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# Screening of sweet and grain sorghum genotypes for green biomass production in different regions of Kazakhstan

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**Abstract:** As the impact of global climate change increases, the interaction of biotic and abiotic stresses increasingly threatens current agricultural practices. The most effective solution to the problem of climate change and a decrease in the amount of atmospheric precipitation is planting extremely drought-resistant and high-yielding crops. Sorghum can grow in harsh conditions such as salinity, drought and limited nutrients, also it is an important part of the diet in many countries. Sorghum can be introduced in many zones of Kazakhstan. Plant height and yield of green plant biomass of 16 sorghum samples in arid conditions were determined based on a set of agrobiological characteristics for field screening. The height of the studied samples of grain sorghum was 0.47 ±0.03 m, and the height of sweet sorghum was much longer, reaching up to 2.88 ±0.12 m. Also, there was a strong difference in green biomass in cultivated areas under different soil and climatic conditions, the green biomass of sweet sorghum was 3.0 Mg·ha$^{-1}$, and in grain sorghum, it reached up to 57.4 Mg·ha$^{-1}$. Based on the data of the field assessment for various soil and climatic conditions, the following samples were identified for introduction into production: samples of sweet sorghum for irrigated and rainfed lands of the Almaty Region and in the conditions of non-irrigation agriculture of the Aktobe Region – a promising line ICSV 93046. For non-irrigation agriculture of the Akmola Region, genotypes of sweet and grain sorghum are 'Chaika', 'Kinelskoe 4' and 'Volzhskoe 44'.

**Keywords:** biomass, collection, drought-tolerance, plant height, *Sorghum bicolor*, variety

## INTRODUCTION

The adverse effects of climate variability and extreme events are putting increasing pressure on rural farmers, whose livelihoods depend on nature. The cultivation of crops that are resistant to environmental conditions is a strategic direction in agriculture. Sorghum, as one of the drought-resistant crops, is important to grow in adverse weather conditions [MEKONEN, BERLIE 2021].

The scarcity of forage, aggravated in the dry season, and the low nutritional value of the forage in the natural pastures compromise the growth and development of animals, resulting in decreased productivity, and a decrease in the production of milk and meat, which makes producers depend on the availability of conserved forages as hay or silage of cultivated fodder plant, and crop residues to feed cattle in semi-arid regions [LIMA *et al.* 2004].

Sorghum (*Sorghum bicolor* L. Moench) is currently considered the fifth most important cereal in the world, followed by wheat, corn, rice and barley [LUNA *et al.* 2018]. It is a drought-tolerant C4 crop from the cereal family and can be adapted to most temperate and tropical climates as annuals or short-stemmed perennials [BELLMER *et al.* 2010; KHALIL *et al.* 2015; MAHAPATRA *et al.* 2011; SHUKLA *et al.* 2017].

Producing highly drought-tolerant, high-yielding crops, such as sorghum, that can grow nationwide, is the most effective solution to the change of climate and rainfall. In severely dry years, as a rule, crop losses increase, so there is no stability in agriculture. Until now, sorghum has not been widely used in Kazakhstan. The main limiting factors for the introduction of sorghum into production are poor knowledge of various genetic resources of sorghum crops from the domestic and world gene pool. Sorghum in world agriculture occupies 70–75 mln ha and ranks fifth in sown areas after wheat, rice, maize and barley and third among forage crops. [Katkov 1999]. Its crops are concentrated mainly in Asia (49–50%). The increase in sorghum cultivated areas in recent years, especially in Africa, is associated with exceptional drought and heat resistance, sun tolerance and undemanding soil.

According to FAO [FAOSTAT 2008], sorghum is cultivated in 104 countries around the world. The area of world crops of sorghum and annual grain production in 2007, including in the main countries (87% of world crops and 89% of world production), amounted to 43.8 mln ha, grain yield – 1.5 Mg·ha$^{-1}$, and gross production – 64.6 mln Mg.

In 2017, the production of sorghum in the world reached 63.9 mln Mg, and the average yield is 1427 kg·ha$^{-1}$. The main producers of sorghum are the United States, Nigeria, Sudan, Mexico, Ethiopia and India [Popescu *et al.* 2018]. It can be easily grown on all continents, in tropical, subtropical, temperate, semi-arid regions, and in poor-quality soils. It is known as the desert sugarcane and is also known as the "camel among crops" for its drought-tolerance [Sanderson *et al.* 1992].

Stress factors for sorghum crops are a short frost-free period, a deficit of active positive temperatures and insufficient moisture supply. Therefore, assessing the starting material according to its ability to use favourable environmental factors most effectively and at the same time resist environmental stressors is the main condition for the selection of new varieties, characterised by a decrease in costs per yield unit [Kameneva, Buenko 2011].

Sorghum is often grown in regions with 350 to 700 mm of annual rainfall [NRI, FSD 1999]. Since it is predominantly a rainfed crop, its yield largely depends on its drought-tolerance. In drier regions, it is usually replaced by pearl millet [Toderich *et al.* 2018]. Field screening of 16 samples of sweet and grain sorghum was assessed according to agrobiological characteristics: plant height and green biomass of plants.

The main regions for sorghum cultivation are the arid zones of Kazakhstan. The value of the sorghum crop, consisting in the ability to endure periods of drought and high temperatures without much damage to the harvest, effectively use the precipitation of the second half of summer, start growing after a long dry period and form sufficiently high yields, allows it to be grown in arid zones. During very dry periods, sweet sorghum can go dormant, as it grows, renewing when sufficient moisture returns [Gnansounou *et al.* 2005]. In these regions, from 2011 to 2017, tests of domestic and foreign genotypes of sorghum crops were carried out and promising lines were identified for creating varieties [Kunypiyaeva *et al.* 2018; Zhapayev *et al.* 2015a, b], also based on the effect of mineral fertilisers on sugar content and productivity [Nokerbekova *et al.* 2018a, b], and in the conditions of irrigation of the desert zone of southeastern Kazakhstan, a sorghum cultivation technology has been developed [Ospanbayev *et al.* 2017]. In the Republic of Kazakhstan, in 2017, 38 varieties and hybrids of sorghum crops were allowed to use, including 13 created by the Kazakh Research Institute of Agriculture and Plant Growing (KRIAPG) LLP, which is the only breeding institution for the selection and seed production of sorghum crops and has a valuable gene pool [Zhapayev *et al.* 2017].

In addition, the preliminary results obtained on the basis of the Karaultubinsk reference point of the Kyzylorda Region in collection nurseries for the reproduction of sorghum showed the effectiveness of sorghum cultivation on marginal lands, including in rice crop rotation, and adapted to salinity, which helps to stabilise the process of salt accumulation in the root layer. as well as soil desalinisation [Tautenov *et al.* 2016a, b].

Thus, the widespread introduction of highly productive drought-resistant crops such as sorghum, conservation agriculture and effective processing of technologies, both in the country and in Central Asia, will provide an opportunity for adaptation and mitigation of the effects of global climate change [Zhapayev *et al.* 2015c].

The aim of the research was screening of sweet and grain sorghum samples for green biomass production in different regions of Kazakhstan.

## MATERIALS AND METHODS

### PLANT MATERIAL

Sorghum is a high-yielding and promising crop for the arid zones of Kazakhstan, and as an intensive crop type, it can widely reveal its potential in conditions of intensive technology. In the southern regions of the Republic, under irrigation conditions, annual grasses and sorghum crops provide a yield of green mass of 8–10 Mg or more per hectare.

To determine drought-tolerance, sorghum seeds were disinfected with a weak solution of hydrogen peroxide and germinated in Petri dishes on a filter pad in a thermostat at 25°C for 48 h, and grown under room conditions to the stage of 2–3 leaves. Drought was simulated with a 15% polyethylene glycol PEG 6000 solution, which creates an osmotic pressure of 295 kPa as calculated [Michel, Kaufmann 1973].

Experimental seedlings were exposed to PEG for 18 h. Leaf relative water content (*RWC*) was measured on 3–4 leaves of control and experimental seedlings by weighing them after cutting (fresh weight – FW), then the cut leaves were placed in vials, which were filled with deionised water. Leaves were kept in water for 6 hours and removed, dried and weighed (turgid weight – TW). Next, the samples were placed in an oven and dried at 70°C for 18 h and weighed, dry weight (DW) was determined. *RWC* was calculated according to Hussain *et al.* [2019].

### DESCRIPTION OF STUDY AREA

Field experiments were carried out in three regions of Kazakhstan: southeast – Almaty Province, west – Aktobe Province, north – Akmola Province (Fig. 1). Experimental site soil type characteristics in the Almaty Province – light chestnut calcareous soils located on the sloping eroded plains of the foothills, occupying absolute elevations of 700–800 m, the humus content of 2.0–2.4%. In the study area in the Akmola Province, the soil


**Fig. 1.** Research sites in three provinces of Kazakhstan; source: own elaboration

type is southern carbonate chernozem. The humus content is in the range of 3.4–4.1%. The soil of the experimental site in the Aktobe Province is dark chestnut and medium loamy in texture. The humus content in the upper soil layer is 2.46–2.74%.

## WEATHER CONDITIONS DURING THE VEGETATION PERIODS OF THE TRIALS

To characterise climatic conditions and describe their influence on the production process of sorghum, the data of the meteorological station "Almalybak" LLP KRIAPG (Almaty Region), Aktobe meteorological station and meteorological station of Shortandy settlement (Akmola Region) were used (Tab. 1). According to the meteorological station of LLP KRIAPG, meteorological conditions for 2015–2017 were favourable for the Almaty Region.

Thus, under the prevailing sowing conditions at the optimum time and a very dry summer in general, sorghum vegetation ended in early September, with the onset of early autumn frosts. Despite the phenomenon of a very severe drought, which has shown itself at almost all stages of organogenesis, possibly, with the exception of only the germination phase, the level of green biomass obtained under the conditions of the year turned out to be average.

## FIELD EXPERIMENTS

Field experiments were carried out in 2015–2017, the object of research was a collection of 8 samples of sweet sorghum and 8 samples of grain sorghum, including three varieties ('Kazakhstanskoe 16', 'Kazakhstanskoe 20' and 'Zhetysu 1'), approved for use in Kazakhstan. The research was carried out in irrigated conditions and rainfed areas of the Almaty Region, in the conditions of non-irrigated agriculture in the Aktobe Region, and in the conditions of non-irrigated agriculture in the Akmola Region. The sowing of sorghum crops was carried out with an SSFK-6 seeder in three repetitions, the plot area was 7 $m^2$ (width 1.4 m, length 5 m), with row spacing of 0.7 m each row. Sowing of sorghum according to three soil and climatic conditions was carried out at the optimum time: in the Almaty Region – in the first decade of May; in Aktobe and Akmola regions – in the second decade of May.

## STATISTICAL ANALYSIS

Comparisons of the parameters were made between treatments using an analysis of variance and differences were considered significant at $p < 0.005$. using two-way ANOVA. In Excel, we used the linear regression CORREL function to find the correlation coefficient between two variables.

**Table 1.** Precipitations and air temperatures for the vegetation period (May–August) in different regions

| Region | Precipitation (mm) | | | | | | | Air temperature (°C) | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | May–Aug | | | long-term mean | ±long-term mean | | | May–Aug | | | long-term mean | ±long-term mean | | |
| | 2015 | 2016 | 2017 | | 2015 | 2016 | 2017 | 2015 | 2016 | 2017 | | 2015 | 2016 | 2017 |
| Almaty Province | 183.1 | 464.7 | 195.5 | 163.3 | 19.8 | 301.4 | 32.2 | 23.1 | 21.6 | 22.7 | 21.0 | 1.0 | 0.7 | 1.0 |
| Aktobe Province | 48.0 | 143.7 | 92.0 | 125.0 | –77.0 | 18.7 | –33.0 | 21.2 | 20.5 | 20.5 | 19.8 | 1.4 | 0.7 | 0.7 |
| Akmola Province | 217.7 | 222.5 | 103.5 | 166.1 | 51.6 | 56.4 | –62.6 | 18.0 | 16.3 | 18.0 | 17.0 | 1.0 | –0.7 | 1.0 |

Source: own elaboration based on the data of the meteorological station "Almalybak" LLP Kazakh Research Institute of Agriculture and Plant Growing (KRIAPG) (Almaty Province), Aktobe meteorological station and meteorological station of Shortandy settlement (Akmola Province).

Statistical processing of data from the structural analysis of grain and sweet sorghum was carried out by the R–Studio program.

## RESULTS

### FIELD TRIALS

As can be seen in Table 2, the studied samples of sweet and grain sorghum cultivated in different soil and climatic conditions differed greatly in plant height (from 0.47 to 2.88 m) and green biomass of plants (from 3.0 to 57.4 Mg·ha$^{-1}$).

In the conditions of the south-east of Kazakhstan, according to the annual precipitation height, absolute altitude above sea level and the value of total radiation, it is accepted to divide rainfed lands into unsecured (with annual precipitation of 200–280 mm), semi-provided (280–400 mm) and provided (over 400 mm) by rainfall. It should be noted that in the conditions of the Almaty Region, the studies were carried out in conditions of irrigation and unsecured rainfed lands, where the annual amount of precipitation is only 200–280 mm.

Plant height and green biomass under irrigation conditions were within 0.91–2.88 m and 15.4–57.4 4 Mg·ha$^{-1}$, respectively. At the same time, the following samples of sweet and grain sorghum can be distinguished for the Almaty and Aktobe regions for introduction into production – 'Kazakhstanskoe 16', 'Kazakhstanskoe 20', promising line 'ICSV 93046', 'Zhetysu 1' and 'Jugara'. As can be seen in (Tab. 3), in the conditions of unsecured rainfed Almaty Region, the height of plants and the yield of green biomass were 0.5–1.24 m and 1.88–23.58 Mg·ha$^{-1}$, respectively.

Under the conditions of spring and early summer drought, late crops, such as millet, oats, sorghum, and corn, occupy an important place in the total harvest of crop production, which, due to precipitation in the second half of summer, give relatively high harvests of grain and green mass [KURMANBAYEVA *et al.* 2021]. In this regard, the selection and introduction into production of an unconventional fodder crop, such as sorghum, which has a high yield of green mass, unlimited possibilities for versatile purposes and adapts to unfavourable environmental factors, can significantly supplement the list of widespread fodder crops and strengthen the raw material base of fodder production.

Plant height and green biomass of plants in the conditions of non-irrigated agriculture in Aktobe and Akmola regions, depending on the biological characteristics of the studied samples, ranged within 0.47–1.85 m; 7.1–36.6 Mg·ha$^{-1}$ and 0.59–1.84 m; 3.0–15.1 Mg·ha$^{-1}$, respectively. At the same time, the following samples of sweet and grain sorghum can be determined for the Akmola Region for introduction into production – 'Chaika', 'Kinelskoe 4' and 'Volzhskoe 44'.

**Table 2.** Plant height and green biomass of sweet and grain sorghum in different regions

| Genotype | Almaty province | | Aktobe province | | Akmola province | |
|---|---|---|---|---|---|---|
| | plant height (m) | green biomass (Mg·ha$^{-1}$) | plant height (m) | green biomass (Mg·ha$^{-1}$) | plant height (m) | green biomass (Mg·ha$^{-1}$) |
| **Sweet sorghum** | | | | | | |
| 'Kazakhstanskoe 16' | 2.58 | 57.4 | 1.62 | 26.6 | 1.20 | 7.6 |
| 'Kazakhstanskoe 20' | 2.88 | 49.5 | 1.40 | 30.9 | 1.33 | 8.5 |
| 'ICSV 93046' | 2.30 | 49.4 | 1.35 | 36.6 | 0.70 | 8.7 |
| 'Chaika' | 2.27 | 39.2 | 1.11 | 17.6 | 1.67 | 15.1 |
| 'Phlagman' | 2.26 | 35.0 | 1.79 | 24.2 | 1.52 | 9.8 |
| 'Saratovskoe 90' | 2.06 | 35.0 | 1.36 | 10.0 | 1.41 | 3.0 |
| 'Krepysh' | 1.94 | 28.0 | 1.15 | 7.1 | 1.43 | 8.0 |
| 'Kinelskoe 4' | 2.06 | 18.2 | 1.44 | 15.2 | 1.84 | 10.6 |
| **Grain sorghum** | | | | | | |
| 'Zhetysu 1' | 1.91 | 26.1 | 1.24 | 18.9 | 0.83 | 8.1 |
| 'ICSV 112' | 1.42 | 22.7 | 1.05 | 12.7 | 0.61 | 10.1 |
| 'Volzhskoe 4' | 1.57 | 19.8 | 0.47 | 12.3 | 1.02 | 11.3 |
| 'Volzhskoe 44' | 1.81 | 19.4 | 1.23 | 13.2 | 1.37 | 13.3 |
| 'Slavyanka' | 0.91 | 15.4 | 1.42 | 14.4 | 1.55 | 8.6 |
| 'Orion' | 1.52 | 27.8 | 1.00 | 10.8 | 0.93 | 11.2 |
| 'Ayushka' | 1.36 | 23.8 | 0.76 | 12.5 | 0.59 | 10.8 |
| 'Jugara' | 2.04 | 41.1 | 1.85 | 13.3 | 0.94 | 7.3 |

Source: own study.

**Table 3.** Plant height and green biomass of sweet and grain sorghum in the rainfed condition of Almaty Province

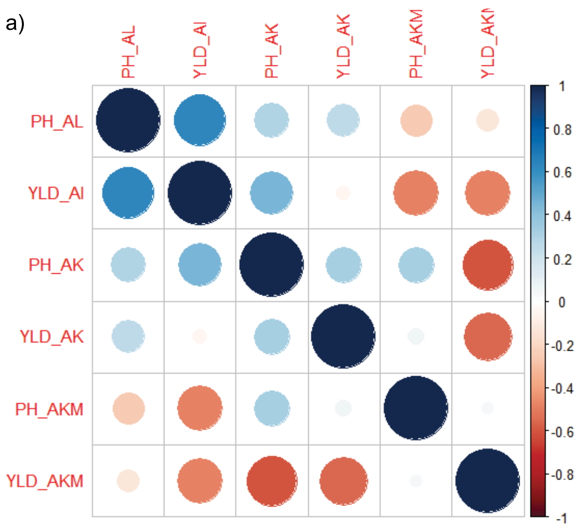
| Genotype | Plant height (m) | Green biomass (Mg·ha$^{-1}$) |
|---|---|---|
| **Sweet sorghum** | | |
| 'Kazakhstanskoe 16' | 0.50 | 7.73 |
| 'Kazakhstanskoe 20' | 0.84 | 11.39 |
| 'ICSV 93046' | 1.20 | 20.73 |
| 'Chaika' | 0.70 | 13.12 |
| 'Phlagman' | 0.80 | 11.45 |
| 'Saratovskoe 90' | 0.85 | 11.79 |
| 'Krepysh' | 0.80 | 10.52 |
| 'Kinelskoe 4' | 1.24 | 9.24 |
| **Grain sorghum** | | |
| 'Zhetysu 1' | 0.90 | 23.58 |
| 'ICSV 112' | 0.88 | 16.52 |
| 'Volzhskoe 4' | 0.87 | 13.58 |
| 'Volzhskoe 44' | 0.93 | 13.04 |
| 'Slavyanka' | 0.51 | 1.88 |
| 'Orion' | 0.85 | 5.21 |
| 'Ayushka' | 0.82 | 17.70 |
| 'Jugara' | 0.69 | 6.48 |

Source: own study.

## GENOTYPE AND ENVIRONMENT INTERACTIONS

The yield of the green mass of grain and sweet sorghum in the Akmola Province is lower than in the Almaty and Aktobe provinces (Fig. 2).

In the Almaty Region, the height of sweet sorghum is very tall, respectively, the green mass is high, but the yield is about three times less than that of grain sorghum. Although the height of grain sorghum is three times lower, the yield is three times higher (Fig. 3).



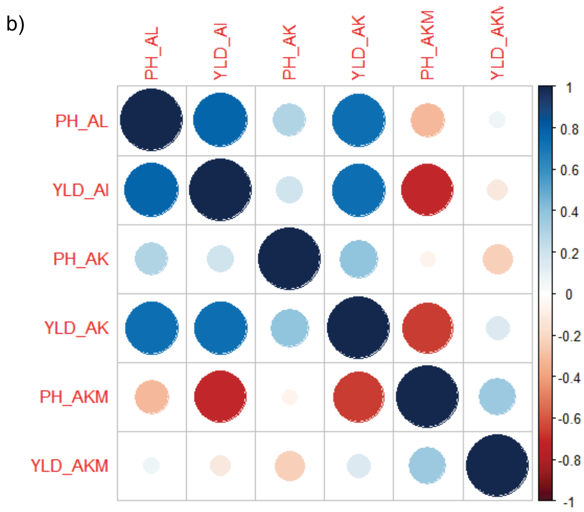




**Fig. 2.** Plant height (PH) and green mass yield (YLD) of two types of sorghum in Almaty (AL), Aktobe (AK) and Akmola (AKM) provinces: a) grain sorghum, b) sweet sorghum; source: own study.

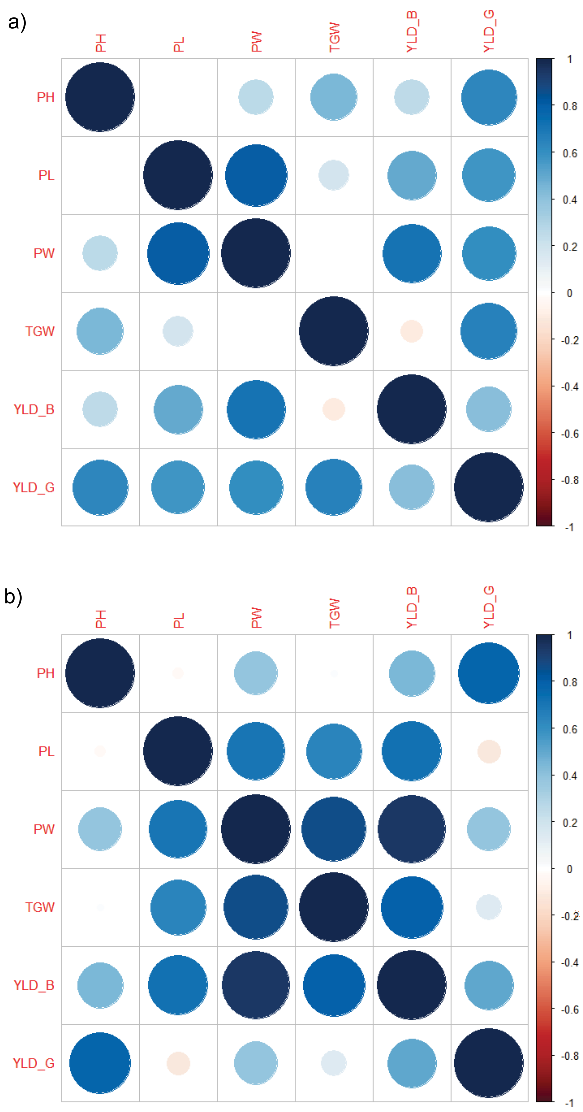
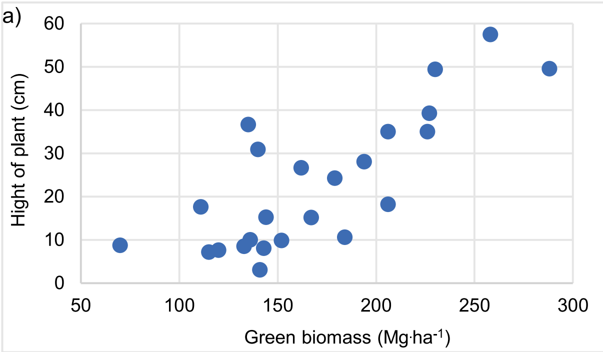



**Fig. 3.** Plant height (PH), panicle length (PL), panicle width (PW), 1000-grain weight (TGW), biological grain yield (YLD_B) and green mass yield (YLD_G) of two types of sorghum in Almaty Province; a) grain sorghum, b) sweet sorghum; source: own study

The correlation coefficients between the plant height of sweet and grain sorghum are shown in Figure 4. For a linear relationship, the correlation coefficients are 0.787 and 0.675, which means that the height of plants contributes to an increase in the green biomass of plants, i.e. analysis of the regression equation – average and above average.



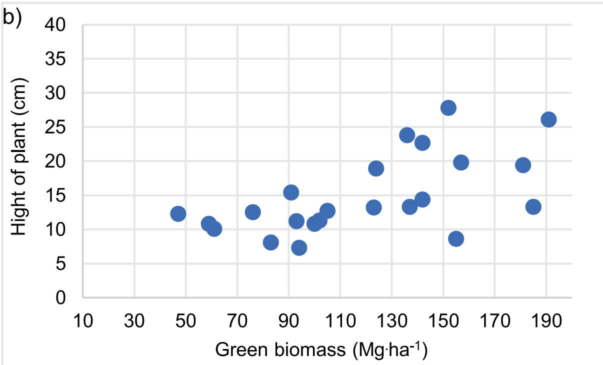
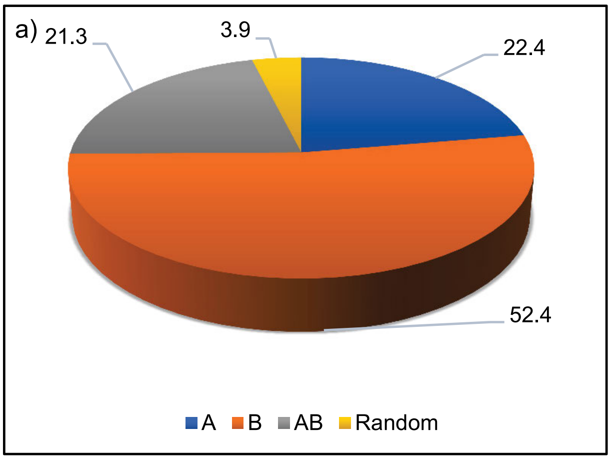




**Fig. 4.** The correlation coefficients between plant height and green biomass (16 sorghum samples): a) sweet sorghum, b) grain sorghum; source: own study



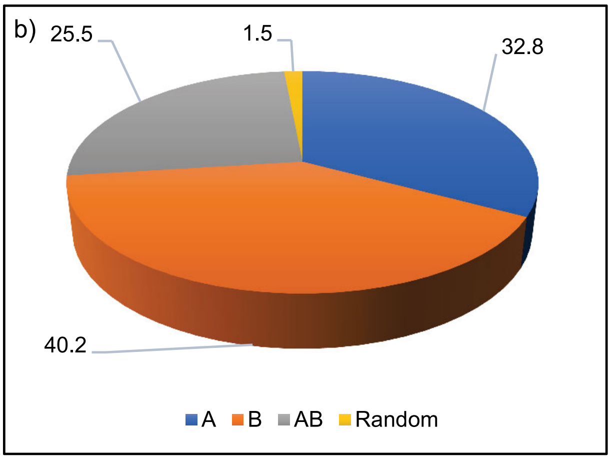




**Fig. 5.** Two-way ANOVA analyse of sorghum (16 samples): a) sweet sorghum (%), b) grain sorghum (%); A = genotype, B = environment, AB = genotype and environment; source: own study

Data processing by two-factor analysis of variance shows a significant influence of the studied genotypes, environmental conditions and the interaction of the environmental genotype (Fig. 5). At the same time, the share of the contribution of genotypes to the formation of green biomass of sweet sorghum was 22.4%, grain sorghum – 32.8%, the share of environmental conditions – 52.4 and 40.2%, and the share of genotype–environment interaction – 21.3 and 25.5%, respectively. It should be noted that the formation of green biomass was 40–50% influenced by the conditions of the cultivation environment.

Thus, the studied samples of sweet and grain sorghum cultivated in different soil and climatic conditions differed greatly in plant height (from 0.47 to 2.88 m) and green plant biomass (from 3.0 to 57.4 Mg·ha$^{-1}$). Based on the data of the field assessment for various soil and climatic conditions, the following samples were identified for introduction into production: samples of sweet sorghum for irrigated and rainfed lands of the Almaty Region and for non-irrigation agriculture of the Aktobe Region – a promising line 'ICSV 93046'. For non-irrigation agriculture of the Akmola Region, samples of sweet and grain sorghum are 'Chaika', 'Kinelskoe 4' and 'Volzhskoe 44'.

High temperature strongly affects water relations when water is limited. Increasing the thermotolerance of wheat might improve its potential to acclimate to both high temperatures and drought [Mohammed *et al.* 2021].

**Table 4.** The relative water content (*RWC*) in the leaves of sorghum seedlings

| No. | Name | *RWC* (%) | |
|---|---|---|---|
| | | control | experience |
| 1 | 'Kazakhstanskoe 16' | 93.0 ±5.98 | 99.1 ±0.11 |
| 2 | 'Galiya' | 98.9 ±0.08 | 98.6 ±0.12 |
| 3 | 'Stavrapolskoe 63' | 98.2 ±0.35 | 98.5 ±0.06 |
| 4 | 'Sylosnoe 88' | 98.8 ±0.06 | 98.6 ±0.15 |
| 5 | 'Alga' | 98.9 ±0.07 | 99.2 ±0.16 |
| 6 | 'Uzbekiston 18' | 99.2 ±0.09 | 99.1 ±0.02 |
| 7 | 'ICSR 93039' | 99.3 ±0.05 | 99.3 ±0.02 |
| 8 | 'ICSV 93046' | 99.2 ±0.18 | 99.0 ±0.19 |
| 9 | 'ICSR 93034' | 98.7 ±0.11 | 98.8 ±0.23 |
| 10 | 'ICSV 25275' | 97.0 ±0.10 | 98.9 ±0.24 |
| 11 | 'Vakhshinskoe' | 98.4 ±0.10 | 98.7 ±0.05 |
| 12 | 'ICSSH 58' | 99.0 ±0.06 | 99.1 ±0.13 |
| 13 | 'Zhetysu 1' | 99.5 ±0.12 | 98.9 ±0.05 |

cont. Tab. 4

| No. | Name | *RWC* (%) | |
|---|---|---|---|
| | | control | experience |
| 14 | 'Pychevoe 7' | 99.5 ±0.16 | 98.9 ±0.08 |
| 15 | 'Yrgyz' | 99.7 ±0.02 | 98.5 ±0.23 |
| 16 | 'Topaz' | 99.2 ±0.22 | 97.2 ±0.70 |
| 17 | 'Creamovoe' | 98.9 ±0.14 | 97.9 ±0.14 |
| 18 | 'Ayushka' | 99.5 ±0.15 | 99.0 ±0.12 |
| 19 | 'Vyctoriya 4' | 100.0 ±0.27 | 98.8 ±0.02 |
| 20 | 'Kazakhstanskoe 3' | 99.0 ±0.09 | 98.0 ±0.08 |

Source: own study.

The results of the studies showed that the relative water content in the experimental seedlings that were under the influence of osmotic stress, created by PEG, changed slightly, from which it can be concluded that the predominant part of the analysed samples is drought-resistant. From this set, 'Topaz' and 'Creamovoe' hybrids are less resistant to drought.

## DISCUSSION

Water scarcity is expected to affect almost two billion people by 2025 [Nellemann *et al.* 2009] and will become a more serious problem in urban areas. In this regard, sorghum can adapt to various environmental conditions, especially in conditions of water scarcity, as it is very useful in cultivated regions with irregular precipitation distribution and high air temperature [Almeida Filho *et al.* 2014; Griebel *et al.* 2019].

Sorghum is a relatively unpretentious crop, having a powerful root system, it can form a good harvest for a number of years on depleted soil after other crops. The main advantage of sorghum is the ability to germinate on saline soils, and the plants have exceptional drought–heat resistance, and salt resistance [Orlovsky *et al.* 2016]. The contribution of sorghum as a fodder crop has increased the value of production in recent years, so selection criteria in breeding programs could include biomass production and quality as well as grain yield [Hassan *et al.* 2015].

Xu *et al.* [2021] note that the high demand for higher-quality materials has contributed to the emergence of numerous sorghum genotypes with a certain size (high, medium or low), cycle (early or late) and suitability (dual-purpose feed or grain), which have a strong impact on the nutritional value of the silage produced. One of the advantages of sorghum is its ability to grow back after mowing the original crop in the field, mainly when applying fertilisers [Afzal *et al.* 2012].

After germination, the ideal average temperature is from 24 to 27°C to obtain high yields. Low temperatures can limit the growth of sorghum [Carter *et al.* 1989], and most plants die when exposed to negative temperatures [Plessis 2003].

The timing of plant maturation, the passage of phenological phases, resistance to adverse weather conditions, diseases and pests depend on the correct choice of varieties and hybrids. All this together in the end allows you to get a high yield of good quality with less cost. Taking into account the emerging problems of various ecological and geographical origins, ecological variety testing of the genotypes of sweet and grain sorghum is carried out in different conditions in Kazakhstan. The results of our research showed that the late-maturing samples 'Kazakhstanskoe 16', 'Kazakhstanskoe 20' and the promising line 'ICSV 9304' were leaders in the formation of green plant biomass, both in the conditions of Almaty and in the conditions of the Aktobe Region, adapted to withstand higher average temperatures than most other grain crops [Hall *et al.* 2000]. However, in the Akmola Region, these samples showed an average yield of green biomass, this is due to the fact that the thermal resources of the northern part of the studied territory of the country meet the requirements of soft and hard wheat varieties, but are insufficient for sunflower and corn. In the south, heat resources are sufficient for wheat, all sunflower varieties and for medium-late-ripening corn varieties [Baisholanov *et al.* 2018], as well as for sorghum crops. In addition, in the conditions of the Akmola Region, early-maturing sorghum samples do not have time to pass the full cycle of vegetation, and early-maturing samples do not have time to form full-fledged viable seeds due to early frosts.

The results of the two-way analysis of variance showed that genotype (A) had an insignificant effect of 22.4 and 32.8% on the yield of green biomass, and environmental conditions had a significant effect on the yield of green biomass of plants 52.4 and 40.2% (Fig. 1).

Thus, the ecological variety testing of the genotypes of sorghum crops of various ecological and geographical origin is a progressive, highly effective direction in fodder production, capable of increasing the economic efficiency of not only livestock breeding but also other areas of activity of an individual economic entity, district and even region. A high yield of green biomass and a very high drought-resistance allow them to be widely cultivated in many regions of Kazakhstan.

## CONCLUSIONS

Our results of field screening of 16 sorghum samples showed that the studied samples of sweet and grain sorghum cultivated in different soil and climatic conditions differed greatly in plant height (from 0.47 to 2.88 m) and green biomass of plants (from 3.0 to 57.4 $Mg \cdot ha^{-1}$). Based on the field assessment data for various soil and climatic conditions, the following samples were identified for implementation in production: samples of sweet sorghum for irrigated and rainfed lands in the Almaty Region and for non-irrigated agriculture in the Aktobe Region – promising line 'ICSV 93046'. For non-irrigated agriculture in the Akmola Region, such samples of sweet and grain sorghum were chosen: 'Chaika', 'Kinelskoe 4' and 'Volzhskoe 44'. Environmental conditions had a significant impact on green biomass yield (i.e. 52.4% and 40.2% impact based on two-way ANOVA analysis) and a negligible effect on genotype (22.4 and 32.8%). When determining the drought-resistance of sorghum seeds, the studied samples showed high drought-resistance. A high yield of green biomass and a very high drought-resistance allows them to be widely cultivated in many regions of Kazakhstan.

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