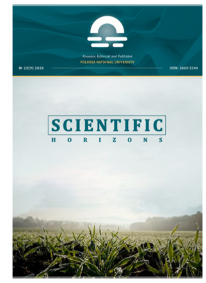
SCIENTIFIC HORIZONS

Journal homepage: https://sciencehorizon.com.ua

Scientific Horizons, 25(6), 55-64



UDC 631.5: 633.174 (1-924-85)

DOI: 10.48077/scihor.25(6).2022.55-64

Elements of Plant Productivity and Biological Yield Capacity of Grain Sorghum Hybrids Depending on the Inter-row Width and Seed Sowing Rate

Stanislav Davydenko[1], Arthur Rozhkov[1], Lesia Karpuk[2*], Serhii Popov[3], Volodymyr Mykhailyn[4]

[1]State Biotechnological University
61002, 44 Alchevskikh Str., Kharkiv, Ukraine

[2]Bila Tserkva National Agrarian University
09110, 8/1 Soborna Sq., Bila Tserkva, Ukraine

[3]Plant Production Institute named after V.Ya. Yuriev of NAAS of Ukraine
61000, 142 Heroiv Kharkova Ave., Kharkiv, Ukraine

[4]Institute of Vegetables and Melons Growing of NAAS of Ukraine
62478, 1 Institutskaya Str., Selectsiyne, Kharkiv region, Ukraine

Article's History:
Received: 11.07.2022
Revised: 10.08.2022
Accepted: 11.09.2022

Suggested Citation:
Davydenko, S., Rozhkov, A., Karpuk, L., Popov, S., & Mykhailyn, V. (2022). Elements of plant productivity and biological yield capacity of grain sorghum hybrids depending on the inter-row width and seed sowing rate. *Scientific Horizons*, 25(6), 55-64.

Abstract. Sorghum is one of the most important food, fodder, and energy crops in the world. The crop is resistant to stress factors, especially moisture deficiency. This biological feature allows it to form high and stable grain yields in conditions of moisture deficiency and hot temperature. Grain sorghum has a significant advantage in terms of several physiological, biological, yield characteristics compared to other crops, but the acreage under it in Ukraine stays limited. The main reason for this is, first, the lack of varietal technologies for its cultivation with improved elements. Therefore, the study of the complex influence of the rate of sowing seeds and the width of the row spacing on the formation of productivity elements is currently a relevant area of research. The main goal of the research was to study the influence of a complex of factors: row spacing, seed sowing rates on the productivity and biological yield of sorghum grain. The research was carried out in 2019-2021 at FE "Diunis", Kreminskyi district, Luhansk region. The scheme of the experiment: width between rows – 35, 45 and 70 cm, hybrids – Swat and Flagg, sowing rates – 100,000 pieces/ha, 140,000, 180,000 and 220,000 pieces/ha. The Flagg hybrid formed a higher panicle productivity of the main and side stem systems. As to sorghum hybrid Flagg, the grain mass from panicle of the main and lateral stems was 45.1 and 39.0 g, respectively; that of hybrid Svat were 39.5 and 31.1 g. A higher panicle productivity of hybrid Flagg was formed due to a much larger mass of 1,000 grains (by 35-40%); sorghum hybrid Svat had a larger number of grains in panicle of both stem systems. The biological grain productivity of both stem systems was higher for sorghum hybrid Flagg – 5.87 t/ha, as compared with that of early-ripening hybrid Svat, which was equal to 4.75 t/ha

Keywords: the number of panicles, main stems, side stems, grain size of the panicle, weight of 1,000 grains, correlation

Corresponding author

INTRODUCTION

Ukraine is characterized by remarkably diverse soil-climatic conditions, which is why crop production in the east zone of the north Steppe is to be based on the effective use of the agro-climatic potential by a proper choice and location of the crops which can develop high yield capacity and good quality output in certain conditions. The efficient cultivation of the field crops in the areas with moisture deficit and high summer temperatures appears to be possible due to their high ecological resistance, the latter levels the effect of stress factors (Kalenska *et al*., 2017).

A typical representative of these crops is sorghum (grain, sugar, technical sorghum, Sudanese grass). Owing to their high plastic and adaptive nature, the area of sorghum crop cultivation can be very widespread (from tropical and semi-desert regions to temperate latitudes); sorghum crops have a high ability to resist negative weather conditions during their vegetation (Klymovych *et al*., 2011; Fedorchuk *et al*., 2016; Alieksieiev, 2021).

Sorghum can easily adapt to moisture deficit and use it sparingly. This biological feature makes it possible for sorghum to develop high and stable grain yields in the conditions of moisture deficit and elevated temperatures. In this respect, sorghum is a leader among other field crops (Polovyi *et al*., 2020).

Mostly sorghum is grown with a fodder purpose; the crop is widely used to produce grain forage, monofodder, hay, haylage, green fodder, and fodder molasses. In recent years sorghum has been widely used in food and technical industry for the manufacture of flour, cereals, starch, glucose-fructose sugar, bioethanol, and other renewable energy sources (Nosko *et al*., 2015; Mehmood *et al*., 2017; Kalenska & Naidenko, 2018).

Despite a considerable advantage of sorghum based on several features (e.g., yield capacity, biological and physiological characteristics) as compared with other crops, proper attention has not been paid to sorghum yet, as its sown areas in Ukraine remain to be rather limited. This situation is explained by the lack of varietal technologies of its cultivation with the improved elements and updated innovations. Thus, nowadays it is expedient to work out varietal, adaptive technologies of the cultivation which can realize a genetic productivity potential of the crop, and in this way to encourage the producers to grow sorghum.

Until now the results of the research which dealt with the development of the elements of the varietal technologies of sorghum cultivation in various soil-climatic zones were summed up; it helps make a complex analysis of their efficiency which will result in a further improvement of the varietal farm practices of its cultivation (Storozhik & Muzyka, 2019; Svyrydova, 2017; Kalenska & Naidenko, 2019). There is a certain disagreement among scientists as to the seed sowing rate and the inter-row width, which is associated with the cultivation region, varietal features, the intensification level of the cultivation technology, etc. (Gondal *et al*., 2017; Mekasha *et al*., 2021; Makarov, 2006).

Usually, grain sorghum is grown with the inter-rows which range within 60-75 cm; but with the development of new production technologies and the introduction of new herbicides, innovative approaches appear on the spread of narrower inter-rows when this crop is grown (Kovalenko, 2014 Ovsiienko, 2015; Gondal *et al*., 2017).

Researchers G.K. Dremlyuk *et al*. (2013) note that under conditions of a dry growing season, the most effective cultivation of sorghum is by wide-row sowing with 45 cm between rows, and in the case of best conditions – by row sowing with 15 cm between rows.

In the opinion of L.A. Svyrydova (2017), in the conditions of the Forest-steppe zone, regardless of a ripening group and a seed sowing rate, the highest yield of sorghum grain is formed by sowing when the inter-row is 45 cm. For instance, the combination of this inter-row width with a seed sowing rate 200 thous. pcs/ha was the best for grain hybrids Prime, Dash E and Sprint W, for hybrid Stepovyi 8 – with a seed sowing rate 160 thous. pcs/ha. (Svyrydova, 2017). In the conditions of the educational-scientific-production centre of the Uman University of Horticulture, the highest grain yield of modern grain sorghum hybrids was provided by the combination of the seed sowing rate of 250,000 seeds/ha with 45 cm between rows (Snider *et al*., 2012; Boiko, 2016).

In the conditions of a steppe zone of the Crimea, the highest yield capacity of grain sorghum hybrids was formed in the treatments of the combination of a seed sowing rate 100-140 thous. pcs/ha with the inter-rows of 45 and 60 cm (Samoilenko, 2009).

The analysis of the reference sources proves the following: firstly, the importance of a complex effect of the inter-row width and a seed sowing rate on the formation of the grain sorghum productivity; secondly, the necessity to consider the features of a morphological biotype of hybrids, the level of farm practices and the cultivation area. Besides, the analysis made confirms the lack of the research results as to the studies of the optimal combinations of a seed sowing rate and the inter-row width for different regions of Ukraine, namely for the conditions of the east zone of the north Steppe; it is this area that is the most promising one for sorghum cultivation.

Based on this, *the purpose of this study* was to investigate the complex effect of a seed sowing rate and various treatments of the inter-row width on the formation of the productivity elements and the biological yield capacity of sorghum in the conditions of the north Steppe.

MATERIALS AND METHODS

In 2019-2021, the research was carried out by the generally accepted methodology at farm enterprise "Diunis", Kreminskyi district, Luhansk Oblast (Yeshchenko *et al*., 2005). The soil in the area under study was sod-podzolic low-humus chornozem. Humus content in a ploughing layer was 2.4-2.8%, that of mobile phosphorus – 11.6 mg, potassium content was 9.1 mg per 100 g of the soil.

The trial was started by a randomized method with four replications. Three treatments of the inter-row width (factor A) – 35, 45 and 70 cm, two hybrids (factor B) – Svat and Flagg and four treatments of sowing rates (factor C) – 100 thous. pcs/ha, 140, 180 and 220 thous. pcs/ha were studied in the experiment. The sown and accounting areas were 100.0 and 80.0 m^2, respectively. Farm practices in the trials were the generally accepted ones for the area of the research, except for the elements under study.

Two new hybrids of grain sorghum – Svat and Flagg – were studied in the research. An early-ripening high yielding Ukrainian hybrid Svat has been included in the National registry since 2017, a medium-early ripening French hybrid Flagg – since the year of 2018. These hybrids are drought-resistant, they have high indicators of their resistance to pathogens, and they are recommended to be grown in the Steppe.

In 2019-2021 weather conditions of sorghum vegetation were contrasting, and it particularly concerned moisture regime. In addition, during these years a general tendency of the precipitation distribution was recorded, namely, more precipitation occurred at the beginning of sorghum vegetation. In 2019 in the first decade of May the amount of precipitation exceeded the indicator of a climatic standard by two times. In May 2020 and 2021 and in June 2021, the amount of precipitation was much higher compared with long-term indicators. For instance, in May 2020 and 2021 the amount of precipitation was equal to 108 and 72 mm, while climatic standard was 49 mm. In June most of the precipitation occurred in the first two decades – 53 and 78 mm, respectively. In these years there was no precipitation beginning from the third decade of June and up to the end of sorghum vegetation.

Totally, in the years under study less than 200 mm of precipitation were recorded during sorghum vegetation, which was much lower than an average long-term indicator, i.e., 240 mm. Along with this, considering the sufficient moisture supply of the sown areas at the first stages of their growth and development as well as a global warming tendency and the decrease of the annual precipitation amount, weather conditions of the area under study can be classified as favourable for sorghum.

In the years of the study, the best temperature conditions for plant growth and development were in 2021. That year, air temperature at the beginning of plant vegetation was a bit higher compared with that in 2020, and it was lower than the indicators of climatic standard. In July 2021, except for a few days in the second decade, the temperature ranged within optimal indicators for sorghum plants – 20-25°C, whereas in 2020 in the first and second decade of this month it was over 35.0°C on some days.

In general, the weather conditions of sorghum vegetation differed considerably from the average long-term indicators; however, their comparison with the weather conditions recorded during the last 10 years proved the fact that they were quite typical, as due to global climate changes the weather conditions of the area under study tended towards warming and decreasing the precipitation amount.

RESULTS AND DISCUSSION

Factors under study had different effect on the variability of elements of the productivity of panicles of grain sorghum stems. In particular, the number of main stem panicles, as well as the panicle grain number of the sorghum main and lateral systems, underwent the greatest changes under the effect of a 220 thous./ha seed sowing rate; the mass of 1,000 grains from the panicles of the stem main and lateral system was under the effect of a hybrid morphotype, and the influence of the studied treatments of the inter-row width was mostly seen in the variability of the panicle number of the lateral stems.

The effect of a sowing rate was mostly displayed in the change of a panicle number of the sorghum main stems. According to the studied treatments of the inter-row width and hybrids, on average the number of main stem panicles increased more than twice – 49.1 thous. pcs/ha with the increase of a sowing rate – 100 thous. pcs/ha; and it was 107.2 thous. pcs/ha at a sowing rate 220 thous. pcs/ha (Table 1).

***Table 1**. Panicle productivity of the main stem depending on the inter-row width and a seed sowing rate (average in 2019-2021)*

Inter-row width, cm (factor *A*)	Hybrid (factor *B*)	Sowing rate, thous./ha (factor *C*)	Panicle number, thous. pcs/ha	Panicle graininess, pcs	Mass of 1,000 grains, g	Grain mass from panicle, g
35	Svat	100	49.1	2,017	20.6	41.5
		140	67.1	2,004	20.5	41.0
		180	87.0	1,970	20.5	40.3
		220	106.0	1,899	20.3	38.6
	Flagg	100	49.5	1,648	29.5	48.6
		140	68.5	1,635	29.6	48.4
		180	88.8	1,577	29.5	46.5
		220	108.5	1,484	29.2	43.3

Table 1, Continued

Inter-row width, cm (factor *A*)	Hybrid (factor *B*)	Sowing rate, thous./ha (factor *C*)	Panicle number, thous. pcs/ha	Panicle graininess, pcs	Mass of 1,000 grains, g	Grain mass from panicle, g
45	Svat	100	49.1	1,998	20.5	40.8
		140	68.1	1,991	20.5	40.8
		180	86.7	1,946	20.4	39.6
		220	107.1	1,854	20.3	37.5
	Flagg	100	48.5	1,640	29.6	48,6
		140	67.8	1,619	29.6	47.9
		180	88.5	1,560	29.4	45.8
		220	108.2	1,452	29.3	42.5
70 (*c*)	Svat (*c*)	100	49.0	1,975	20.5	40.5
		140	67.7	1,946	20.3	39.5
		180 (*c*)	87.4	1,896	20.2	38.3
		220	105.3	1,762	20.1	35.3
	Flagg	100	49.3	1,612	29.4	47.3
		140	68.6	1,576	29.3	46.1
		180	88.1	1,402	29.1	40.7
		220	108.3	1,237	28.9	35.7
Average by factor *A*		35	78.1	1,779	25.0	43.5
		45	78.0	1,758	25.0	42.9
		70 (*c*)	78.0	1,676	24.7	40.4
Average by factor *B*		Svat (*c*)	77.5	1,938	20.4	39.5
		Flagg	78.6	1,537	29.4	45.1
Average by factor *C*		100	49.1	1,815	25.0	44.6
		140	68.0	1,795	25.0	44.0
		180 (*c*)	87.8	1,725	24.9	41.9
		220	107.2	1,615	24.7	38.8

The effect of a sowing rate on the variability of the panicle number of grain sorghum hybrids in the studied of the inter-row width was the same. When a seed sowing rate increased from 100 to 220 thous. pcs/ha, the panicle number of an early-ripening hybrid Svat in the treatments with the inter-row width of 35, 45, and 70 cm increased by 216%, 218%, and 214%, respectively, a sowing rate increased by 220%. A similar tendency was seen in the fields of an average-early-ripening hybrid of French selection Flagg.

The number of panicles from the stems of a lateral system underwent fewer changes under the effect of a 100 to 180 thous. pcs/ha seed sowing rate, besides, the trend of this connection changed. For instance, with the increase of a sowing rate from 100 to 180 thous. pcs/ha one can see the increase of the panicle number of a stem lateral system; contrary to this, with the increase over 180 thous. pcs/ha their number decreased. On average, by other factors, the number of panicles of a lateral system increased by 24.5 thous. pcs/ha (58.5%) when a sowing rate increased from 100 to 180 thous. pcs/h and it decreased by more than 8.0 thous. pcs/ha (14.1%) when a sowing rate increased up to 220 thous. pcs/h (Table 2).

Table 2. *Panicle productivity of the lateral stem depending on the inter-row width and a seed sowing rate (average in 2019-2021)*

Inter-row width, cm (factor *A*)	Hybrid (factor *B*)	Sowing rate, thous./ha (factor *C*)	Panicle number, thous. pcs/ha	Panicle graininess, pcs	Mass of 1,000 grains, g	Grain mass from panicle, g
35	Svat	100	41.8	1,618	20.4	32.9
		140	55.5	1,609	20.3	32.7
		180	67.1	1,583	20.2	32.0
		220	58.5	1,524	20.1	30.6
	Flagg	100	43.8	1,429	29.3	41.9
		140	59.7	1,420	29.2	41.4
		180	72.5	1,391	29.2	40.6
		220	69.3	1,316	29.0	38.1

Table 2, Continued

Inter-row width, cm (factor *A*)	Hybrid (factor *B*)	Sowing rate, thous./ha (factor *C*)	Panicle number, thous. pcs/ha	Panicle graininess, pcs	Mass of 1,000 grains, g	Grain mass from panicle, g
45	Svat	100	42.2	1,610	20.4	32.8
		140	54.0	1,582	20.3	32.1
		180	64.8	1,546	20.1	31.1
		220	53,2	1,479	20.1	29.7
	Flagg	100	43.7	1,422	29.3	41.6
		140	58.1	1,405	29.2	41.0
		180	70.2	1,362	29.0	39.5
		220	64.0	1,290	29.0	37.3
70 (*c*)	Svat (*c*)	100	38.3	1,590	20.2	32.1
		140	50.3	1,543	20.1	30.9
		180 (*c*)	57.0	1,456	20.1	29.2
		220	48.2	1,374	19.9	27.3
	Flagg	100	41.3	1,398	29.2	40.7
		140	54.3	1,371	29.2	39.9
		180	66.9	1,195	29.0	34.6
		220	55.7	1,082	28.7	31.0
Average by factor *A*		35	58.5	1,486	24.7	36.3
		45	56.3	1,462	24.7	35.6
		70 (*c*)	51.5	1,376	24.6	33.2
Average by factor *B*		Svat (*c*)	52.6	1,543	20.2	31.1
		Flagg	58.3	1,340	29.1	39,0
Average by factor *C*		100	41.9	1,511	24.8	37.0
		140	55.3	1,488	24.7	36.3
		180 (*c*)	66.4	1,422	24.6	34.5
		220	58.2	1,344	24.5	32.3

Similar regularities were recorded in the fields of both hybrids with different inter-row width. These changes are quite common, because when seed sowing rate increases productive bushiness will decrease because of a growing competitiveness among plants; increase in the lateral stem number will take place when sowing rate increases to a certain point due to higher plant density; when certain bushiness is reached, further plant density will not overlap the damage of productive plant activity. Other researchers also mentioned similar regularity (Sviridova, 2017; Makarov, 2006; Gondal *et al.*, 2017).

The effect of the inter-row width on the changes of the panicle number of the stem system was not recorded, but this factor had a profound effect on the panicle number of the lateral system. And again, it relates to the level of competitiveness in agro-phytocenosis. Thus, in treatments with a more even distribution of plants on the nutrition area which can be reached at the inter-row width of 35 cm, on average the panicle number of a lateral stem system by other factors was 58.5 thous. pcs/ha, while in the treatments with the inter-row width of 70 cm it was 51.5 thous. pcs/ha (smaller by 14.0%). Hence, only due to the panicle number of a lateral stem system, provided all other elements of the yield structure are the same, in the treatments with the inter-row width of 35 cm, the grain yield capacity of a lateral stem system will be higher by 14.0% as compared with that at the inter-row width of 70 cm.

Panicle graininess of the stems of the main and lateral system was much higher in the fields of an early-ripening hybrid Svat which could be explained by its morphotype. On average, according to the sowing rates and treatments of the inter-row width under study, the number of grains in panicle of the main and lateral stem system of sorghum hybrid Svat was 1,938 and 1,543 pieces, respectively, as to hybrid Flagg these indicators were 1,537 and 1,340 pieces, respectively. Along with this, hybrid Flagg had a much higher average panicle productivity of both stem systems, as its peculiar feature was a larger mass of 1,000 grains. On average, by the studied treatments of the inter-row width and seed sowing rates, the mass of panicle grain of the main and lateral stem system was 39.5 and 31.1 g, respectively, while for hybrid Flagg the indicators were 45.1 g and 39.0 g.

Totally in the trial, the largest mass of panicle grain of the main stem system was formed in the treatments with the widest distance between plants, i.e., in the treatments with the inter-row width of 35 cm and a seed sowing rate 100 thous. pcs/ha. In the years under study, on average, the mass of panicle grain of the central stems of sorghum hybrids Svat and Flagg in these treatments was 41.5 and 48.6 g, respectively.

In the field of both hybrids the effect of a seed sowing rate on the changes of the mass of panicle grain of the stem system was much higher in the treatments with the inter-row width of 70 cm. For example, with the increase of a seed sowing rate up to 220 thous. pcs/ha, grain mass from the central panicle of hybrids Svat and Flagg decreased by 14.7 and 32.4%, respectively, in the treatments with the inter-row width of 70 cm, while in the treatments with the inter-row width of 35 cm this indicator decreased only by 7.5 and 12.2%.

The interaction between the inter-row width and a seed sowing rate had a greater effect on the changes of the indicators of the mass of panicle grain of a stem lateral system. Thus, when seed sowing rate increased from the smallest to the largest one, in the treatments with the inter-row width of 70 cm, the mass of panicle grain from a lateral stem system of hybrids Svat and Flagg decreased by 17.8% and 31.0%, respectively; this indicator decreased by 7.5% and 10.0%, respectively, in the treatments with a two-time narrower inter-row.

As to sorghum hybrid Flagg, when a nutrition area and its patter were changed, the grain mass from both panicle systems varied in a wider range; which is why it is advisable to have a serious approach to the choice of a plant nutrition area and its pattern for this hybrid. This hybrid forms a much larger mass of panicle grain of both stem systems in more "favourable" conditions, which is an important precondition for the formation of its higher yield capacity. As the plant density grows, the difference by this indicator between the studied hybrids partially levels.

The variability of the mass of panicle grain from the lateral and main stem system of the studied hybrids under the influence of a seed sowing rate was first connected with the change in panicle graininess, as the mass of 1,000 grains did not change much.

The analysis of the indicators of the panicle productivity elements of both sorghum hybrids showed that their decrease took place mainly because a seed sowing rate increased from 180 to 220 thous. pcs/ha. This was particularly seen in the treatments with the inter-row width of 70 cm. Furthermore, as was mentioned earlier, the number of panicles of the lateral stem system increased when a seed sowing rate was higher – up to 180 thous. pcs/ha; then, on the contrary, the larger plant density led to the decrease of their number. Authors are very much interested in a final result, i.e., the plant grain productivity per unit of a sown area; the best option is the one which will ensure the highest yield capacity of the fields. In view of this, it is not correct to give preference to a certain treatment based only on the indicators of the individual plant productivity. Thus, the indexes of the biological productivity of the studied sorghum hybrids were analysed. Besides, to better understand a mechanism of the influence of the studied factors, authors considered their influence on the level of the grain biological productivity of sorghum stems of the main and lateral systems.

The grain biological yield capacity of the main stem system of both sorghum hybrids in all treatments of the inter-row width was the highest when a seed sowing rate was the largest – 220 thous. pcs/ha. With the increase of a seed sowing rate the individual stem productivity of the main system decreased, but due to the increase of a seed sowing rate, and accordingly that of the plant number per unit of the sown area, the biological grain yield capacity of the main stem system was the highest when seed sowing rate was the largest.

When a seed sowing rate was gradually increasing to the established point – 40 thous. pcs/ha, the indicator growth decreased. Logically, the individual panicle productivity decreased more intensely. This tendency was mostly recorded in the treatments with the inter-row width of 70 cm. Thus, it is in the treatments with this inter-row width that the difference of the indexes of grain yield capacity of the main stem panicles was the lowest.

In the conditions of "a better" pattern of the plant nutrition area, namely, in the treatments with the inter-row width of 35 cm, when sorghum plants did not suppress each other very much, the effect of a seed sowing rate was considerably higher. When the grain biological productivity of the main sorghum stems (hybrids Svat and Flagg) increased by 1.73 t/ha (87.0%) and 1.56 t/ha (66.6%), respectively, in the treatments with the inter-row width of 70cm and with the increase of a seed sowing rate from 100 to 220 thous. pcs/ha; then in the treatments with the inter-row width of 35 cm the biological productivity increased by 2.05 (100.5%) and 2.30 t/ha (95.4%) (Table 3).

***Table 3**. Biological grain yield capacity of sorghum hybrids of the different stem systems under the effect of the inter-row width and a sowing rate, t/ha (average in 2019-2021)*

Inter-row width, cm (factor *A*)	Hybrid (factor *B*)	Sowing rate, thous. pcs/ha (factor *C*)	Biological grain yield capacity		
			Main stems	lateral stems	Total
35	Svat	100	2.04	1.46	3.50
		140	2.75	1.91	4.66
		180	3.50	2.23	5.73
		220	4.09	1.87	5.96
	Flagg	100	2.41	1.92	4.33
		140	3.32	2.57	5.89
		180	4.14	3.08	7.22
		220	4.71	2.75	7.46

Table 3, Continued

Inter-row width, cm (factor *A*)	Hybrid (factor *B*)	Sowing rate, thous. pcs/ha (factor *C*)	Biological grain yield capacity		
			Main stems	Lateral stems	Total
45	Svat	100	2.00	1.44	3.44
		140	2.78	1.81	4.59
		180	3.43	2.12	5.55
		220	4.02	1.70	5.72
	Flagg	100	2.36	1.92	4.28
		140	3.25	2.49	5.74
		180	4.07	2.92	6.99
		220	4.62	2.54	7.16
70 (*c*)	Svat (*c*)	100	1.99	1.29	3.28
		140	2.68	1.62	4.30
		180 (*c*)	3.35	1.74	5.27
		220	3.72	1.40	5.12
	Flagg	100	2.34	1.79	4.13
		140	3.15	2.28	5.43
		180	3.60	2.44	6.04
		220	3.90	1.82	5.72
Average by factor *A* 45 70 (*c*)		35	3.37	2.22	5.59
		3.32	2.12	2.12	5.44
		3.09	1.80	1.80	4.89
Average by factor *B* Flagg		Svat (*c*)	3.03	1.72	4.75
		3.49	2.38	2.38	5.87
Average by factor *C* 140 180 (*c*) 220		100	2.19	1.64	3.83
		2.99	2.11	2.11	5.10
		3.68	2.42	2.42	6.10
		4.18	2.01	2.01	6.19
SSD_{05} main effect of factor A			0.11	0.12	0.19
SSD_{05} main effect of factor B			0.09	0.10	0.16
SSD_{05} main effect of factor C			0.13	0.14	0.22
SSD_{05} interaction of AC			0.22	$F_{\phi}<F_{m}$	0.39

Note: *when SSD_{05} was calculated, years were taken as replications. A difference as compared with the control is shown in a dominator*

In the area under study, the effect of a seed sowing rate on the grain biological yield capacity of the stem lateral system was manifested a bit differently, namely: with its increase to 180 thous. pcs/ha the panicle grain biological productivity of the lateral stem system of both sorghum hybrids increased, and with its further increase the biological productivity decreased. This tendency was recorded in all studied treatments of the inter-row width. For instance, with the increase of sowing rate up to 220 thous. pcs/ha and in the treatments with the inter-row width of 35 cm the panicle grain biological productivity of the lateral stem system of sorghum hybrids Svat and Flagg decreased by 0.36 and 0.33 t/ha (19.3 and 12.0%); in the treatments with the inter-row width 4 cm this indicator decreased by 0.42 and 0.38 t/ha (24.7 and 15.0%); in the treatments with the inter-row width of 70 cm the biological productivity decreased by 0.38 and 0.62 t/ha (24.3 and 31.9%), respectively.

The decrease of the panicle grain biological productivity of the lateral stem system when the seed sowing rate increases from to 220 thous. pcs/ha occurs for two reasons: on the one hand – the decrease of the lateral panicle number (due to a severe competitiveness among plants), on the other hand – the decrease of their individual productivity. According to the statistical analysis made, the highest grain biological yield capacity of the lateral sorghum stem system was formed at a seed sowing rate 180 thous. pcs/ha. Both the increase and the decrease of a seed sowing rate led to its significant decrease.

Among the studied treatments of the inter-row width, the narrowest inter-rows of 35 cm formed the highest panicle grain yield capacity of both stem systems. As compared with the control treatment of factor A (the inter-row width of 70 cm), on average the grain biological yield capacity of the main and lateral stem system by other factors increased by 0.28 and 0.42 t/ha, respectively.

The total yield capacity was the highest in the treatments with the inter-row width of 35 cm and a seed sowing rate 220 thous. pcs/ha. In this treatment it was 5.96 t/ha for the early-ripening hybrid Svat, the medium-early ripening hybrid Flagg had it at the level of 7.46 t/ha. However, according to the statistical analysis, it did not differ statistically from the indicator received with a sowing rate 180 thous. pcs/ha.

Among the studied correlations of the factors, only the interactions of a seed sowing rate and the inter-row width was significant. This is natural, because in the treatment with the inter-row width of 35, 45 and 70 cm, the effect of a seed sowing rate on the overall biological yield capacity of sorghum grain was seen in diverse ways. In the treatments with the inter-row width of 70 cm the highest total biological grain yield capacity of both sorghum hybrids was formed in the treatments with a seed sowing rate 180 thous. pcs/ha (5.27 t/ha for hybrid Svat and 6.04 t/ha for hybrid Flagg), while in the treatments with the inter-row width of 35 cm, as noted above, a seed sowing rate was 220 thous. pcs/ha.

It has to be noted that there is no significant difference between the indicators of the biological grain yield capacity of hybrids in the treatments with the inter-row width of 35 and 45 cm. Regardless of this, the narrower inter-rows (35 cm) are more preferable, because in the context of the studied hybrids and a seed sowing rate the tendency towards the yield capacity increase is recorded with the decrease of the inter-row width from 45 to 35 cm. Other researchers confirm this fact (Snider *et al.*, 2012; Semin *et al.*, 2016; Mekasha *et al.*, 2021). Furthermore, there is an increased difference between the biological grain yield capacity in these treatments when a seed sowing rate is larger. It is quite logical since when the plant density grows the role of the nutrition area pattern is higher. Since the increase of a seed sowing rate (180 and 220 thous. pcs/ha) resulted in the formation of a higher biological yield capacity, then the preference is given to the 35 cm inter-rows. For instance, at a seed sowing rate 100 thous. pcs/ha and in the treatments with the inter-row width of 35 cm the total biological grain yield capacity of sorghum hybrids Svat and Flagg was higher only by 0.06 and 0.05 t/ha than in the treatments with the inter-row width 45 cm, while in the treatments with a seed sowing rate 220 thous. pcs/ha the yield capacity was 0.24 and 0.30 t/ha, respectively.

It is of a certain interest to determine the density and the trend of the connections of the biological grain yield capacity and the panicle productivity elements of the various stem systems of the studied grain sorghum hybrids with a seed sowing rate of the various treatments of the inter-row width. The inter-row width of 35 cm and 70 cm, i.e., the control and the best treatment, were taken as an example. In the studied area the closest direct connection was between a seed sowing rate and the panicle number of the main stems. In the fields of sorghum hybrids Svat and Flagg in the treatments with the inter-row width of 35 cm it was as follows: r=0.98 and r=0.97, with the inter-row width of 70 cm – r=0.97 and r=0.96 (Fig. 1).

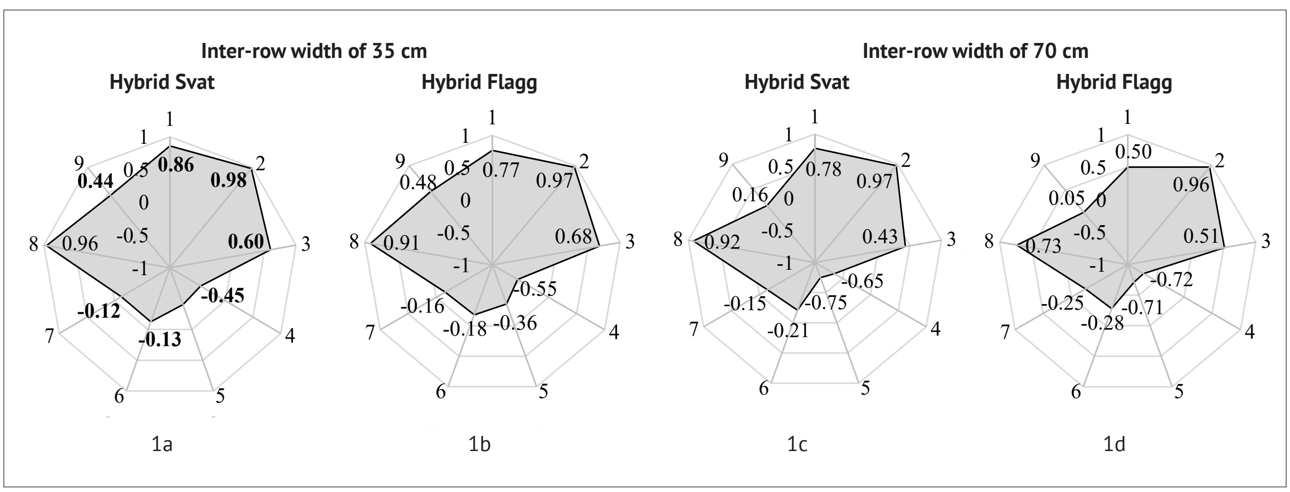


***Figure 1**. Strength and trend of the connections between a seed sowing rate with the elements of the plant productivity and the biological grain yield capacity of grain sorghum (Inter-row width of 35 cm: 1a – Hybrid Svat, 1b – Hybrid Flagg; Inter-row width of 70 cm: 1c – Hybrid Svat, 1d – Hybrid Flagg)*

***Note:** 1 – biological grain yield capacity; 2 – panicle number of the main stems per 1 ha; 3 – panicle number of the lateral stems per 1 ha; 4x– graininess of the central panicle; 5 – graininess of the lateral panicle; 6 – mass of 1,000 grains from the central panicle; 7 – mass of 1,000 grains from the lateral panicle; 8 – biological grain yield capacity of the main stem system; 9 – biological grain yield capacity of the lateral panicle system*

A close direct connection between a seed sowing rate and the biological grain yield capacity of the central stem panicles was common for both hybrids in the treatments of the inter-row width (r=0.73-0.96), as well as the average direct connection with the panicle number of the lateral stems (r=0.43-0.68) and a weak reverse connection with the mass of 1,000 grains from the central (r=−0.13-0.28) and lateral panicle (r=−0.12-0.25).

The strength of the connection of a seed sowing rate with other productivity elements depended on the inter-row width. In particular, in the treatments with the inter-row width of 35 cm a seed sowing rate had a weak direct connection with the biological grain yield capacity of the lateral stems of both hybrids (r=−0.44-0.48), whereas in the treatments with the inter-row width of 70 cm this connection was weak (r=−0.05-0.16). In the treatments with the inter-row width of 35 cm an average reverse connection (r=−0.36-0.47), (r=−0.36-0.47) was recorded between a seed sowing rate and panicle graininess of the lateral stem system of both hybrids, whereas in the treatments with the inter-row width of 70 cm there was a strong reverse connection (r=−0.71-0.75).

CONCLUSIONS

The results of this study allow drawing the following conclusions: among the treatments of the inter-row width under study, the preference is given to the narrowest one – 35 cm. A higher biological yield capacity of the main stem system on these inter-rows was formed due to a larger number of grains in the panicle, as the mass of 1,000 grains did not in fact change. A higher grain yield capacity of both sorghum hybrids in the treatments with the inter-row width of 35 cm was formed both due to a larger number of lateral panicles per area unit and to their higher graininess; the total biological grain yield capacity was the highest in the treatments with the inter-row width of 35 cm and a seed sowing rate of 220 thous. pcs/ha. By the years, on average, in the case of hybrids Svat and Flagg it was 5.96 and 7.46 t/ha, respectively. At the same time, according to the statistical analysis, it did not differ much from the treatment with a seed sowing rate 180 thous. pcs/ha. Based on this, it is inexpedient to increase a seed sowing rate to 220 thous. pcs/ha. Moreover, the research was carried out in favourable weather conditions which are rare for the area under study. And with moisture deficit, a seed sowing rate is to be set at a lower level of an optimal range, hybrid Flagg developed the highest panicle productivity of the main and lateral stem system. Grain mass from panicle of the main and lateral stems was 45.1 and 39.0 g, respectively, for hybrid Svat these indicators were 39.5 and 31.1 g. The higher productivity of sorghum panicles of hybrid Flagg was formed due to a much larger mass of 1,000 grains (by 35-40%), while the number of grains in the panicles of both stem systems was higher in sorghum hybrid Svat. Sorghum hybrid Flagg had a higher biological grain yield capacity of both stem systems – 5.87 t/ha as compared with that of early-ripening hybrid Svat which amounted to 4.75 t/ha. However, these hybrids are of a different morphotype, and they belong to different ripening groups. Svat is an early-ripening hybrid; having many advantages, it presents certain interest for the production.

REFERENCES

[1] Alekseev, Ya.V. (2021). Comparative characteristics of the productivity of grain sorghum depending on the feeding area in the conditions of the Northern Steppe of Ukraine. *Agrarian innovations*, 5, 7-11.

[2] Boiko, M.O. (2016). Justification of agrotechnical methods of growing grain sorghum in the conditions of Southern Ukraine. *Scientific Bulletin of NULES of Ukraine. Series "Agronomy"*, 235, 33-39.

[3] Dremlyuk, H.K., Hamadiy, V.L., & Hamadiy, I.V. (2013). Basic elements of sorghum cultivation technology. *Ukrainian Farmer's Guide*, 3, 274-277.

[4] Fedorchuk, M.I., Kokovikhin, S.V., & Kalenska, S.M. (2016). *Scientific and theoretical principles and practical aspects of the formation of ecologically safe technologies for growing and processing sorghum in the steppe zone of Ukraine*. Kherson: Boyarkin D.M.

[5] Gondal, M.R., Hussain, A., Yasin, S., Musa, M., & Rehman, H.S. (2017). Effect of seed rate and row spacing on grain yield of sorghum. *SAARS Journal of Agriculture*, 15(2), 81-91. doi: 10.3329/sja.v15i2.35154.

[6] Kalenska, S.M., Yeremenko, O.A., Taran, V.G., Krestyaninov, E.V., & Ryzhenko, A.S. (2017). Adaptability of field crops under variable growing conditions. *Scientific works of the Institute of Bioenergy Crops and Sugar Beet*, 25, 48-57.

[7] Kalenska, S.M., & Naidenko, V.M. (2018). The yield of grain sorghum is fallow depending on the width of the interrow and the fertilizer system. *Scientific Practices of the Institute of Bioenergy Crops and Sugar Beets*, 26, 67-75.

[8] Kalenska, S.M., & Naidenko, V.M. (2019). Economic assessment of the growth of grain sorghum hybrids in the minds of the Left-bank Forest-Steppe of Ukraine. *Scientific Reports of NULES of Ukraine*, 2(78), article number 11. doi: 10.31548/dopovidi2019.02.011.

[9] Klymovych, P.V., Sichkar, A.O., Kononenko, L.M., & Klymovych, N.M. (2011). The influence of seed sowing rate on the growth and development of grain sorghum. *Collection of scientific works of the Uman National University of Horticulture*, 75(1), 76-81.

[10] Kovalenko, A. (2014). Technology for sorghum. *Ukrainian Farmer*, 3(51), 72-74.

[11] Makarov, L.Kh. (2006). *Sorghum culture*. Kherson: Ailant.

[12] Mehmood, M., Ibrahim, M., Rashid, U., Nawaz, M., Ali, S., Hussain, A., & Gull, M. (2017). Biomass production for bioenergy using marginal lands. *Sustainable Production and Consumption*, 9, 3-21. doi: 10.1016/j.spc.2016.08.003.
[13] Mekasha, A., Min, D., Bascom, N., & Vipham, J. (2021). Seeding rate effects on forage productivity and nutritive value of sorghum. *Agronomy Journal*, 9, 1-15. doi: 10.1002/agj2.20856.
[14] Nosko, V.L., Boyko, I.E., Kamishanov, V.V., & Leshchuk, Yu.I. (2015). Prospects for the development of energy cultures in Ukraine. *Biological Systems: Theory and Innovations*, 214, 216-221.
[15] Ovsienko, I.A. (2015). Formation of sorghum grain productivity depending on agrotechnical measures. *Fodder and Fodder Production*, 1, 146-151.
[16] Polevyi, A.M., Bozhko, L.Yu., Volvach, O.V., & Barsukova, O.A. (2020). Agroecological conditions of formation of sorghum productivity in the southern regions of Ukraine under conditions of climate change. *Bulletin of the Poltava State Agrarian Academy*, 4, 61-68.
[17] Samoilenko, A., & Shevchenko, T. (2009). Sorghum cultivation technology. *Agroexpert*, 5, 14-16.
[18] Snider, J.L., Raper, R.L., & Schwab, E.B. (2012). The effect of row spacing and seed rate on biomass production and plant stand characteristics of non-irrigated photoperiodsensitive sorghum (*Sorghum bicolor* L. Moench). *Industrial Crops and Products*, 37, 527-535.
[19] Storozhik, L.I., & Muzyka, O.V. (2019). Peculiarities of molding the productivity of hybrids of sorghum fallow in the presence of agrotechnical factors: The width of the row, the density of planting and processing by the growth regulator. *Plant Varieties Studying and Protection*, 15(2), 171-181. doi: 10.21498/2518-1017.15.2.2019.173567.
[20] Svyrydova, L.A. (2017). The influence of the rate of seed sowing and the method of sowing on the variability of the biological yield of grain sorghum hybrids. *ScienceRise*, 9, 19-23.
[21] Yeschenko, V.O., Kopytko, P.G., Opryshko, V.P., & Kostogryz, P.V. (2005). *Basics of scientific research in agronomy*. Kyiv: Diya.

Елементи продуктивності рослин та біологічна врожайність зерна гібридів сорго зернового залежно від ширини міжрядь та норми висіву насіння

Станіслав Юрійович Давиденко[1], Артур Олександрович Рожков[1], Леся Михайлівна Карпук[2],Сергій Іванович Попов[3], Валентин Ігоревич Михайлин[4]

[1]Державний біотехнологічний університет
61002, вул. Алчевських, 44, м. Харків, Україна

[2]Білоцерківський національний аграрний університет
09110, пл. Соборна, 8/1., м. біла Церква, Україна

[3]Інститут рослинництва ім. В.Я. Юр'єва НААН
61000, вул. Героїв Харкова, 142, м. Харків, Україна

[4]Інститут овочівництва і баштанництва НААН
62478, вул. Інститутська, 1, с. Селекційне, Харківська обл., Україна

Анотація. Сорго є однією з найбільш важливих продовольчих, кормових та енергетичних культур в світі. Культура є стійкою до стресових чинників, особливо дефіциту вологи. Ця біологічна особливість дозволяє йому формувати високі та стабільні врожаї зерна в умовах дефіциту вологи і високої температури. Сорго зернове має значну перевагу за рядом фізіологічних, біологічних, врожайних ознак порівняно з іншими культурами, але посівні площі в Україні під ним залишаються обмеженими. Основною причиною цього є, насамперед, відсутність сортових технологій його вирощування з удосконаленими елементами. А тому вивчення комплексного впливу норми висіву насіння та ширини міжрядь на формування елементів продуктивності є наразі актуальним напрямом досліджень. Основною метою досліджень було вивчення впливу комплексу чинників: ширини міжрядь, норми висіву насіння на продуктивність та біологічну врожайність зерна. Дослідження проводили протягом 2019–2021 рр. на базі ФГ «Дюніс» Кремінського району Луганської області. Схема досліду: ширина міжрядь – 35, 45 і 70 см, гібриди – Сват і Флагг, норми висіву – 100 тис. шт./га, 140, 180 і 220 тис. шт./га. Гібрид сорго зернового Флагг сформував вищу продуктивність волоті головної і бічної систем стебел. Маса зерна з волоті головних і бічних стебел у нього становила 45,1 39,0 г відповідно, тоді як у гібрида Сват – 39,5 і 31,1 г. Вища продуктивність волотей гібриду Флагг формувалася за рахунок значно вищої маси 1000 зерен (на 35–40 %), при цьому кількість зерен у волоті обох систем стебел більшою була в гібриду сорго Сват. Біологічна врожайність зерна обох систем стебел вищою була також у гібриду сорго Флагг – 5,87 т/га, проти 4,75 т/га – у ранньостиглого гібрида Сват

Ключові слова: кількість волотей, головні стебла, бічні стебла, озерненість волоті, маса 1000 зерен, кореляційний зв'язок