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RESEARCH OF COMBINING ABILITY OF MID-EARLY MAIZE LINES

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In 2016–2018, the promising maize lines (FAO 290–399) of the Golden West Seed Bulgaria Ltd. breeding company, containing more than 50 % of the plasm of the Iodent heterotic group and 6 testers, mainly of the Lancaster group, were evaluated. It was established that the lines GW59024 and GWC06021 (Iodent heterotic group) are the most suitable as recurrent parents in new breeding programs for intensive and drought tolerant hybrids. Among the testers of the Lancaster heterotic group, the most interesting were GW59008, which showed the highest general combining ability in favorable years for maize development, and GW57010, which had a very high general combining ability in all three years of research.

Keywords*: maize; lines and hybrids; combining ability on grain yield*

Introduction. Maize yield is one of the most polygenic traits that depends on the environmental conditions. Maize grain yield in the USA, however, was increased from 1.3 t/ha (in 1939) to 7.8 t/ha (in 2005). This means an improvement of about 99 kg/ha per year. Similar results were observed in Canada for the same period – about 80 kg/ha per year [1]. In the Corn Belt of the United States until the 1930s, an increase in yield of open-pollinated maize varieties was not practically observed [2, 3]. During 1930–1955, production based on hybrid maize provided an increase in grain yield at the level of 57 kg/ha per year. For the period 1955–1982, this progress was even higher in the USA – 144 kg/ha per year. This progress has been achieved both by breeding new, more productive hybrids and by applying agricultural practices, with the ratio between the two categories being about 50/50 [4, 5]. One of the main reasons for such an improvement was the modern breeding methods of single-cross hybrids.

Modern breeding of commercial maize hybrids is mainly based on recurrent breeding by prongey. For this purpose, lines with high indicators of improved traits are used for further cyclical breeding programs and selection of donor material according to the required number of traits [6]. Therefore, the success of breeding depends on the duration of the breeding cycle and a sufficient selection of regenerants, which leads to the use of winter nursery, significant amounts of work and quality breeding material, which are constantly in the focus of breeders.

Material and Methods. The source material was 6 maize lines (FAO 290–399) of Golden West Seed Bulgaria Ltd. breeding, related to the Iodent genoplasm (GW59024, GW58005, GW57091, GWC06021, GW58268, GW59005), which were balanced for the main economically valuable traits.

To evaluate the material for combining ability on grain yield, the lines were crossed with 6 testers of alternative Lancaster genoplasm (GW58008, GW57010, GW57095, GW51150, GW58012, GW52090). The testcrosses of the lines were tested in the control nursery during 2016–2018 in the experimental field of Golden West Seed Bulgaria Ltd, which is located in the Brashlen village, Ruse region, Bulgaria at an altitude of 26.5 m above sea level. The soil is highly leached chernozem of medium strength, characterized by a dark brown, loose, crumbly humus layer of 60–100 cm [7].

The experiments were conducted in single-crop field according to the methodology adopted by the company for non-irrigated areas, in four replications. Ammonium nitrate was applied as a fertilizer at a dose of 100 kg a.i./ha, Dual-Gold pre-emergence herbicide was applied after sowing and Ekip post-emergence herbicide – during the growing season in doses recommended for the crop.

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The standard method based on inbreeding was used to create the lines. Processing and systematization of data, mathematical calculations were carried out using Microsoft Excel 2010.

The estimation of combining ability parameters in the topcross system was carried out according to the methodological recommendations of Volef et al. [8]. The general model of analysis of variance is as follows:

xijR =μ+ gi+g j +si j +eijR, *where:*
xijR – yield of hybrids (i x j); R – number of replications; μ – average yield in the field trial; g_i–g_j – general combining ability (GCA) of line and tester; s_{ij} – specific combining ability (SCA) effect of the ij^{th} crosses; e_{ijR} – random error term for ijR^{th} observation.

The purpose of the research was to evaluate promising maize lines (FAO 290–390) bred by Golden West Seed Bulgaria Ltd. for combining ability on grain yield trait in order to use them in the breeding new lines of the next cycles.

Results and Discussion. The variability of the experimental conditions allows to evaluate tolerance of maize hybrids to different stress levels (Table 1). A high coefficient of variation was observed in 2018 (V = 27.16 %), when the grain yield was the lowest (4.22 t/ha), and low (V = 13.32 %) in 2016, the average yield was 9.74 t/ha. The largest range of variation in the trait "grain yield" of hybrids was found in 2017 – 13.72 t/ha, and in 2016 and 2018, it was at the level of 6.23 t/ha and 5.25 t/ha, respectively. Thus, the studied years can be conditionally divided into differentiating (2018), stabilizing (2017) and leveling (2016), which is a good prerequisite for a full assessment of maize hybrids. According the general experimental error, there are significant differences in grain yield between the hybrids, since the null hypothesis is rejected in all years of research and the influence of the genotype on the resulting trait (F fact ≥ F tab.). The relevant data allow to make calculations for the analysis of the components of combining ability for grain yield.

Table 1. Variation parameters for grain yield of maize hybrids testcrosses, t/ha

Parameters		2016	2017	2018
Average grain yield		9.74	14.02	4.22
Lim	min	5.42	8.24	1.62
	max	11.65	21.96	6.87
Coefficient of variation, %		13.32	19.13	27.16
Statistical error		0.21	0.44	0.19

The data of the three-year research indicate that there are statistically significant differences in both GCA and SCA of maternal and paternal lines. At the same time, these differences are proven even at the $F_{0.01}$ level.

The analysis of combining ability of the Iodent group lines on grain yield in the experiments showed that the GW58268 line was characterized by stable positive estimates of the GCA effects for all three years of research, and the GW57091 line, on the contrary, by negative GCA effects (Table 2). Indicators of the GCA effects of other lines were unstable.

In 2016 and 2017, the lines of the Iodent heterotic group – GW59024 and GW58268 – showed the highest GCA, and GWC06021 and GW57091 – the lowest. However, GCA effects for years with sufficient moisture supply of maize show more stable values. However, if the line GW59024 had positive GCA in the first two years of research and negative in stressful conditions in 2018, GW59005 showed the lowest GCA in the most favorable and stressful years, and the average in the year with average grain yields – 2017. The line GWC06021, which in other years had negative values of GCA with a positive vector of its growth under deteriorated conditions for the formation of the yield, stood out with the highest assessment of GCA in stressful 2018. Thus, in

Table 2. GCA effects and SCA variances on grain yield of Iodent group lines, t/ha

Line	2016		2017		2018	
	GCA effects	SCA variances	GCA effects	SCA variances	GCA effects	SCA variances
GW59024	0.67	1.08	2.98	0.59	- 0.52	0.10
GW58005	- 0.76	0.90	0.08	1.83	0.24	0.48
GW57091	- 0.07	0.34	- 2.99	1.22	- 0.01	0.46
GWC06021	- 0.22	1.18	- 1.35	0.68	0.87	0.50
GW58268	0.31	0.72	2.05	4.92	0.16	0.96
GW59005	0.07	1.68	- 0.77	2.98	- 0.74	0.34
$LSD_{0.05}$	0.08		0.12		0.10	

years with stressful weather conditions, drought tolerance had a significant impact on the manifestation of GCA for the lines of the Iodent heterotic group.

In 2018, the GWC06021 and GW58005 lines had the highest GCA. The specific combinations of these lines can provide hybrids with drought tolerance, especially in extremely arid conditions. In 2017, a high variance of SCA was detected, which indicates the presence of specific combinations with high grain yield. The highest it was demonstrated by the line GW58268 and together with the high GCA we can expect the high-intensive combination. It should be noted that in 2018, GW58268 line was characterized by the highest SCA variance. GW59005 line had high variance but low GCA effects, which makes it less valuable.

Table 3 shows the results of the assessment for the combining ability of the Lancaster group testers.

In 2016, the GW58008 and GW52090 lines showed the highest GCA effects. In 2017, GW58008 line also had the highest GCA effects, while GW52090 had the lowest ones, but in the dry 2018, it also had the best result, which indicates its stress tolerance. Over the three years of the study, the GW57010 line was characterized by consistently the lowest GCA effects, which may be due to its ability to form the lowest grain moisture content at harvesting. However, over the three years of the research, GW57010 line showed the highest SCA variance among the Lancaster heterotic group testers involved in the trial, which indicates the presence of highly heterotic combinations with specific combining ability. This line can be recommended for programs to develop genotypes with low grain moisture content at harvesting using the specific hybrid model [9]. It should be noted that the weather conditions had less influence on the manifestation of the GCA effects of the Lancaster testers than in the lines of the Iodent heterotic group.

Table 3. GCA effects and SCA variances for grain yield of tester lines of Lancaster group, t/ha

Tester	2016		2017		2018	
	GCA effects	SCA variances	GCA effects	SCA variances	GCA effects	SCA variances
GW58008	0.53	0.58	2.01	5.54	- 0.08	0.10
GW57010	- 1.37	2.47	- 1.08	1.91	- 1.49	0.87
GW57095	- 0.41	0.82	0.51	1.08	0.14	0.02
GW51150	0.30	1.10	0.52	2.29	0.08	0.51
GW58012	0.13	0.75	- 1.08	0.35	0.33	0.83
GW52090	0.82	0.18	- 0.89	1.04	1.02	0.51
$LSD_{0.05}$	0.08		0.12		0.10	

Conclusions.

1. The weather conditions of the year have a greater influence on the manifestation of GCA effects of the Iodent group lines than on GCA

effects of the Lancaster group testers.

2. GW59024 line is the most suitable for breeding as recurrent parents for new breeding programs of Iodent group maize on high grain yield in intensive conditions. It showed quite consistently high GCA effects of the years with sufficient moisture supply, and GWC06021 line had high GCA effects in the stressful 2018, that shows its drought tolerance.

3. Among the maize testers of the Lancaster heterotic group, the GW59008 line had the highest GCA in the years favorable for maize development, and the GW57010 line was characterized by consistently low GCA but high SCA variants during all three years of the research that indicates the presence of specific heterotic combinations.

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У 2016–2018 рр. проведено оцінку перспективних ліній кукурудзи (ФАО 290–399) селекційної компанії Golden West Seed Bulgaria Ltd., що містять понад 50 % плазми гетерозисної групи Iodent та 6 тестерів, переважно групи Lancaster. Встановлено, що лінії GW59024 та GWC06021 (гетерозисна група Iodent) є найбільш придатними в якості рекурентних батьків у нових програмах селекції інтенсивних та посухостійких гібридів. Серед тестерів гетерозисної групи Ланкастер найбільш цікавими виявилися GW59008, який показав найвищу загальну комбінаційну здатність у сприятливі для розвитку кукурудзи роки, та GW57010, який мав дуже високу загальну комбінаційну здатність у всі три роки досліджень.