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COMBINING ABILITY OF SELF-POLLINATED MAIZE LINES OF BSSS GERMPLASMA IN TERM OF GRAIN YIELD IN THE CONDITIONS OF THE NORTHERN STEPPE OF UKRAINE

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Topicality. *Development of modern hybrids adapted to different climatic conditions of the Northern Steppe of Ukraine, able to provide high and stable yields, requires expansion of the gene pool of mid-early self-pollinated maize lines of BSSS germplasm.* ***Purpose.*** *The research was aimed at determining the combining ability of self-pollinated lines of BSSS germplasm in relation to grain yield for their further implementation in breeding programmes.* ***Materials and Methods****. The combining ability of 25 maize lines was assessed by crossing with unrelated testers of alternative heterotic groups, followed by testing the progeny of the resulting test crosses for two plant densities. The reliability of the results and indicators of trait variability was determined by the mathematical and statistical method.* ***Results.*** *The parameters of combinational ability of the lines for grain yield were determined. The lines were classified into three classes according to the assessment of general combining ability (GCA) effects. The self-pollinated maize lines SDM95-30, SDM15, SDM2A, SDM96, MS2439, SDM73 and SDM84-35 with high values of combining ability effects for grain yield in both years of research and at different plant densities were identified and recommended for introduction into the further breeding process.* ***Conclusions.*** *Lines SDM15, SDM2A, SDM96, MC2439 and SDM84-35 are recommended for the development of high-yielding hybrids adapted to the conditions of the Northern Steppe of Ukraine in breeding programs.*

Key words*: maize, general combining ability, self-pollinated lines of maize, grain yield of testcrosses, plant density*

Introduction. The history of the selection of self-pollinated maize lines from the standard method to recurrent selection is a search for more efficient methods of synthesis of source material and selection of recombinants in the process of inbreeding [1]. The development of self-pollinated lines for their further use as parental forms of high-yielding maize hybrids is the main goal of breeding programmes. At the same time, much attention was paid to solving the problems of developing hybrids adapted to specific growing zones and climatic conditions [2].

Maize yields are increasing year on year, driven mainly by improved genetic qualities of hybrids, better agricultural practices and advances in biotechnology [3].

Positive results in the breeding of high-yielding hybrids are possible thanks to parental forms with high combining ability [4]. Evaluation of the combining ability of self-pollinated lines for grain productivity and grain yield determines the breeding suitability of lines [5, 6].

In maize breeding, the terms ‘general combining ability’ (GCA) and ‘specific combining ability’ (SCA) are commonly used to define the potential of lines. In modern breeding programmes, high values of GCA and SCA effects of lines determine the availability for their use in commercial hybrids [7].

Combining ability is the ability of a line or variety to provide heterosis in hybrid combinations for certain traits that differs from the population average. Higher-yielding hybrids are obtained by crossing lines with high combining ability, while lines with low combining ability produce offspring that are significantly less pro-

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A reliable method for evaluating the combining ability of self-pollinated lines is crossing them with testers and further testing the offspring [9].

Assessments of the GCA and SCA should be used with caution as they are only relevant to the specific lines included in a given set [1]. Lines tested with one tester set may have very different values for GCA and SCA with other testers [10].

Usually, the grain yield of hybrids determines the combining ability, as it is the most practically important trait [11]. Therefore, to obtain the necessary data on the combining ability of lines, the most reliable way is to cross with the following testing of hybrid offspring [12]

The research objective is to identify the best inbred lines of BSSS germplasm in terms of grain yield, which will be included in the breeding process to obtain hybrids adapted to the conditions of the Steppe of Ukraine with stable yields and tolerant to crop thickening.

Materials and Methods. In 2021–2022, the research was carried out in the breeding crop rotation of the Research and Production Farm "MAYS COMPANY", located in the Synelnykove district of the Dnipro region. Two plant densities were used as an additional background for the drought tolerance assessment: 50,000 and 70,000 plants/ha, which were formed in the 4–5 leaf stage. The grain yield of developed testcrosses was determined during harvesting with a Haldrup plot combine with simultaneous weighing of grain and determination of its moisture content. As a source material, 25 mid-early and mid-season self-pollinated maize lines of the BSSS genetic plasm, such as DK239 MV, DK3938, SDM95-10, SDM95-10A, SDM95-30, SDM95-30A, SDM125, SDM33, SDM51, SDM27A, SDM24A, SDM121, SDM121A, SDM15, SDM29A, SDM111-9A, SDM96, SDM2A, SDM46, MS2439, SDM77A, SDM73, SDM84-35, SDM103, SDM103A were used. The drought-resistant, cold-resistant hybrid DKS3939 (FAO 320) with high yield potential was used as a standard.

Results. The weather conditions of the growing season in 2021–2022 differed in terms of temperature and moisture availability. In particular, 2021 was favourable for the maize growth and development: the effective temperature sum was 1397 ºC and the precipitation during the growing season was 376 mm, while in 2022 it was characterised by a combination of high air temperature and minimum precipitation (effective temperature sum was 1526 ºC, precipitation was 143 mm).

The grain yield of testcrosses varied depending on the growing conditions (Table 1).

The contrasting weather conditions of the two years of research revealed the peculiarities of the grain yield trait in testcrosses developed

Table 1. Variation of the grain yield trait at different plant densities, t/ha, for 2021–2022

Indicator	2021		2022	
	50,000 plants/ha	70,000 plants/ha	50,000 plants/ha	70,000 plants/ha
$\bar{x} \pm t_{s(\bar{x})}$	7.61±0.62	7.91±0.70	4.50±0.61	4.32±0.68
V, %	0.68	0.52	0.66	0.72
Lim (min-max)	6.36–9.16	6.57–9.60	3.41–5.28	2.89–5.43
Number of variants	100	100	100	100

on the basis of self-pollinated maize lines of the BSSS genetic plasm. The trait was more stable at a plant density of 50,000 plants/ha. The minimum grain yield was 2.89 t/ha at a plant density of 70,000 plants/ha in 2022. In 2021, the grain yield trait of the testcrosses was almost equal at a plant densities of 50,000 and 70,000 plants/ha – 7.61 and 7.91 t/ha, respectively.

In our research, we determined the parameters of combining ability of the 25 lines of BSSS germplasm in terms of grain yield. Testcrosses developed by crossing them with testers (two related hybrids DK744MxMS361, DK365MxDC3751 and two lines DK315 and MS3472 of the Iodent plasm) were studied at two plant densities of 50,000 and 70,000 plants/ha. The lines were divided into three classes according to the general combining ability (GCA) effects. The first class included lines with GCA assessments that were significantly higher than the LSD_{05}; the second class included lines with GCA assessments that were within the least significant difference; and the third class included lines with GCA assessments that were significantly lower than the NIR_{05}.

The seven lines SDM95-30, SDM96, SDM2A, MS2439, SDM73, and SDM84-35 were characterised by significant and stable and high values of GCA effects at different plant densities in both years of research. The testcrosses based on these lines almost did not reduce the assessment of GCA effects by grain yield under deteriorating growing conditions.

In 2021, the lines SDM33, SDM27A, SDM96, and MS2439 were characterized by the highest assessments of combining ability at a plant density of 50,000 plants/ha (Table 2).

In both years of testing and at different

Table 2. Assessment of GCA effects of 25 lines of BSSS germplasm on the grain yield trait at different plant densities, t/ha for 2021–2022

Parental component	2021				2022			
	50,000 plants/ha		70,000 plants/ha		50,000 plants/ha		70,000 plants/ha	
	GCA effects of the lines	SCA variances of the lines	GCA effects of the lines	SCA variances of the lines	GCA effects of the lines	SCA variances of the lines	GCA effects of the lines	SCA variances of the lines
1	*2*	*3*	*4*	*5*	*6*	*7*	*8*	*9*
DK239MB (St)	-0.44 ^{3*}	0.61	-0.32 ^{3}	0.24	-0.37 ^{3}	0.32	-0.26 ^{2}	0.17
DK3938	-0.18 ^{2}	0.26	-0.09 ^{2}	0.20	-0.35 ^{3}	0.26	-0.37 ^{3}	0.68
SDM95-10	0.02 ^{2}	1.10	0.50 ^{1}	0.59	-0.09 ^{2}	0.10	0.12 ^{2}	0.13
SDM95-10A	-0.07 ^{2}	0.31	0.00 ^{2}	0.07	0.03 ^{2}	0.02	-0.23 ^{2}	0.06
SDM95-30	0.23 ^{2}	0.91	0.21 ^{1}	0.62	0.44 ^{1}	0.30	0.13 ^{2}	0.07
SDM95-30A	0.01 ^{2}	0.39	0.06 ^{2}	0.13	0.06 ^{2}	0.02	-0.18 ^{2}	0.07
SDM125	-0.26 ^{2}	0.15	-0.45 ^{3}	0.41	-0.03 ^{2}	0.19	-0.18 ^{2}	0.07
SDM33	0.48 ^{1}	0.58	0.20 ^{1}	0.14	0.12 ^{2}	0.18	-0.06 ^{2}	0.00
SDM51	0.17 ^{2}	0.07	0.20 ^{1}	0.11	0.05 ^{2}	0.11	-0.05 ^{2}	0.31
SDM27A	0.39 ^{1}	0.42	0.44 ^{1}	0.44	-0.22 ^{2}	0.12	-0.02 ^{2}	0.21
SDM24A	-0.57 ^{3}	0.80	-0.99 ^{3}	1.53	-0.01 ^{2}	0.18	-0.03 ^{2}	0.02
SDM121	-0.09 ^{2}	1.03	0.21 ^{1}	0.25	-0.15 ^{3}	0.44	0.08 ^{2}	0.37
SDM121A	0.10 ^{2}	0.18	0.12 ^{2}	0.21	-0.31 ^{3}	0.10	-0.03 ^{2}	0.14
SDM15	-0.04 ^{2}	0.02	0.21 ^{1}	0.32	0.06 ^{2}	0.09	0.19 ^{2}	0.54
SDM29A	0.30 ^{2}	0.33	0.22 ^{1}	0.30	-0.47 ^{3}	0.44	-0.17 ^{2}	0.09

Table 2 continuation

1	2	3	4	5	6	7	8	9
SDM111-9A	-0.13 ^{2}	0.14	-0.09 ^{3}	0.44	-0.15 ^{3}	0.26	-0.07 ^{2}	0.03
SDM96	0.33 ^{1}	0.24	0.19 ^{2}	0.10	0.26 ^{2}	0.07	0.22 ^{2}	0.22
SDM2A	0.01 ^{2}	0.15	0.16 ^{1}	0.39	0.04 ^{2}	0.00	0.03 ^{2}	0.12
SDM46	-0.21 ^{2}	0.07	-0.13 ^{2}	0.12	-0.05 ^{2}	0.31	-0.07 ^{2}	0.00
MS2439	0.50 ^{1}	0.42	0.21 ^{1}	0.06	0.07 ^{2}	0.07	0.06 ^{2}	0.05
SDM77A	-0.94 ^{3}	1.20	-0.88 ^{3}	1.08	0.18 ^{2}	0.23	0.23 ^{2}	0.03
SDM73	0.02 ^{2}	0.49	0.11 ^{2}	0.10	0.29 ^{2}	0.11	0.34 ^{1}	0.02
SDM84-35	0.24 ^{2}	0.27	0.62 ^{1}	0.59	0.12 ^{2}	0.12	0.17 ^{2}	0.12
SDM103	0.18 ^{2}	0.45	-0.36 ^{3}	0.38	0.15 ^{2}	0.08	0.20 ^{2}	0.07
SDM103A	-0.06 ^{2}	0.33	-0.32 ^{3}	0.17	0.35 ^{1}	0.29	0.40 ^{1}	0.41
Average	0.00	0.44	0.00	0.38	0.00	0.18	0.00	0.16
LSD_{05} GCA testers	0.32		0.15		0.30		0.30	

*Note: * – GCA effect assessment class.*

plant densities, the testcrosses based on these parental components had mostly consistent high values of the GCA effects, especially the line SDM96.

In 2021, the highest assessments of GCA effects were observed in the lines SDM96, SDM27A, SDM33 and MS2439 (0.33, 0.39, 0.48 and 0.50 t/ha, respectively) at the optimal plant density (50,000 plants/ha). Only testcrosses based on the standard line DK239 MV, as well as lines SDM24A and SDM77A had significantly lower assessments of the GCA effects compared to their average in this ecogradient. At thickening up to 70,000 plants/ha, the assessments of GCA effects in terms of grain yield were significantly higher than the average of eleven lines.

In 2022, all lines were characterised by low values of GCA effects at the optimal density of 50,000 plants/ha, except for SDM103A and SDM95-30, which showed higher than average values. At the same time, the assessments of GCA effects in six lines were significantly lower than the average in the experiment, including DK239 MV and SDM121, SDM111-9A, SDM121A, DK3938 and SDM29A (respectively -0.37, -0.15, -0.15, -0.31, -0.35 and -0.47 t/ha). At a plant density of 70,000 plants/ha, the values of GCA effects in the lines SDM73 and SDM103A were significantly higher (0.34 and 0.40 t/ha, respectively). In general, the growing conditions in 2022 had a negative impact on the grain yield of the studied lines and testcrosses.

The self-pollinated maize lines SDM95-30, SDM15, SDM2A, SDM96, MS2439, SDM73 and SDM84-35 with high values of assessments of combining ability effects in terms of yield in both years of research at different plant densities were identified.

Conclusions

The following conclusions can be drawn on the basis of our research:

1. The study has shown that self-pollinated maize lines SDM95-30, SDM15, SDM2A, SDM96, MS2439, SDM73 and SDM84-35 are promising for further breeding process because they have high values of combining ability effects in terms of grain yield in both years of research and at different plant densities..

2. The lines SDM15, SDM2A, SDM96, MS2439 and SDM84-35 are recommended for breeding programmes to develop high-yielding hybrids adapted to the conditions of the Northern Steppe of Ukraine. They will increase the efficiency of breeding work and produce more productive maize hybrids.

3. The contrasting weather conditions of the two years of research contributed to the identification of the peculiarities of the grain yield trait of testcrosses based on self-pollinated maize lines of the BSSS genetic plasm under different growing conditions. This emphasises the importance of climate factors in the breeding of new hybrids.

4. Lines with high values of combining ability effects were stable under different growing conditions, which indicate their potential for using them in breeding programmes. In particular, the line SDM96 showed the highest stability in terms of grain yield.

5. Assessment methods for combining ability of self-pollinated maize lines by crossing

them with unrelated testers and further testing of the progeny proved to be effective in determining the breeding suitability of the lines. This confirms the need to use similar methods in further research.

6. The study showed that plant density has a significant impact on grain yield. Thus, the highest yields were achieved at a plant density of 50,000 plants/ha, which emphasises the importance of optimising agronomic practices to maximise yields.

7. Considering the study results, we recommend that breeders include self-pollinated lines SDM95-30, SDM15, SDM2A, SDM96, MS2439, SDM73 and SDM84-35 in their breeding programmes to develop new high-yielding maize hybrids adapted to different growing conditions.

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[1]Дзюбецький Б. В., [2]Пазюк Н. В. Комбінаційна здатність самозапильних ліній кукурудзи зародкової плазми BSSS стосовно врожайності зерна в умовах Північного Степу України.

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Актуальність роботи полягає у необхідності розширення генофонду середньоранніх самозапилених ліній кукурудзи зародкової плазми BSSS для створення сучасних гібридів, адаптованих до різних кліматичних умов Північного Степу України, здатних забезпечувати високий і стабільний рівень урожайності. **Метою** досліджень було визначення комбінаційної здатності самозапилених ліній зародкової плазми BSSS стосовно показника врожайності зерна для подальшого включення їх в селекційні програми. **Матеріали і методи**. Оцінку комбінаційної здатності 25 ліній кукурудзи проводили методом схрещування із неспорідненими тестерами альтернативних гетерозисних груп з подальшим випробуванням потомства отриманих тесткросів за двох густот стояння рослин. Визначення достовірності результатів та показників варіабельності ознак проводили математично-статистичним методом. **Результати**. Визначено параметри комбінаційної здатності ліній за ознакою врожайність зерна. Вони були розділені на три класи згідно з оцінками ефектів загальної комбінаційної здатності (ЗКЗ). Виділено самозапилені лінії кукурудзи СДМ95-30, СДМ15, СДМ2А, СДМ96, МС2439, СДМ73 і СДМ84-35, які мали високі значення ефектів комбінаційної здатності за врожайністю зерна в обидва роки досліджень і за різної густоти стояння та рекомендовані до включення їх у подальший селекційний процес. **Висновки**. Лінії СДМ15, СДМ2А, СДМ96, МС2439 і СДМ84-35 рекомендовано використовувати в селекційних програмах при створенні високопродуктивних гібридів, адаптованих до умов Північного Степу України.

Ключові слова: *кукурудза, загальна комбінаційна здатність, самозапилені лінії кукурудзи, врожайність зерна тесткросів, густота стояння рослин*