Scientific Papers. Series A. Agronomy, Vol. LXVII, No. 1, 2024
ISSN 2285-5785; ISSN CD-ROM 2285-5793; ISSN Online 2285-5807; ISSN-L 2285-5785

PRODUCTIVITY EVALUATION OF GRAIN SORGHUM CULTIVARS AND PROMISING LINES

Kalin SLANEV[1], Gergana IVANOVA-KOVACHEVA[2], Stanimir ENCHEV[1]

[1]Agricultural Academy, Agricultural Institute - Shumen, 3 Simeon Veliki Blvd, Shumen, Bulgaria
[2]Agricultural Academy, IASS "Obraztsov Chiflik", 1 "Prof. Ivan Ivanov" Street, Ruse, Bulgaria

Corresponding autor email: kalin_3@abv.bg

Abstract

The high drought tolerance and plasticity of sorghum renews its economic importance for a stable production of fodder grain in the frequently appearing extreme droughts. During the period 2020-2022 a wide range of varieties and promising lines of grain sorghum from foreign and native selection were tested in terms of grain productivity. Climatic changes in recent years require the maintenance of varieties and hybrids with a wide ripening range and the selection of varieties with greater adaptability to extreme abiotic factors. The obtained results confirm the high productive potential of grain sorghum. The selected promising grain sorghum lines have high potential for grain yield and optimal biotype.

Key words*: sorghum, productivity, promising lines.*

INTRODUCTION

Against the backdrop of looming global climate warming in recent years, sorghum is expected to occupy an increasing share of the world's feed grain production. Sorghum ranks fourth among cereals worldwide with a production of over 65 million tons from 450 million acres (Smith and Frederiksen, 2000). According to Faostat data, on average for the period 2012-2021. more than 61 million tons of sorghum grain were produced in the world. (Table 1). The USA is the leader in the world production of this crop with over 10 million. tons of annual production, followed by Nigeria and Mexico with 6.6 and 5.5 million tons, respectively (Boyles, R.E. et al., 2019; Fano D. et al., 2017; Fantaye B.M. et al., 2018).

If we trace the production of sorghum grain by continent, we must note that Africa is in first place, followed by the continents of Asia and America. The member countries of the European Union annually produce 533 thousand tons of sorghum grain, which represents only 0.8% of world production. For this reason, the organization Sorghun ID was created within the EU with the main task of expanding the production of culture not only within the EU, but also throughout Europe.

Table 1. Sown areas and sorghum grain production in the world and EU countries on average for 2012-2021

Country	Areas sown (ha)	Production (thousands t)	Average of ha (t)
World	41877338	61146	1.5
USA	2361722	10259	4.3
Nigeria	5519888	6630	1.2
Mexico	1549883	5468	3.5
India	5443337	4892	0.9
Ethiopia	1795426	4626	2.6
Sudan	6797623	4206	0.6
Argentina	698960	2832	4.0
China	593219	2752	4.6
Total EU	172000	533	3.1
France	61972	344	5.5
Italy	44825	292	6.5
Spain	6955	83	4.7
Bulgaria	5174	16	3.1

Within the EU, France stands out with the largest production of sorghum grain (344 thousand tons per year), followed by Italy (292 thousand tons) and Spain (33 thousand tons).

From the data presented in the table, it is clear that this culture is not very popular in Bulgaria. About 51 thousand decares are harvested annually, from which an average of 310 kg is obtained. Grain with which the total annual production of grain from the crop does not exceed 16 thousand tons.

It is known that wheat and barley are the main carbohydrate feeds that are involved in the production of compound feed mixtures for animals. In recent years, sorghum has been added to them, with which they can be partially or completely replaced. Thanks to its high drought resistance and plasticity, grain sorghum is increasingly used in Bulgaria to obtain a stable yield of fodder grain during frequent extreme droughts. In agro-meteorological regions with insufficient rainfall, sorghum can be a preferred crop for improving the forage balance (Wenzel, 1991; Zarkov, 1995).

A major task in the selection of grain sorghum is obtaining a high and stable yield and suitability for mechanized harvesting (Lafarge et al., 2002). This suggests the creation of low-stemmed forms with erect and large panicles (De Weet et al., 1972). Grain yield is a complex trait that characterizes the economic value of sorghum origins and hybrids for grain. It is polygenically determined and strongly influenced by environmental factors. Knowledge of factors and traits is necessary in designing an effective selection program (Smith and Frederiksen, 2000).

In Bulgaria, sorghum is used mainly in two directions - for the production of fodder grain and for the production of green mass and silage. Grain yields vary depending on the variety, agricultural techniques and soil and climatic conditions. Under non-irrigated conditions, 600 to 1000 kg/da of grain can be obtained (Slanev and Kikindonov, 2017; 2021).

The aim of the present research is to evaluate new varieties and promising lines from the native and foreign selection. To compare some results of the local selection with the achievements of other researchers, as well as the use of the materials - object of research, as sources of economic valuable traits.

MATERIALS AND METHODS

In a comparative experiment between 2020 and 2022, 24 variants of grain sorghum were tested by block method in 4 replications and 10.8 m^2 size of the experimental plot. The variants include samples of the latest grain sorghum hybrids in Europe, as well as promising lines selected at the Agricultural Institute, Shumen.

The experiments were carried out under non-irrigated conditions on carbonate chernozem soil with sugar beet precursor and fertilization with 250 kg of nitrogen fertilizer per ha. Sowing was done with 280,000 germinated seeds per hectare, at 70 cm row spacing. Grain samples were taken for moisture determination at harvest.

The grain yield data were processed statistically according to Shanin (Shanin, 1977), and the Maxibel and Maxired varieties from the selection of the Agricultural Institute, Shumen, and Armida and Alize, which are from the European selection, were used as the standard. The varieties Maxibel and Alize have a white color of the grain, while Maxired and Armida have a red color of the grain.

RESULTS AND DISCUSSIONS

The Table 2 presents the results of the rainfall between 2020 and 2022. It can be seen from the data that 2020 is characterized as extremely unfavorable, with record values of water deficit. Winter precipitation is half of normal. March and April are practically without precipitation, and the whole of May is a third of the norm. The subsequent prolonged extreme drought in July and August irreversibly affected record low productivity levels.

Table 2. Precipitation between 2020 and 2022

Month	Precipitation, mm			Norm
	2020	2021	2022	
I	0.6	113.4	15.1	35.0
II	20.3	20.3	26.5	28.0
III	5.8	66.4	10.1	31.0
IV	1.6	60.8	57.9	41.0
V	26.4	34.3	33.9	64.0
VI	78.4	164.8	127.2	41.0
VII	14.8	21.1	4.3	64.0
VIII	21.4	6.7	30.6	42.0
IX	31.1	3.1	55.2	53.0
X	47.9	77.1	12.5	51.0

Climatically, 2021 and 2022 were warm with rainfall significantly below the norm - 321.6 mm and 429.7 mm respectively for the growing season from April to September. A significant difference is the fact that rainfall in individual years was unevenly distributed during the growing season, which also affected the studied parameters.

The observed dynamics of meteorological factors during the individual years and its interaction with the genotype has an influence on the formation of differences in the studied varieties and promising lines of grain sorghum. The analysis shows that conditions in individual years have a strong influence on productivity.

The results of the trials in 2020 are presented in Table 3. It is clear from the data that the extremely dry and unfavorable year for sorghum had a strong impact on the obtained grain yields. From the results presented in the table, it is clear that all the investigated variants have moisture that allows the harvest of the grain and its storage without the need for additional drying. During the studied year, the yield of grain was relatively close. Here we can single out R-OC and R-OSH and R-OB, from which respectively 1.2 t/ha and 1.3 t/ha of grain were obtained.

Figure 1. Experimental field with promising grain sorghum lines

Figure 2. Promising red color grain sorghum line

The MR-6 line has the highest grain yield - 3.0 t/ha, which exceeds the group standard by 25%. A total of 9 of the tested origins exceed the group standard. Average yield for the standard is 2.40 t/ha. From the prospective lines studied, we can distinguish the MR-6 line with 3.00 t/ha, followed by the Gold variety with a grain yield of 2.90 t/ha.

The R-OBH and R-OB pollinators have extremely low grain yields - only 1.30 t/ha. The moisture content of the grain at harvest of the studied variants was within the limits of 11.0% for the Maxired variety to 14.1% for MR-7. We can explain the low humidity of the grain with the extremely dry year 2020, which contributes to the rapid ripening and release of moisture to the grain during harvest.

Table 3. Productivity of varieties and perspective lines of sorghum for grain 2020. Group standard - Maxired, Maxibel, Armida, Alise

Variant	Grain moisture, %	Grain yield, t/ha	Relative, %
Maxibel - St.	11.2	2.6	110.0
Maxired - St.	11.0	2.5	104.2
R-OA	12.0	1.4	57.1
R-OBH	13.0	1.3	55.0
R-OB	12.7	1.3	54.2
R-OD	12.9	1.8	72.9
R-OC	12.3	1.2	50.8
R-27	11.6	1.8	74.5
R-47	11.7	1.5	61.7
MB-10	11.4	2.6	110.0
MB-13	11.9	2.2	90.8
MB-14	13.0	2.2	90.4
MB-17	13.1	2.1	87.5
MB-27	13.7	2.2	89.6
MR-6	13.6	3.0	125.0
MR-7	14.1	2.6	110.8
MR-8	13.8	2.2	92.1
MR-32	13.4	2.7	113.3
MR-47	12.5	2.3	97.5
Armida - St.	13.2	2.5	104.2
Alise - St.	13.1	2.0	81.3
Aisberg	12.9	2.7	111.07
Gold	12.1	2.9	121.3
For the sstandard		24	100.0
GD 5%		2.3	43.5
GD 1 %		4.5	52.0
P%		12.1	

In 2021, 8 cultivars, 8 pollinators – R and 8 MB/MR grain lines were tested in a comparative variety - Table 4. The results presented in Table 3 clearly show the influence

of climatic conditions during the year. This is reflected both in the moisture content of the grain at harvest and in the yield obtained. In the wetter year, the grain was not able to release its moisture in time, which resulted in higher values for this indicator.

Table 4. Productivity of varieties and perspective lines of sorghum for grain 2021. Group standard - Maxired, Maxibel, Armida, Alise

Variant	Grain moisture, %	Grain yield, t/ha	Relative, %
Maxibel - St.	21.3	6.5	98.6
Maxired - St.	13.6	6.1	92.3
R-OA	18.5	5.3	80.7
R-OBH	18.5	4.7	71.4
R-OB	20.0	5.8	88.1
R-OD	11.4	4,3	85.3
R-OC	12.7	4.5	66.0
R-6	17.0	6.2	94.3
R-27	14.1	4.4	64.8
R-47	15.9	4.6	69.6
MB-10	17.3	5.1	76.5
MB-13	18.8	5.0	75.3
MB-14	17.9	5.8	87.4
MB-17	19.7	6.8	102.1
MR-4	13.5	5.5	83.5
MR-7	13.4	6.3	95.2
MR-8	15.0	5.2	78.0
MR-16	14.7	6.4	97.4
Proteus	12.5	6.1	91.5
Albanus	14.0	6.8	102.7
Armida - St.	16.8	7.6	115.3
Alise - St.	16.8	6.6	99.2
Aisberg	13.6	5.9	88.7
Gold	20.2	7.4	111.6
For the Standard		6.7	100.0
GD 5%		1.09	12.0
GD 1 %		1.44	16.4
P%		5.88	

Grain yield, on the other hand, is also higher compared to the previous year. It varies between 4.4 t/ha for the R-6 line and reaches 7.6 t/ha for the Armida variety. On average, for the group standard, 6.7 t/ha grain yield was reported. Grain moisture at harvest varied widely – from 11.4% for R-OD to 21.3% for the Maxibell variety. From the tested lines, we can distinguish line MB-17, which alone exceeds the group standard with a yield of 6.80 t/ha of grain. This year, our Maxired and Maxibell varieties are inferior to tested foreign varieties from the companies Cosade Semences, KWS, RAGT, Euralis Semences.

The super-elite MB components of Maxibell's synthetic population and the red-colored MRs are also of lower productive qualities. This is largely due to poorer germination and a lower initial rate of development.

In Table 5 presents the results of the studies in 2022. As a standard, we used the native varieties Maxibel and Maxired as well as the varieties Albanus and Alize from the French company Euralis Semences.

Table 5. Productivity of varieties and perspective lines of sorghum for grain 2022. Group standard - Maxired, Maxibel, Albanus, Alise

Variant	Grain moisture, %	Grain yield, t/ha	Relative, %
Maxibel -St.	13.2	4.28	87.35
Maxired - St.	13.0	4.99	101.84
R-OA	12.7	2.86	58.37
MR-01	15.8	5.85	119.39
MR-02	15.5	5.46	111.43
MR-03	14.2	5.92	120.82
MB	14.0	5.89	12.,20
MB-4	14.0	5.85	119.39
MB-7	13.8	4.29	87.55
MB-9	13.9	3.90	79.59
MB-10	13,7	5.07	103.47
MB-11	13.0	3.90	79.59
MB-13	13.9	4.60	93.88
MB-14	15,1	4.00	81.63
Flagg	13.1	4.64	94.69
Anggy	13.1	3.92	80.00
Gustav	13.4	3.21	65.51
Huggo	14.2	5.35	109.18
Lupus	13.1	4.28	87.35
Proteus	12.8	3.21	65.51
Albanus St.	13.4	5.71	116.53
Alise St.	13.7	4.64	94.69
Aisberg	12.8	4.64	94.69
Gold	14.3	5.35	109.18
For the Standard	13.3	4.9	100.0
GD 5%		1.08	
P%		4.54	

Five of the prospective lines tested exceeded the group standard for grain yield. We can clearly distinguish the MB and MR-03 lines that exceed the group standard by 20.20% and 20.82%. Their grain yield is within 5.92 t/ha and 5.89 t/ha. The French varieties Gustav and Proteus stand out with the lowest grain yield per hectare, from which 3.21 t/ha of grain were obtained. In all variants studied, grain moisture at harvest was acceptable and varied from 12.7% for the R-OA line to 15.8% for MR-01.

Figure 3. Promising white grain sorghum line

CONCLUSIONS

The promising grain sorghum lines selected at the Agricultural Institute, Shumen, are not inferior, in terms of grain yield, to already established varieties from the European selection. In 2020, we observe 4 prospective lines exceeding the group standard, respectively - MB-10 by 10% to MR-6 - 25%. In 2021, only one of the tested lines exceeds the group standard - MB-17 - 2.1%. The close values in these two years can be explained by the extremely dry conditions and equalization of the studied samples in terms of grain yield. Five of the prospective lines tested in 2022 year exceeded the group standard for grain yield. We can clearly distinguish the MB and MR-03 lines that exceed the group standard by 20.20% and 20.82%. Their grain yield is within 5.92 t/ha and 5.89 t/ha. This makes them suitable for further testing and implementation in practice.
Climatic changes in recent years require the maintenance of lines with greater adaptability and plasticity to abiotic stress.
It is necessary to increase the selection intensity to improve the qualities of the elite lines. The improvement in early maturity and leveling with the foreign samples is perceived as positive, in terms of low grain moisture and grain yield at optimal harvest by mid-September.

REFERENCES

Boyles, R.E (2019). Genetic and genomic resources of sorghum to connect genotype with phenotype in contrasting environments/R.E. Boyles, Z.W. Brenton, S.Kresovich//The *Plant Journal*. – 2019. – V. 97. – P. 19-39.

De Weet, J.M.J., Harlan, J.R., Price, E.G. (1972). Evolutionary dynamics of Sorghum domestication. *Burg Wartensein Simp*. № 56.

Fano, D (2017). Breeding of sorghum for high lysine in the seed/D. Fano//*International Journal of Agriculture Sciences*. – 2017. – V. 9. – I. 43. – P. 4702-4707.

Fantaye, B.M (2018). Genetic improvement of lysine content in sorghum: A Review/B.M. Fantaye/J. Advan. *Plant Sci*. – 2018. – V. 1. – P. 307.

FAOSTAT http://faostat.fao.org

Lafarge, T.A., Broad, J., Hammer, G.L. (2002). Tillering in grain Sorghum over a wide range of population densities: Identification of a common hierarhy for tiller emergence leaf area development and fertility. *Ann. Bot*.(Lond), 90, p.87-98.

Shanin J. (1977). *Methodology of the Field Experiment*, BAS Publishing House, Sofia, pp. 269-276.

Slanev K., Kikindonov Tz. (2017). *Sorghum in Bulgaria and abroad. Monograph*. "Chimera" Publishing House.

Slanev K., Kikindonov Tz. (2021). *Bulgarian varieties of grain sorghum. Study*. Chimera Publishing House.

Smith C.W., Frederiksen R.A. (2000). Sorghum – origin, history, technology and production, *John Wiley, Inc., Texas University*.

Wenzel,W.G. (1991). The inheritance of drought resistance characteristics in grain sorghum seedlings, *S.Afr.J.Plant Sole Sci*. 8: 169-171.

Zarkov B. (1995). Productive capabilities of sorghum grown under non-irrigated conditions. *Bulgarian Journal of Crop Science*, Vol. 6, p. 138-139.