grass (*Sorghum* × *drummondii*), considering a complex of biological and economically valuable traits (Erdal, 2020). The study further progress in observing the various traits of the Sudanese grass.

The trait 1000-seed weight apparently had a range from 14.9 to 28.1 g. The Sudanese grass cultivars with a greater 1000-seed weight can best serve in breeding for productivity, revealing a direct relationship between the 1000-seed weight and grain yield. The said research signified greater importance for breeding Sudanese grass, with the evaluation of the viability of local and foreign cultivars. A large set of the recovered material opens up prospects for further breeding work, with the restored cultivars having a wide range of economically valuable traits, beneficial in breeding for further improvement. The degree of a general relationship between the 1000-seed weight and grain yield revealed the targeted selection for the breeding process (Dzhazina *et al.,* 2023).

Table 1. Sudan grass collection used for viability test.

No.	Name	Mass (g)	Test date	1000-grain weight (g)
1	K-64	50	05.07	19.1
2	K-8222	50	05.07	19.4
3	Saratov-1	30	05.07	21.0
4	Saratov-2	30	05.07	22.0
5	Saban-tui	30	05.07	21.4
6	Kiz. h-150	30	05.07	24.0
7	Kiz b/N.	20	05.07	21.0
8	Kiz precocious	20	05.07	20.4
9	Kiz 718	20	05.07	22.3
10	Kiz 663	20	05.07	23.1
11	Srem	30	05.07	24.5
12	Kizo 16	30	05.07	22.8
13	Saratov-3	30	05.07	21.8
14	Kiz. 623	30	05.07	22.3
15	Chimbayskaya yubileinaya	30	05.07	23.1
16	Kiz. 603	20	05.07	22.8
17	Kiz No. 4	30	05.07	27.1
18	Kiz, grain	20	05.07	24.2
19	Kiz 622	60	05.07	28.1
20	Kiz 1	80	05.07	18.7
21	Kiz 5	110	05.07	16.3
22	Zernogradskaya 93	120	05.07	18.7
23	Kiz 9	80	05.07	15.0
24	Kiz Amber	90	05.07	18.0
25	Kiz #197.	30	05.07	24.9
26	Kiz 714	50	05.07	26.1
27	Kiz GU	20	05.07	28.0
28	Kiz 85	70	05.07	25.0
29	Kiz 19	60	05.07	28.1
30	Kiz, cream.	40	05.07	23.7
31	Kiz. b/p	20	05.07	24.3
32	Kiz 58	80	05.07	22.4
33	Kaskelenskaya 1	50	05.07	18.3
34	Chernoplenchatyy	15	15.07	20.6
35	K – A 63	20	15.07	24.3
36	Zonal 6	20	15.07	22.8
37	Saturn	35	15.07	23.6
38	Saratovskaya 1183	40	15.07	23.4
39	Yubileinaya 20	20	15.07	22.6
40	Spartan	15	15.07	21.0

One of the economically valuable and biological traits that determine the growing region and the effectiveness of varietal production is the growing season duration and the onset of main phases of plant development. The data comprising main phases of the Sudanese grass' growth as per the nurseries of the breeding process is available in Table 2. According to precocity, two cultivars Kiz 25 and Kiz 34 achieved allocation in the competitive nursery, and the phase of full ripeness (28.09 days) occurs two days earlier than the standard Aylana-2017 (30.09 days). Therefore, a sign of precocity was evident in the selected cultivars of Sudanese grass. In the competitive nursery, the flowering phase begins 4–7 days earlier (21.07–27.07 days) than the standard Aylana-2017 (31.07 days). For mowing and obtaining more mass during regrowth, which is particularly crucial, as carrying out mowing occurs before sweeping, and therefore,

Table 2. Viability test of the Sudan grass collection.

No.	Name	Mass (g)	Test date	1000-grain weight (g)
1	B – 51	35	15.07	20.5
2	SSG Mechta Povolzhya	30	15.07	20.1
3	SSG Azimuth	50	15.07	25.1
4	SSG Sarkin	20	15.07	23.0
5	SSG Boldinsky	20	15.07	22.1
6	Sinelnikovskaya 69	25	15.07	22.5
7	K -306	35	15.07	23.2
8	K - 369	50	15.07	26.1
9	SK - 758	50	15.07	20.5
10	Soriz 1517	20	15.07	23.5
11	Kinelskoe	32	15.07	22.6
12	Kiz 143	30	15.07	21.3
13	Kiz 115	30	15.07	21.0
14	Kiz 235	30	15.07	22.6
15	Kiz 2054	45	15.07	25.7
16	Zailiyskaya 15	20	15.07	24.3
17	K – 34	20	15.07	23.1
18	K – 44	25	15.07	20.6
19	Kinelskoe - 3	40	15.07	20.1
20	Sever 162	40	15.07	23.4
21	Pruzhanskaya	20	15.07	25.1
22	Kinelskoe 100	30	15.07	20.3
23	Kiz, grain-herbal	30	15.07	21.0
24	Kiz 42	30	15.07	22.0
25	Kiz grain-herbal 655	30	15.07	21.4
26	Kiz 2	30	15.07	21.8
27	Kiz 255	110	15.07	16.3
28	Kiz grain.	30	15.07	24.9
29	Donskaya 1	80	15.07	19.7
30	AS-108	100	15.07	18.4
31	SK-768	100	15.07	17.3
32	Kiz 3	120	15.07	17.0
33	AS-84/2	80	15.07	18.4
34	Donskaya 8	80	15.07	18.4
35	K-1246	100	15.07	14.9
36	Kazakhstanskaya 23	80	15.07	15.1
37	Kiz local	80	15.07	16.1
38	Odesskaya 25	100	15.07	18.3
39	Kiz 500	80	15.07	16.4
40	Kiz sel.	40	15.07	26.4

obtaining more mass is possible during the growing season. According to Nasiev *et al.* (2019), yield reflects and integrates the action of all factors affecting the plant during its development, and its value is always the result of a compromise between productivity and sustainability. In compliance with this research, authors have verified Nasiev's theories (Nasiev *et al.*, 2019).

The determining indicator of the importance of each crop in cultivation will be the yield per unit area. In the competitive nursery, the results of establishing grain yield after processing the data and identification of a reliable increase in grain yield occurs in Figure 1. A higher grain yield was evident in the Sudanese grass cultivars Kiz 4 and Kiz 25 (2.30 and 2.70 t/ha, respectively). By

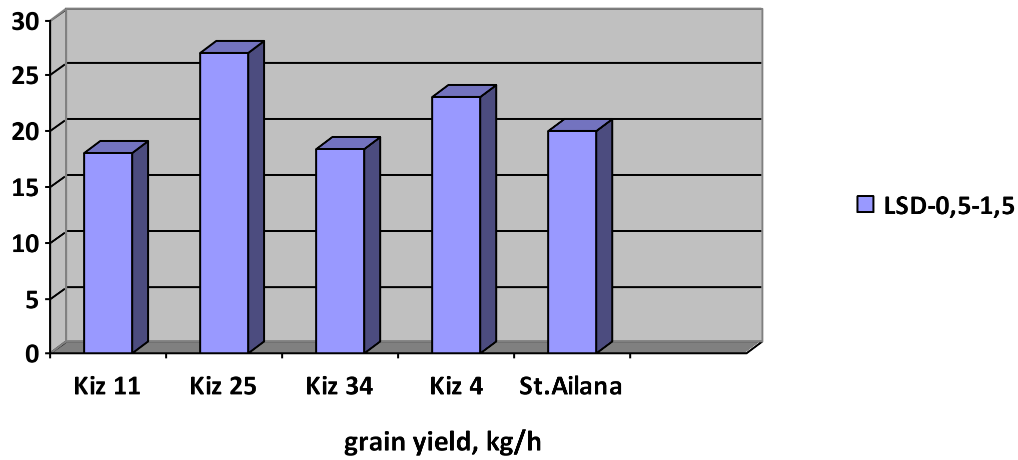

Figure 1. Grain yield (kg/ha) in the competitive varietal testing nursery of Sudan grass.

comparing with the standard cultivar Aylana-2017, the excess ranges from 0.30 to 0.70 t/ha. One of the indicators the latest research focused on was the protein and starch content in the grains of Sudanese grass cultivars in all the breeding nurseries. Sudanese grass yields higher in arid climates and surpasses many annual grasses for digestible protein content. A tendency to increase the content of crude protein arises with a shortening of the growing season. Recent studies of Sudanese grass experiments revealed an increased protein content in early ripening varieties (Kovtunova *et al.,* 2022).

Sudanese grass produced more yield under arid climates, surpassing various annual grasses for digestible protein content. In past studies, a rise in the content of crude protein correlated with a shortening of the growing season (Kunypiyaeva *et al.,* 2021). In the presented experiments, an increased protein content in early ripening cultivars also existed. Figures 2 and 3 show the protein and starch content in the grain of Sudanese grass in the nursery of the breeding processes, such as, selection, control, and competitiveness. The recent results also got support from past findings in studying sowing methods, and the optimal method was sowing with a row spacing of 45 cm at a seeding rate of 1.5–2.0 million seeds per hectare (Dyachenko, 2011).

In the breeding nursery, six Sudanese grass genotypes have higher protein contents, and the cultivar Sarkin SSG has the maximum protein content (12.3%). The starch content also varied in the breeding nursery, ranging from 25% to 39.5%. In the collection nursery, the protein and starch content ranged from 8.3% to 11.8%, and 30.4% to 38.5%, respectively (Figure 2). In the control nursery, the highest protein content appeared in the Sudanese grass cultivars Kiz 20 (12.4%) and Kis 6 (12.6%). The starch content ranged from 32.1% to 39.6% (Figure 3). The protein content is highly critical when developing Sudanese grass cultivars. Therefore, varietal samples identified with higher protein contents can serve to develop the high-protein types. The Sudanese grass cultivars identified with superior protein contents are transferrable to the nursery for competitive varietal testing. When studying the harvesting time, the study came to the conclusion that the optimal harvesting time for Sudanese grass is the ripeness of seeds on the main stalk of the panicle of 70%–90%. The best yields of high-quality seeds are available at the beginning of harvesting, at 121 days of maturation (with 70% of seeds in panicle) and at the end of harvesting (at the maturation of 80%–90% of seeds). These factors have allowed us to confidently continue this research.

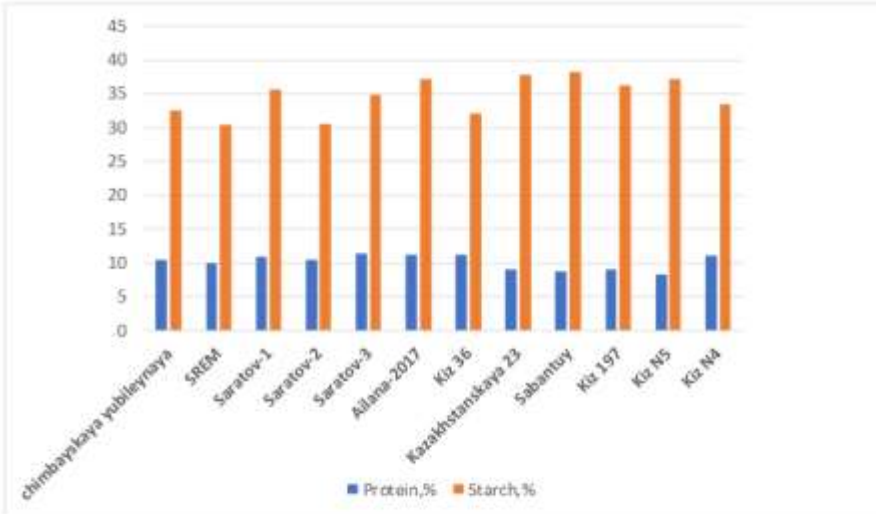

Figure 2. Protein and starch content in the grain of Sudanese grass cultivars on nurseries of the breeding process.

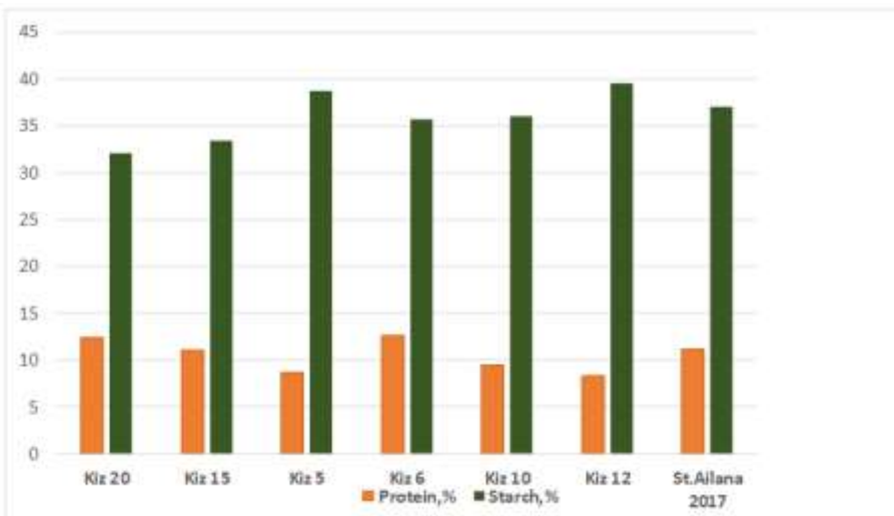

Figure 3. Protein and starch content in the grains of Sudanese grass cultivars in the control nursery.

On experiments studying the elements of technology for obtaining Sudanese grass for seeds by cultivating without irrigation, the methods of sowing and harvesting time for seeds incurred assessment. The results of the structural analysis of the Sudanese grass cultivars in the experiment on sowing methods appear in Table 3. The structural analysis of the cultivars carried out during harvesting showed, with row spacing of 45 cm, the wet, and dry mass of stems, panicles, and leaves of plants were higher than with row spacing of 70 cm. According to Alabushev *et al.* (2019), no consensus existed on which phase of the growing season the harvesting of Sudanese grass is most optimal and provides the highest yield of high-quality feed. It depends on the characteristics of the region, the varietal composition, and in the conditions of Southeast Kazakhstan, these studies are first-time research, and they are relevant and in demand.

Table 3. Phenological traits recorded in the nurseries of the selection process.

No	Cultivars	Development phases			
		Sweeping	Flowering panicles	Wax ripeness	Full ripeness
		Collection nursery			
1	Chimbay anniversary	27.07	04.08	18.08	02.10
2	SREM	27.07	04.08	18.08	02.10
3	Saratov-1	27.07	04.08	18.08	02.10
4	Saratov-2	21.07	27.07	14.08	28.09
5	Saratov-3	21.07	27.07	14.08	28.09
6	Ailana -2017	31.07	06.08	22.08	28.09
7	Court grass 36	31.07	06.08	22.08	28.09
8	Kazakhstanskaya 23	27.07	04.08	18.08	22.09
9	Saban tui	27.07	04.08	18.08	22.09
10	Kiz 197	27.07	04.08	18.08	22.09
11	Kiz No. 5	27.07	04.08	18.08	22.09
12	Kiz No. 4	27.07	04.08	18.08	22.09
		Control nursery			
1	Kiz 20	21.07	27.07	14.08	28.09
2	Kiz 15	21.07	27.07	14.08	28.09
3	Kiz 5	27.07	04.07	18.08	02.10
4	Kiz 6	27.07	04.07	18.08	02.10
5	Kiz 10	27.07	04.07	18.08	02.10
6	Kiz 12	31.07	06.08	22.08	28.09
7	St. Ailana -2017	31.07	06.08	22.08	30.09
		Competition nursery			
1	Kiz 11	27.07	04.08	18.08	02.10
2	Kiz 25	21.07	27.07	14.08	28.09
3	Kiz 34	21.07	27.07	14.08	28.09
4	Kiz 4	27.07	04.08	18.08	02.10
5	St. Ailana - 2017	31.07	06.08	22.08	30.09

The seed yield evaluation ensued in the full-grain ripeness phase (Figure 4). Grain yield at a row spacing of 45 cm after drying was 2.12 t/ha, with a significant increase in yield compared with the control (0.43 t/ha). Therefore, by growing Sudanese grass without irrigation, 45 cm can be considerably an acceptable row spacing in sowing. Dyachenko (2011) studied the sowing methods and also recorded the same findings. The optimal method of sowing was having a row spacing of 45 cm and a seeding rate of 1.5–2.0 million seeds per hectare. During his research, Kovalenko (1982) also came to the similar conclusion while studying the methods of sowing in Sudanese grass.

The research on components of the cultivation technology of Sudanese grass studied the two harvesting periods by growing without irrigation. The structural analysis of various Sudanese grass genotypes with two harvest periods are available in Table 4. Past studies on the timing of harvesting and the height of mowing plants have a significant impact on the quantity and quality of the harvested Sudanese grass (Muslimov *et al.,* 2016).

Structural analysis showed harvesting in the full ripeness phase has an advantage for absolutely dry grain weight (3,960 g), compared with absolutely dry grain weight in the wax ripeness phase (1,100 g), which after drying, has a significantly low grain weight (Table 5). According to the seed yield at different harvest times, a substantial increase in seed yield occurred compared with the control in the case of harvesting carried out in the full ripeness phase. According to Sysoikin (2003), wide-row crops of Sudanese grass surpass ordinary crops by 0.12–0.53 t/ha in

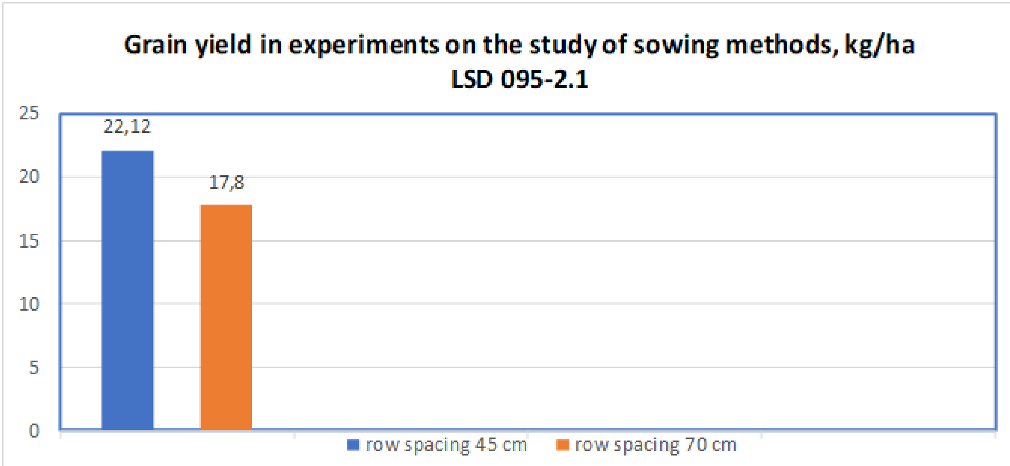

Figure 4. Grain yield in the Sudan grass experiments based on studying the sowing methods.

Table 4. Structural analysis of the Sudan grass genotypes based on studying the sowing methods.

No.	Row spacing (cm)	Air-dry and wet mass (kg)					
		Raw			Dry		
		Stems	Grains	Leaves	Stems	Grains	Leaves
1	45 cm	22.900	2.520	8.805	16.800	1.500	3.825
2	70 cm (control)	16.930	2.750	8.888	16.425	1.100	3.000

Table 5. Structural analysis of Sudan grass experiments based on studying the harvesting technology in waxy and full ripeness phases.

No.	Ripeness phases	Air-dry and wet mass, kg					
		Raw			Dry		
		Stems	Grains	Leaves	Stems	Grains	Leaves
1	Waxy ripeness	22.900	2.520	7.805	16.800	1.100	3.000
2	Full ripeness	-	-	-	31.700	3.960	5.052

seed productivity. The obtained maximum seed yield was at a seeding rate of 1.0 million units/ha, with a row spacing of 45 cm at 14.3 t/ha. On ordinary crops, the maximum yield obtained emerged on the variant with a seeding rate of 2.0 million units/ha at 1.26 t/ha.

The best yield with high-quality seeds appeared at the beginning of harvesting, at 121 days maturation, with 70% of seeds in panicle and at the ripening of 80%–90% of seeds. The presented results confirm the opinion of previous researchers on grain yield. One can note the seed yield of 2.27 t/ha in harvesting during full ripeness phase was higher than the seed yield obtained during harvest at the wax ripeness phase (1.98 t/ha). Therefore, to fully complete the grain formation processes and obtain higher yields, it is necessary to harvest in the full ripeness phase. However, in the case of early autumn frosts, it is possible to make harvesting at the waxy ripeness phase. Polikarpov (2001) also reported the optimal harvesting time is the full ripeness of seeds on the main stalk of the panicles in Sudanese grass.

According to Sharko and Shatrykin (2023), the Sudanese grass has characteristics of increased bushiness and good regrowth after mowing and cutting at the root; however, the main problem is insufficient cultivars combining precocity with high productivity. Thus, the breeding work on developing drought-tolerant and high-yielding cultivars and hybrids, especially involving new source material of Sudanese grass, progressed by considering a complex of biological and economically valuable traits (Sharko and Shatrykin, 2023; Astuti *et al*., 2024).

CONCLUSIONS

In the latest study, the main task of the selection was to determine the economically valuable traits of Sudanese grass (*Sorghum* × *drummondii*) cultivars, which simultaneously determine the grain yield, product quality, and resistance to environmental stress conditions. In developing new drought-resistant and highly productive Sudanese cultivars with good product quality, various genotypes have undergone evaluation, identifying the promising cultivars based on viability, early maturity, and by seed yield with good quality. These genotypes can benefit future breeding programs.

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