THE POSSIBILITY OF SORGHUM CULTURE ZONING IN THE ALMATY REGION OF THE REPUBLIC OF KAZAKHSTAN

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Abstract: The article is devoted to the topical problem of agriculture in the Almaty region of the Republic of Kazakhstan, where sorghum was not widely spread due to the lack of high-yielding varieties and hybrids in production. The article sums up some results of studying the best forms of sugar sorghum samples from the world gene pool and their involvement in the selection process for creating varieties and hybrids of the intensive type using traditional breeding methods that determine vegetative and field methods of agronomic research. The biological features of the studied sorghum varieties have been identified; parental forms with useful traits for using in crossing have been selected. The varieties characterized by high productivity of biomass and sugar content have been distinguished. The full vegetative period of these varieties in the first generation has been determined. As the research problem, the authors have defined an attempt to assess the possibility of conducting breeding work on breeding the varieties and hybrids that meet the requirements of production. As the result of crossing the varieties of sugar sorghum among themselves and sterile lines, hybrids with economically valuable traits were obtained. Crossing the sterile line with sugar forms showed high seed setting.

Keywords: Sorghum sacchartum, selection process, highly productive varieties, hybrid, heterotic forms.

1 Introduction

According to natural and climatic resources and economic factors, the Almaty region of the Republic of Kazakhstan has a great potential of cultivating this crop and development of sorghum production. This zone is characterized by unstable and insufficient moistening along with high heat supply and therefore more suitable for sorghum cultivation than other crops. More than 50% of the area of the Almaty region is in the zone where precipitations are less than 400 mm per year, and the sum of temperatures above 15°C is 2600-3000°C. According to many experts, in a zone where atmospheric precipitation does not exceed 400 mm, sorghum production is more efficient than corn production.

In Kazakhstan selection work on sorghum started in 1976 in the KazSRI (Kazakhstan Scientific Research Institute) of grassland agriculture and lasted until 1985, and then from 1987 to the present time in Kazakhstan Scientific-Production Centre NPC of Agriculture and Crop Production. The selection was started for all sorghum crops (sorghum grains, sugar, Sudan grass, sorghum-Sudan hybrids), and since 1998 sorghum for food-grains. Selection work on sorghum crops was conducted under the guidance of V.M. Makarov, who created varieties and hybrids of sorghum crops for the first time in Kazakhstan. (1)

A deterrent factor for the widespread introduction of sugar sorghum in the arid regions of the Almaty region is insufficient selection work on breeding varieties and hybrids that meet the requirements of production. (2) Many zoned varieties and hybrids of sugar sorghum are late-ripening, fall during ripening, and characterized by low sugar content in the sap of stems.

The next reason why sugar sorghum has not received a proper distribution was the lack of agricultural techniques of cultivation, considering varietal characteristics. At the present stage of agricultural production introduction of new varieties should be carried out with strict adherence to the inherent technology of cultivation, taking specific conditions into account. (3-4)

In this connection, we set the task of identifying high-sugar sorghum samples and involving them in the breeding process to create varieties and hybrids of intensive type, promoting the increase in the yield of sugars from a unit area of cultivation. Further development of the research works on the production of sorghum sugar in industrial scale is possible as a result of using the best forms from the world gene pool of sorghum on the basis of cytoplasmic male sterility of highly heterotic hybrids adapted to local conditions with a high content of sugars in the sap of stems using traditional breeding.

The purpose of this study is to create new high-yielding heterotic domestic forms and sorghum sugar lines (Sorghum sacchartum) in the Almaty region adapted to local conditions (to drought and salinity of soil) using traditional breeding methods.

In this regard, it is necessary to identify high-sugar and high-yield sugar sorghum samples and involve them in the breeding process to create early-ripening varieties and hybrids of the intensive type characterized by high sugar content in the sap of stems and high yield of biomass.

2 Materials and Methods

The objects of the research were domestic and foreign varieties and promising lines of sugar sorghum (Sorghum sacchartum (L.) Pers.). Modern physiological, biochemical, genetic and breeding methods, as well as agronomic approaches to plant research, were used in the work. The content of soluble sugars in some organs was determined by the refractometric method. Sampling the studied samples consisted of the forms that were distinguished by the signs of early-ripeness, tallness and high content of sugars in the sap of stems and high productivity of biomass. Experimental samples were sown on one-row plots (S-5m3). Agrotechnical works included pre-sowing cultivation, sowing with dropping and subsequent tillage harrowing, three-time weeding and single spraying of plants with herbicides. (5)

The crossing was performed according to generally accepted methods with modifications on the experimental field of the Main Botanical Garden of the NAS RK (National Academy of Science) and on the fields of Kazakhstan Scientific-Production Centre NPC of Agriculture and Crop Production. Morphometric parameters were determined by the results of the structural analysis. Growth biological parameters such as plant height, the length of the panicle, the number of nodes, the number of lateral shoots, and the dry biomass of some organs were studied by measuring and weighing. (6-7) The qualities of seeds sown, such as germination energy, the intensity of endosperm reserves consumption and germination capacity were determined. The obtained results of the studies were subjected to statistical analysis according to N.L. Udolskaya (8) and the computer program Excel 97. (9)

Sorghum is an exclusively drought-resistant crop, withstands heat, dry hot winds, and grows on salty soils. Many farmers of Kazakhstan in the last couple of years are interested in this culture, beneficial for the zones of risky farming, its peculiarities, consider the possibilities of its cultivation. (10-11)

High-yield forage and food crops of sorghum belong to the genus Sorghum, from its many species in Kazakhstan, mainly two are cultivated: Sorghum vulgare and grass sorghum - sudanense, cultivated as a forage plant.

By the nature of the use, sorghum is divided into three groups: Sorghum bicolor, sugar (high-yield) sorghum and Sorghum technicum. (12)

According to the panicles structure, the forms of sorghum are distinguished: branchy (broomcorn), compressed and lump. For cultivation on bread grains use a species with a lump form of panicle (Figure 1). For cultivation as sugar (or high-yield)

sorghum (green forage, hay, silage, for obtaining treacle and grain), varieties are used mainly with a branchy form of a panicle. (13) Sorghum technicum has no high-yield value, mainly represented by varieties with a compressed form of panicle, which does not have the main axis. (14) From the latter make brooms, brushes.

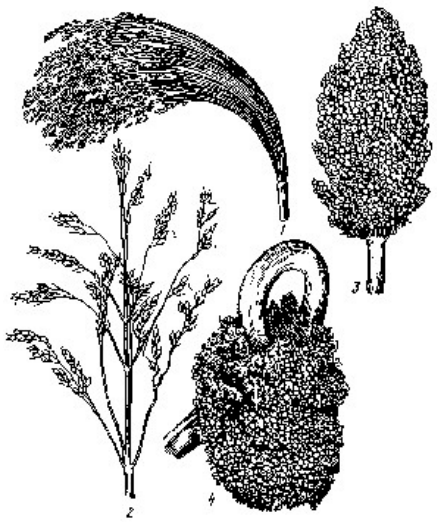

Figure 1. Sorghum Subspecies:
1 – branchy with a shortened main axis and long lateral branches (paniculate); 2 – branchy with the developed main axis; 3 – lump with an upright stem; 4 – lump with the crooked stem (drooping sorghum/Sorghum cernuum).

By all forms of sorghum in our country, currently, there are selection cultivars and hybrids.

2.1 Cultivar from Kokshetau

If you look through the Register of Agricultural Plants allowed for use in the RK, it can be seen that mainly varieties of drought-resistant crops are zoned in the south, west and east of Kazakhstan.

At Shokan Ualikhanov Kokshetau State University, for two years the work has been in progress to create a variety of grain sorghum for southern humus and chestnut soils of Northern Kazakhstan. The prospectivity of this direction is proved by the world trend towards the expansion of sown areas in the regions of semi-arid and dry-steppe arable farming. The yield of individual hybrids of the nursery is already over 30 centner/ha.

The creators are aiming to obtain a highly productive, plastic variety of Sorghum bicolor under conditions of artificial overcrowding, suitable for solid planting, so that it can be cultivated on the traditional technology of grain growing, without additional costs for the acquisition or re-equipment of technics. (15-16) Here they also started developing biomass production technologies for obtaining bioethanol from this plant.

2.2 Biological characteristics

Sorghum is cross-pollinated, heat-loving, spring crop, capable of forming high yields with total annual precipitation of 200-250 mm. Where there is little rainfall for corn, and without irrigation, it does not yield good harvests, sorghum can be used. Also, this culture is equivalent to corn as a precursor for spring grains.

In the process of evolution, sorghum developed a great deal of adaptability to the lack of moisture and its economical expenditure. It has been established that sorghum consumes 300 parts of water for the formation of a dry matter unit (for comparison: sugar sorghum - 340, maize - 338, wheat - 515, barley - 534, oats - 600, pea - 730, alfalfa - 830, sunflower - 895). (17)

A characteristic feature of sorghum is the slow initial growth of the aboveground part (30-40 days from the emergence of the shoots) and at the same time the intensive formation of the root system penetrating to a depth of 2-2.5 m. This is why sorghum has strict requirements for the choice of the preceding crop, processing technique, crop tending, especially in the control of weeds. The best preceding crops are the cultures leaving after themselves pure from weeds fields, grain, pulse, and also arable crops. (18-19) It is not advisable to sow sorghum after millet, Sudan grass, and sunflower. With appropriate farming standards, sorghum for hay and grazing can be grown on the same field for 3-5 years. Since the culture produces a significant amount of sodium, chlorine, and magnesium with the yield and bears a concentration of soluble salts of 0.6-0.8% or 1.5 times more than corn, so it can be placed as the first culture by the reclamation of salty soils. (20)

At strong droughts in roots of a plant, the protective silicon layer is formed, protecting them from drying. The waxy bloom on stems and leaves of plants has the same value. If the soil retains a little moisture, the culture continues to grow, despite the heat, low air humidity, and dry hot winds. (21-22)

When the air temperature rises above 350C, sorghum falls into anabiosis, that is, it stops its growth for 45-55 days, and as soon as the slightest moisture appears, it again begins to grow to 5 cm per day. (23) However, if the drought lasts too long, the culture may not be in time to “wake up” and form a full panicle.

2.3 Methods of cultivation

Agrotechnics of sorghum is similar to the agronomics of corn. The culture responds well to deep plowing, dung application, phosphorus fertilizers.

Sowing is carried out when the soil warms up to 12-15 °C. The sorghum is sown on grain with a wide-row (70-90 cm) or square-pocket planting method (70 × 70 or 90 × 90 cm) with 4-6 seeds in a nest.

It should be remembered that if we plant sorghum too early, the weeds will start to develop faster than the crop itself, and can suppress its growth. This fact is mentioned by Ukrainian experts as one of the reasons why sorghum in Russia was not widely spread: many farmers did not observe the sowing time, sowed it early, because of this, they received poor results and refused to cultivate in the future.

The norm of sowing with a wide-row method is from 10 to 15 kg per 1 hectare, the seeds are embedded to a depth of 3 to 7 cm.

For the green mass, the sorghum can be sown by a continuous row-crop method or double-row planting (45-60 × 15), the sowing rate 20-25 kg per 1 hectare. At the same time, mineral fertilizers are added at the rate of N60P60 (24). To obtain even sprouts, pre-sowing and post-sowing compacting should be applied.

Sorghum for grain is harvested at its full ripeness by a combine; sugar sorghum - at the end of the wax ripeness in the close cut, and Sorghum technicum - at the end of the milk state (first a panicle and then a mass). (25)

2.4 The secret of proper cleaning

Sorghum grain is very hygroscopic, and by moving of the stem (which is usually very juicy) with an ordinary cutter, the stem is connected to the grain in the hopper, its moistening takes place. It turns out that if the grain has a moisture content of about 12% on the field, after mowing it is unloaded with a moisture content of 18-20%. Which, of course, is bad for storage. Therefore, it is better to use a combing cutter when harvesting sorghum for grain. (26)

For green fodder and hay sorghum, it is advisable to mow down to the blooming phase. In this case, the green mass is eaten well by cattle. In addition, one can expect to receive an after-growth, since all sorghum crops grow well after the first mowing, and their green mass can be used in the late summer and autumn periods before the onset of frost. In this case, moving in the amount of two cuts is usually 10-20% more than one for a single moving.

The harvested vegetative mass at a later date can be used to lay high-quality haylage and silage. Due to the high content of sugars (14-20%), sorghum is easily silaged not only in pure form but also in a mixture with straw, chaff.

Grains of sugar sorghum are often used for the preparation of mixed fodders, and by way of concentrated feed for all farm animals. Scientists of the South-Kazakhstan region actively recommend that farmers use sorghum grain for fattening sheep.

Nutritiousness of sorghum grains is quite high. Specialists note that the use of sorghum grains in the supplement feeds is equivalent to barley grain, pigs give the same gain in weight and quality. However, the yield of sorghum is much higher than spring barley, so from 1 hectare of sorghum, it is possible to get twice as much pork as from 1 hectare of barley. (27)

According to the protein content, sorghum is not equal among other forage crops. Sorghum grains consist of 12-15% protein, about 70% starch, and 3.5-4.5% fat. In one centner of the grain, there are from 118 to 130 feed units. The energy content in the sorghum crop is 18.3 MJ/kg.

Sorghum effectively silages to one and a half months from the moment of the onset of the optimal phase (milk-wax) ripeness of grain. (28) This means that for farms limited in cleaning tools and transport equipment, this culture is a real find. Due to the good growth after grazing, the crop can be used to create annual pastures. The leaves and stems of the plants remain juicy until the full ripeness of the grain. In 100 kg of silage from sorghum contains 20-24 fodder units and 1.31-1.67 kg of digestible protein.

2.5 World consumption and market

According to FAO, in the world in 2012, 58.09 million tons of sorghum was harvested. The average yield was 1.53 tons per hectare.

In the United States and South American countries, sorghum is one of the main crops for the production of bioethanol, the cereal provides an alcohol yield of 25-30% more than that of corn and wheat. Therefore, one of the main factors influencing the price of sorghum is the cost of oil. The world's largest producer and exporter of sorghum is the United States. China imports a large amount of sorghum from Australia for processing to alcohol.

From the CIS countries, the leading producer and exporter of sorghum is Ukraine. The production of culture takes fifth place here after wheat, barley, rice, and corn. Sugar cereal is a safety net for farmers in the event of an unfavorable seasonal outcome for the main crops. The geography of exports is the Middle East and Africa, where there is a long tradition of using culture, as well as Europe, where it is intensively recycled to ethanol.

2.6 Kazakhstan market

It is gratifying to report that in our country there is also the processing of sorghum into syrup. This is done by LLP “Zhetysu Kant” in Shardarinsky district of South Kazakhstan region on a universal sugar mini plant with a capacity of 50 tons per day. As raw materials, they use their own sorghum and also buy it. Finished products are for sale in Kazakhstan, for export to Central Asian republics.

Export of its own cereals can also be done through Kazakhstan's large grain traders who place their ads on the Internet. Last season, according to Irina Ivanova, a representative of the export company LLP “Unistone Company”, the export of sorghum did not fully develop, as domestic farmers kept a high price with low quality, and European buyers have very high requirements in this regard.

4 Results and Discussion

3.1 Experimental part

Breeding experiments with some experimental sugar sorghum material were carried out in the foothill zone on light chestnut soils, the thickness of the humus horizon is 50 cm with a humus content of 2.7 to 3%, in the fields of the Main Botanical Garden (MBG) of National Academy of Science of the RK and Kazakhstan Scientific-Production Centre NPC of Agriculture and Crop Production in 2016.

The agro-climatic conditions on the average long-term observations were favorable for growth and development of sugar sorghum. Season 2015 was distinguished by a significant amount of atmospheric precipitation in May - 80.7 mm, average - 61.6 mm, and in general during the spring months their height was 201.1 mm, which is much higher than the average annual norm - 163.9 mm. The weather conditions were characterized with high temperatures and low precipitation during the period of 2016, which had a positive effect on the accumulation of sugars in the sap of plant stems and ripening of sugar sorghum samples. A small number of precipitations during flowering and ripening of samples in 2016 season affected the concentration of sugars in the sap of plant stems. In general, different weather conditions contributed to the comprehensive study of the collection material to highlight environmentally plastic samples. In 2016, 30 collection samples of sugar sorghum and 3 sterile sorghum lines were selected for the study. Sampling consisted of samples that were distinguished by the signs of early ripeness, tallness and high content of sugars in the sap of stems.

The material for the study consisted of varieties and lines of sorghum crops (grain, sugar, birch, sorghum-sudan grass from the world collection of sugar sorghum. Promising hybrid lines of sugar sorghum have been identified and selected for use in the breeding process.

Previously, in the laboratory conditions, the seed quality of the seeds of the varieties studied and the lines, such as germination and germination energy were determined (Table 1).

Table 1. Germination of the Seed of Varieties and Line of Sugar Sorghum, 2016

Variety	Germination
1	2
Shortgrowing-81 sterile line	90 ± 0,8
MSL-26 sterile line	96 ± 0,5
Sakharnoye- 32	100 ± 0,0
Oranzhevoye 160	100 ± 0,0
Uzbekistan 18	100 ± 0,0
Kazakhstanskoye - 16	96 ± 0,5
Larets	100 ± 0,0
Sugar drip	100 ± 0,0
Dela Varieta	100 ± 0,0
Sudan grass of Kazakhstanskaya 3	100 ± 0,0
SPV 1411	100 ± 0,0
Kazakhstan -20	100 ± 0,0

According to Table 1, all varieties and lines showed high seed germination (from 90 to 100%).

Studies of biological characteristics and conducted phenological observations of varieties and lines of sugar sorghum collection nursery in the period of 2016 found that hybrid varieties of Uzbekistan 18 and Kazakhstan-20 are superior to all other varieties and lines for all biological parameters. For instance, the dry weight of stem and leaves of one plant varieties of Uzbekistan 18 with the leading shoot was up to 365 g, with side shoots 272,5 g, dry weight of panicle of the leading shoot 165,0 and 127,5 g. with side shoots. The dry weight of stem and leaves of one plant varieties Kazakhstan -20 with the leading shoot is up to 670,0 g, with side shoots - 180.0 g, dry weight of panicle of the leading shoot -136,7 g and 58.3 g from side shoots.

Biological features of the investigated sorghum varieties were determined by the structural analysis (Table 2). According to the results of the analysis and such parameters as dry mass of the above-ground part of plants, the height and sugar content in the stem, breeding varieties Uzbekistan 18 and Kazakhstan -20 can be noted, where full vegetation period of these varieties was 144 days, which can be attributed to a number of late-ripening varieties (Table 2, 3). Considering biomass accumulation, the height of plants, the variety of Uzbekistan-18 can be noted, which ripening period is 141 days and the average sugar content is 11%. Varieties of Sakharnoye - 32, Sugar drip, DelaVarieta, SPV 1411, Kazakhstan-16, Kazakhstan-20 and Uzbekistan 18 showed high rates of above-ground biomass and sugar content, the full ripening period is 120-135 days. Varieties of Orange 160, Borotal, Larets - these lines are grains, sugar content and the mass of the above-ground part and height of plants were low, but the panicle mass was high compared to sugar varieties. The hybrid variety of SST Kazakhstan-3 differed in plant height and bushiness, but the dry mass of the aboveground part is medium, the sugar content is low, the period of full ripening refers to the early-ripening hybrids - 95-110 days (Table 2).

Table 2. Structural Analysis of Biological Characteristics of Sorghum

Variety	Shoot	Length of shoot, cm	Length of panicle, cm	Number of internode, pcs	Number of side shoots, pcs	The dry weight of panicle, gram	The dry weight of stems and leaves, gram	Soluble sugars, %
1	2	3	4	5	6	7	8	9
Shortgrowing-81	Leading	119,0	21,0	7	1	108,0	168,0	5,0
	Side	129,0	17,0	8		31,0	68,0	
MSL-26	Leading	78,7	20,7	6	3	55,0	61,0	4,0
	Side	97,5	18,6	7		28,9	43,9	
Sakharnoye - 32	Leading	126,7	24,7	7	4	91,0	168,0	7,5
	Side	155,2	19,3	7		38,7	129,0	
Uzbekistan 18	Leading	230,7	51,0	9	3	100,0	176,7	0,0
	Side	198,7	41,7	6		37,2	183,3	
Kazakhstanskaya-16	Leading	95,0	25,7	7	1	121,7	170,0	----
	Side	88,3	19,7	6		40,0	51,7	
Larets	Leading	117,3	21,0	8	3	110,0	113,3	7,0
	Side	146,8	15,1	8		70,5	106,7	
Sugar drip	Leading	218,0	28,0	9	3	65,0	215,0	14,0
	Side	204,0	22,5	9		25,0	111,7	
DelaVarieta	Leading	93,3	22,3	7	2	115,0	116,7	8,0
	Side	127,3	17,3	7		53,3	70,0	
SPV 1411	Leading	200,0	23,0	10	3	95,0	291,7	16,0
	Side	159,8	19,0	8		53,3	172,2	
Kazakhstanskaya–3 SST	Leading	229,3	42,0	9	4	76,7	151,7	16,0
	Side	246,4	33,1	9		41,9	141,9	
Kazakhstanskaya -20	Leading	210,3	20,3	8	3	93,3	333,3	15,0
	Side	204,3	17,6	9		37,9	227,3	

The full vegetative period of the most early-ripening MSL - 26 line was only 99 days, while varieties of Short growing - 81 early, Uzbekistan 18, Sudan grass, Kazakhstan - 3 full vegetation period was 106-115 days; The varieties and lines that are full-

grown are the varieties and lines whose full vegetation period is 115-130 days: Kazakhstanskaya 16, Kazakhstanskaya 20, Oranzhevoye 160. All other varieties and lines are late-ripening: Sugar drip, Uzbekistan 18, Simon, SPV-1411, DelaVarieta.

3.2 Reciprocal crossing for obtaining F1

To attract forms of sorghum to the breeding process when creating high-yielding, early-ripening and resistant to lodging, diseases, drought, and other environmental factors, we have selected zoned in Kazakhstanskaya varieties, such as Kazakhstanskaya 20 (sugar), SST (hybrid) Kazakhstanskaya 3, Oranzhevoye-160, Larets, Sakharnoye - 32, etc. The varieties are distinguished by the following agronomically valuable characteristics, such as yield, resistance to unfavorable environmental factors, sugar content and early-ripening. The main biological features of these varieties are given in Table 3.

Table 3. Biological Characteristics of Varieties on Agronomically Valuable Traits

Varieties	Biometric indicators and properties					
	Yield	Plant height	Lodging resistance	Persistence to diseases	Precocity	Amount of soluble sugars
Sakharnaya - 32	High	250-300	Low	Low	(115-122 days)	16,5 %
Orange 160	Average	200-250	High	Low	(115-122 days)	16 %
Larets	Average	200-250	High	Low	(115 -122 days)	12 %
Kazakhstan -20	Average	200-250	High	High	(115-122 days)	20 %
Kazakhstan – 3 SST	High	300-350	High	High	(95-105 days)	7 %

To obtain the source material of sorghum, the breeding method of hybridization and artificial breeding by castration was used, removing male flowers on short stems. The flowers on a panicle were castrated on one or several branches, and then each of them was isolated, which allowed receiving the possibility of pollinating individual branches by different paternal forms and getting a few hybrid seeds on one panicle.

Castration and hybridization methods were performed in the flowering stage in the morning from 8 00 to 10 00. For this purpose, well-developed flowering branches of panicles were selected. After pollination, each branch was insulated with parchment paper and then numbered.

As source material, 4 varieties and 1 hybrid of SST were used (Sorghum Sudan grass of Kazakhstanskaya 3, Oranzhevoye-160, Sakharnaya-32, Larets, Kazakhstanskaya-20), differing in length of vegetation period, an element of crop structure, soluble sugars and other agronomically-valued attributes and properties.

As the result of the reciprocal crossing in the combinations of the ♀SST Kazakhstanskaya 3x ♂Oranzhevoye 160, with the direct and reverse crossings, the seeds did not set. In the combinations of the ♀SST Kazakhstanskaya 3 x ♂Rostov with direct crossing, the number of set seeds was 141, which was 21%, and with the reverse crossing, the seeds did not set. In the combinations of the ♀STT Kazakhstanskaya 3 x ♂ Larets of direct crossing - 39 seeds were set, i.e. 9,5%, and with the reverse crossing - 49 seeds, i.e. 4% (Table 4).

Table 4. Reciprocal Cross-breeding of Selected Varieties of Sorghum Sugar

Parental forms		Repetition	Number of castrated flowers	Seed setting (hybrid) F1 pcs	The result of setting, %
♀	♂				
SST Kaz-3	Kazakhstan-20	4	68±5	8±0,1	3
SST Kaz-3	Orange-160	6	68±5	0	0
SST Kaz-3	Sugar-32	10	68±5	141±10	21
SST Kaz-3	Larets	6	68±5	39±2,8	9,5
Orange-160	SST Kaz-3	23	65±5	0	0
Laters	SST Kaz-3	21	58±4	49±3,0	4
Sugar-32	SST Kaz-3	12	50±4	0	0
Total		82	445	237±17	

As can be seen from Table 4, in 7 crossing combinations with the number of castrated branches in each combination from 4 to 23 and the total number of castrated flowers 445 pieces, the number of bound seeds was 237 pieces. In the combinations, ♀SST Kazakhstanskaya - 3 x ♂ Oranzhevoye -160, ♀ Oranzhevoye -160 x ♂ CCT Kazakhstanskaya - 3 and ♀ Sakharnaya - 32 x ♂ CCT Kazakhstanskaya - 3 the seeds did not set. Only in the reciprocal crossing combination of the variety of Larets with the hybrid of SST Kazakhstanskaya -3 the percent of setting in the direct and reverse case was from 4 to 9.5%.

Thus, the highest percentage of setting (21%) of hybrid grains was obtained in the combination of ♀STT Kazakhstanskaya-3 ♂ Sakharnaya-32 as the result of direct crossing (Table 4), and in the reverse order of crossing (♀ Sakharnaya - 32 x ♂SST Kazakhstanskaya - 3), the seeds did not set. As a result of reciprocal hybridization, 237 hybrid seeds were obtained, which were directed to study the properties and selection of promising plant forms in the first generations.

The conducted studies of the biological characteristics and phenological observations of the F1 hybrids obtained in 2016 and their parental forms have been conducted. As the source material, 4 varieties of sugar sorghum (Oranzhevoye-160, Sakharnaya-32, Larets, Kazakhstanskaya-20) and 1 hybrid of sorghum of the Sudan grass of the Kazakhstanskaya-3 (SST Kaz-3) were taken, differing in length of vegetative period, yield structure elements, the content of soluble sugars and other economically valuable characteristics and properties.

The effect of heterosis was calculated relative to the best parental form – the "true" heterosis (Ftrue). To determine the economic value, the characteristics of the heterosis hybrid were compared with the standard, Soriz variety. A reliable symptom of the excess hybrid combination on a certain basis of the standard was attributed to heterosis as "competitive" (Fcom). The degree of heterosis display was calculated by the formulas: (8)

$$Ftrue = ((F1 - Ct) \div Ct) \times 100; \quad (1)$$

$$Fcom = ((F1 - Pbest) \div Pbest) \times 100$$

where: Ftrue - the degree of heterosis relative to the best parental form, %;

Fcom - the excess characteristic of the F1 hybrid over the standard variety, %;

F1 - the characteristic value of the hybrid combination;

P best -the characteristic value of the best parent form;

Ct - the characteristic value of the standard.

The experimental data were processed by mathematical modeling using statistical methods and programs. The study took the significance level of 5%.

It was found out that when crossing the ♀SST Kazakhstanskaya-3 × ♂ Sakharnaya - 32 and ♀Larets x ♂Kazakhstanskaya 20, and ♀ Larets x ♂SST Kazakhstanskaya-3, the resulting hybrids did not have a heterosis effect (Table 6).

Table 5. Biometric Parameters and Sugar Content of Stems of Hybrids F1 and Their Parent-forms, 2016

Shoot	Plant height, cm	Length of panicle, cm	Number of internodes	Sugar content, %	Number of side shoots, Pcs	Raw weight of stems and leaves, gram	Raw weight of panicle, Gram
Hybrid 1 ♀SST Kaz-3x ♂Sakharnaya – 32 (135 days)							
Leading	270,0±20,3	54,5±2,0	12	7,2±1,1	6	310,0±11,5	91,7±5,2
Side	273,4±10,1	50,9±4,2	10			1635,0±10	465,0±5,8
Hybrid 4 ♀Larets x ♂Kazakhstan 20 (135 days)							
Leading	204,3±25,1	21,3±2,9	10	---	3	737,5±49,1	180,0±28,9
Side	215,0±9,8	19,8±2,0	11			1462,5±18	335,0±5,8
Hybrid 6 ♀Larets x ♂SST Kaz-3 (135 days)							
Leading	216,0±16,6	21,0±0,4	10	---	3	606,7±18,6	200,0±0,0
Side	222,0±14,7	20,9±1,0	11			1390,0±75	370,0±0,0
Parental forms							
SST Kaz-3 (115 days)							
Leading	336±4,2	52	10	7	9	240±18	90±8
Side	358,2±0,2	46,4±0,5	10,1±0,			1480±45	385±28
Larets (120 days)							
Leading	215±5,3	24	11	15	4	640±52	200±18
Side	204,7±4,3	17,9±0,1	11			1545±87	465±32
Kazakhstan 20 (125 days)							
Leading	246±16,2	24,7±1,4	14	20	2	567,5±2,9	120,0±5
Side	244±6,9	19,6±1,3	12			730,0±46	115,0±0,
Sakharnaya – 32 (125 days)							
Leading	235,0±1,2	28,0±4	10	18	2	325,0±5,8	100,0±0,0
Side	196,0±11	18,2±2	10			492,5±25,9	75,0±0,0

In the height of the plants, the length of the panicle and tillering, the first hybrid plant showed a significant lag behind the parental forms. However, in raw biomass, the hybrid plant approached the parental form. The main morphological characteristics of the Hybrid 4 – Larets X Kaz-20 and Hybrid 6 - Larets X CCT Kaz-3 are similar to the parental form by the following characteristics: height of the plant, length of the panicle, tillering and raw biomass of the plants.

The data obtained showed that Hybrid 1, Hybrid 4 and Hybrid 6 were not heterotic. These hybrids are morphologically similar to the maternal form. For example, the main features of hybrid 1 (SST Kaz-3 X Rostov) are similar to the maternal form (CST Kaz-3), Hybrid 1 in plant height (270/273 cm) was lower from maternal forms (336/196 cm), but higher from the father's forms (235/196). Only the length of the panicle is 2 cm more from the parent forms. All other signs are similar to the Kaz-3 STS maternal form. Exactly the same indicators were observed in the Hybrid 2 Larets X Kazakhstanskaya-20.

The heterosis phenomena were found in crossings of the ♀SST Kazakhstanskaya 3 × Larets (hybrid 2) and ♀ Larets x ♂ Oranzhevoye 160 (hybrid 5) (Table 6-7).

Table 6. Display of Heterosis in Hybrids by Morphological Features in Comparison With Parents With More Expressed Signs (All Figures Are Based on 1 Whole Plant 2016)

Hybrids and their parental forms	Shoot	Height of stem	Tilling capacity	Number of above-ground internodes	Length leaves	Width of leaves	Length of panicle	Vegetation period
		cm	pcs	pcs	cm	cm	cm	
Hybrid 2 ♀SST Kaz-3x ♂Larets F1	Leading	437±3,5	8±5,5	16	100±5,3	6	30	135
	Side	341,3±13,7		12,75±0,28			31,0±0,4	
Hybrid 5 ♀Larets x ♂Orange-160F1	Leading	292±6,2	3±0,1	16	97±10	12	0	150
	Side	250±5,4		15,1±0,01			0	

SST Kaz-3	Leading	336±4,2	9±1,5	10	82±7,2	7	52	105
	Side	358,2±0,2		10,1±0,01			46,4±0,5	
Larets	Leading	215±5,3	4±0,2	11	65±5,6	8	24	115
	Side	204,7±4,3		11±0,00			17,9±0,15	
Orange-160	Leading	234±4,6	2±0,01	13	70±8,2	7,3	24	130
	Side	246,0±4,0		12,0±0,00			20,0±0,5	

The data in Table 6 indicate that heterosis of hybrids 2 and 5 is displayed by several characteristics. For example, the hybrid 2 is superior to its parental forms in plant height, a number of aboveground internodes, the length, and width of the leaf. Signs on the tillering and the length of the panicle were between the paternal and maternal forms, and also according to the indications of raw biomass, hybrid forms are twice as high as the content of soluble sugars from the average indication of parental forms.

Thus, according to the data in Tables 6-7, it can be concluded that hybrid 2 is a heterotic plant.

Table 7. Productivity of Heterotic Hybrid Plants F1 and Parental Forms

Hybrids and their parental Forms		Raw weight of stems and leaves, gram	Raw weight of panicle, gram	Raw biomass of above-ground parts of 1st plants, kg.	The content of soluble sugars, %
♀SST Kaz-3x ♂Larets F1	Leading	765±12	65±5	3,390	13
	Side	2330±36	230±12		
♀Larets x ♂Orange-160F1	Leading	2285±85	0	6,930	19
	Side	4645±52	0		
Parental forms					
SST Kaz-3	Leading	240±18	90±8	2,195	7
	Side	1480±45	385±28		
Larets	Leading	640±52	200±18	2,850	15
	Side	1545±87	465±32		
Orange-160	Leading	470±25	110±6	1,510	16
	Side	825±63	105±4		

Hybrid 5 - obtained from intraspecific crossings of sugar forms of sorghum (Larets x Orange-160) also has a heterotic property. According to Table 6, the height of the grown hybrid-5 was 292/246 cm, while the height of the maternal form is 215-204 cm, and the shape of the paternal form is 234/246 cm. The number of side shoots of plants does not differ from the parent forms. However, in terms of the number of aboveground internodes (16 pcs), it considerably exceeds the parent forms (13-11 pcs).

The heterosis symptoms in hybrid 5 are better displayed in the length, leaf width and in the content of soluble sugars in stems. While the length of the leaf of the parent forms was 65-70 cm, and the hybrid 97 cm, the width of the leaf of the parent forms was 7-7.3 cm, in the hybrid this index reached up to 12 cm. The content of soluble sugars of the hybrid is 19%, whereas in the parental forms this rate was 15-16%. According to the data in Table-7, the hybrid-5 for raw biomass far exceeds the parent forms. This means that hybrid-5 is heterotic, where the raw biomass of the above-ground parts of the hybrid exceeds 2-3 times that of the parent forms. If the maternal form of Larets raw biomass of aboveground parts is 2,850 kg, for the paternal form of Orange-160 it equals to 1,510 kg, then in the hybrid this figure was 6,930 kg. Analyzing the obtained data of tables 6 and 7, it should be noted that the grown hybrid plants are heterotic.

4 Conclusion

During this research, we selected and chose parental forms of varieties and hybrids of sugar sorghum for using in reciprocal crossing with the use of thermo-castrating technology. Hybrids were obtained on the basis of fertile and sterile crossing using cytoplasmic male sterility. As a result, crossing on a fertile basis from 3 to 21%, set seeds were obtained. A high seed setting in crossing using cytoplasmic male sterility was shown. From 32 to 2200 hybrid seeds per panicle were obtained. The biological properties of promising hybrids in the first generation were investigated. Using the method of the group and individual selection we selected prospective heterosis hybrids with economically useful traits. The obtained hybrid material can be used in breeding work to create new varieties in the future, high-yielding and environmentally resistant varieties and sugar sorghum for use in the food industry, feed production and bioenergy.

Thus, the hybrids resulting from inter- and intraspecific crossing in 2016 showed different characteristics. One of the six hybrids (hybrid 3) was not viable, in three hybrids (1.4 and 6) heterotic phenomena were not detected, and hybrids 2 and 5 showed heterosis in economically valuable traits.

The phenological observations have shown that in hybrids the vegetation period is 135 days, which makes it possible to classify them as mid-late forms of sorghum.

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Literature:

1. Zhuk EA. World collection as a source material for creating new varieties of paniculate sorghum. In: Breeding, technology of cultivation and use of sorghum and other forage crops. Saratov; 2006.
2. Omarova AS, Makarov VM, Almakhanov BA. The results of breeding work on corn and sorghum in Kazakhstan. In: KazNIIZ – 70 years: Collection of scientific papers of NPCZR. Almaty: Nurly Alem; 2004: 172-178.
3. Poyda VB. Features of yield formation and accumulation of sugar in sorghum under the influence of agrotechnical methods on ordinary chernozem soil in the North Caucasus [dissertation]. [Saint-Petersburg]; 1994.
4. Hakeem AA, Folorunso MA, Kunihya A, Jerome J. Productivity and Water Use Efficiency of Sorghum [Sorghum bicolor]. Int J of Agron; 2018.
5. Shen F, Hu J, Liu MLY, Saddler JN, Zhong Y, Liu R. Ethanol production from steam-pretreated sweet sorghum with high substrate consistency enzymatic hydrolysis. Biomass Bioen. 2012; 41:157-164.
6. Dospekhova BA. Methods of field techniques. Moscow; 1979.
7. Sharma YS, Dhillon MK, Reddy BVS. Expression of resistance to Anterigonasoccata in F1hubrids involving shoot fly-resistant and susceptible cytoplazmatie male sterile and restorer lines of sorghum. Plant breeding. 2006; 125:473-477.
8. Udolskaya NL. Introduction to biometry. Alma-Ata: Nauka Kaz. SSR; 1976.
9. Patel PC, Patel JR, Joshi RS, Raman S. Scheduling irrigation in ratoon sorghum on the basis of critical stages of plant growth. Gujarat. Agr Univ Res. 1989; 2:1-6.
10. De Wet JMJ, Huckabay JP. The origin of sorghum bicolor. Distribution and domestication. Evolution. 1967; 21:787-802.
11. Hunter EL, Anderson IC. Sweet Sorghum; 2010.
12. Awika JM, Rooney LW. Sorghum phytochemicals and their potential impact on human health. Phytochemistry. 2004; 65:1199-1221.
13. Rooney WL, Blumenthal J, Bean B, Mullet JE. Designing sorghum as a dedicated bioenergy feedstock. Biofuels Bioproducts Biorefining-Biofpr. 2007; 1:147-157.
14. Vanderlip RL, Reeves HE. Growth Stages of Sorghum [Sorghum bicolor]. Agron J. 1972; 64:13-16.
15. Ma H, Hua X. Breeding for sweet sorghum with high grain yield and sweet stalks. Sorghum Newsl. 1986; 29:2-3.
16. Lu N, Ma J. Research on sweet sorghum and its synthetic applications. Biomass. 1989; 20:129-139.
17. Karve AD, Ghaneker AR, Kshirsagar SH. Further investigations on sweet sorghum. Sorgum Newsl. 1975; 18:40-41.
18. Broadhead DM. Influence of bagging sweet sorghum panicles on stalk yield and juice quality. Crop Sci. 1979; 19:195-196.
19. Hoshikawa K. Pre-experiment of cultivation of biological energy sweet sorghum. Agri and horticulture. 1981; 56:497-503.
20. Sharpley AN, Smith SJ, Williams JR, Jones OR, Coleman GA. Water Quality Impacts Associated with Sorghum Culture in the Southern Plains. J of Environ Qual. 1991; 20:239-244.
21. Broadhead DM, Freeman KC. Stalk and sugar yield of sweet sorghum as affected by spacing. Agronomy J. 1980; 72:523-524.
22. Sorghum production. ARC-Grain Crops Institute; n.d. Available from: https://www.nda.agric.za/docs/Infopaks/FieldCrops_Sorghum.pdf
23. Breeding and cultivation of sweet sorghum; n.d. Available from: http://www.fao.org/docrep/t4470E/t4470e05.htm
24. Strokes IE, Coleman OH, Dean JL. Culture of sorgo for sirup production. Washington, D.C.: U.S. Dept of Agri; 1957.
25. Garshin AYu, Zhuzhukin VI, Semin DS. Determination of combining ability of variety samples of sweet sorghum for grain quality in tester crosses. Kukuruza Sorgo. 2014; 1:20-23.
26. Beta T, Corke H. Genetic and Environmental Variation in Sorghum Starch Properties. J of Cereal Sci. 2001; 34:261-268.
27. Kulamarva AG, Sosle RS, Raghavan GSV. Nutritional and Rheological Properties of Sorghum. Int J of Food Properties. 2009; 12.
28. Brannan GL, Setser CS, Kemp KE, Seib PA, Roozeboom K. Sensory characteristics of grain sorghum hybrids with potential for use in human food. Cereal Chem. 2001; 78:693-700.

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