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Study of heritability estimates and their genetic variability for yield traits and its components in yellow maize (*Zea mays* L.)

Yasser Hamad Humada [1], Raeed Mejbel Abdullah [2] and Farhan Khaleel Hussein [3, *]

[1] *Department of Biology, College of science, University of Kirkuk, Iraq.*
[2] *College of Health and Medical Techniques, Northern Technical University, Kirkuk, Kirkuk, Iraq.*
[3] *Department of Biology, College of Education for Pure Sciences, University of Kirkuk, Iraq.*

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Abstract

The experiment was conducted in one of the farmers' fields affiliated with the Kirkuk Irrigation Project for the agricultural season (2022-2023). Ten genetic materials (Gimbson , Saganto,DK6050, Agr-183, ZM47W, CML494, IK58, ZP505, ZP670, ZP197) of yellow maize (*Zea mays L.*) were used in this study. These materials were involved in diallel crosses and were planted in a farmer's field in Kirkuk province using a Randomized Complete Block Design (RCBD) with three replications. Data were recorded for traits such as number of ears per plant, ear length, ear diameter, number of rows per ear, number of kernels per row, number of kernels per ear, 300-kernel weight, and individual plant yield. The results showed that the general combining ability variance components were more significant than one for all the studied traits. There were significant effects of general combining ability in the desired direction for parent (8) for all studied traits. Meanwhile, significant effects of specific combining ability in the desired direction were observed in the crosses (1×3), (1×8), (1×10), (2×5), (2×6), (7×10), and (9×10) for most of the traits. These crosses can be utilized to select individuals who combine the desired traits in segregating generations.

Keywords: Heritability; *Zea mays L*; Agricultural season; Kirkuk Irrigation Project

1. Introduction

Yellow maize (Zea mays L.) is considered one of the important cereal crops in many countries around the world, including Iraq. Globally, yellow maize ranks second after wheat in terms of cultivated area and first in terms of production [1] and [2]. The world production of maize during the 2019 season reached 1.077 billion tons, with the United States leading global maize production, producing a total of 370.096 million tons, followed by China with 259.007 million tons, Brazil with 82 million tons, the European Union with 62.010 million tons, Argentina with 32 million tons, and Ukraine with 24.012 million tons, Meanwhile, the area planted with maize in Iraq during 2020 for both spring and autumn seasons reached approximately 405,400 hectares, with a total production of 419,300 tons [3] and [4].

The economic importance of yellow maize lies in its high content of carbohydrates (81%), protein (10.6%), oil (4.6%), and ash (2%) [5] and [6], with the ash containing essential minerals such as calcium, magnesium, phosphorus, aluminium, sodium, potassium, and chlorine [7]. Additionally, maize kernels contain vitamins B1, B2, and E. Maize ranks third after wheat and rice in planted areas and productivity [8] and [9]. Yellow maize also has medicinal benefits; for instance, maize oil helps raise beneficial cholesterol levels and reduce harmful cholesterol, making it a recommended treatment for heart patients to prevent heart attacks and artery blockages. [10] Moreover, [11] It also helps lower blood sugar levels, in addition to other medical uses [12] and [13].

* Corresponding author: Farhan Khaleel Hussein

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Hybridization is one of the essential techniques used to develop hybrids tested to select the superior ones with traits suitable for prevailing environmental conditions [14] and [15]. Hybridization offers significant genetic diversity and provides the opportunity to select suitable genetic materials, either by utilizing the hybrid vigour phenomenon to produce new hybrids or by forming new genetic combinations [16] and [17]; this technique requires testing the general combining ability of the parental lines and then testing the specific combining ability of the resulting hybrids [18] and [19]. The production of hybrids begins with obtaining pure lines through inbreeding [20] and [21], followed by evaluating the performance of the hybrids to assess the combining ability of the parental lines [22] and [23]. Using various statistical and genetic methods, maize breeders can estimate several genetic parameters to understand the genetic behaviour of critical economic traits that play a significant role in breeding programs [24] and [25].

To achieve this goal, a suitable breeding program is necessary for its improvement [26]; steps to help achieve these goals include selecting a group of genetically diverse pure lines to form a broad genetic base[27] and [28], which can then be used in various breeding systems to obtain useful genetic information in the first generation, such as identifying genetic behaviour and combining ability[29] and [30]. This study aims to achieve the following objectives: to use Griffing's method (1956)[31] to estimate the general combining ability of the parents and the specific combining ability of the hybrids according to each mating system in order to identify the best parents and hybrids for continued use in breeding programs for yellow maize improvement[32].

2. Materials and Methods

This study used ten purebred lines of yellow maize (details in Table 1). The lines were introduced into a diallel-crossing program based on the second method of Griffing (1956)[33] during the 2020 autumn season. A total of 45 individual hybrids were obtained. The land was prepared by performing two perpendicular ploughing operations, then smoothing, levelling, and dividing the field as needed. Superphosphate (P_2O_5) fertilizer was applied at a rate of 200 kg/ha as a source of phosphorus during the first ploughing. Nitrogen fertilizer was applied at 400 kg/ha using urea (46% active nitrogen) in two splits: the first at planting and the second 30 days after planting [34]. Corn stalk borer (Sesamia cretica) was controlled using granular diazinon pesticide at a 10% concentration, applied locally twice during each season: the first application 20-25 days after planting and the second two weeks after the first. The experiment was irrigated as needed, and weeds were controlled manually throughout the seasons.

Table 1 Strains used in the study and their source

No. of strain	Strain name	Source	Source to obtain it
1	Gimbson	Italian	College of Agriculture - University of Mosul(UOM)
2	Saganto	Turkish	College of Agriculture - University of Duhok (UOD)
3	DK 6050	Turkish	College of Agriculture - University of Duhok (UOD)
4	Agr-183	Locally	College of Agriculture - University of Duhok (UOD)
5	ZM47W	American	College of Agriculture - University of Mosul(UOM)
6	CML494	Mexican	College of Agriculture - University of Mosul(UOM)
7	IK58	Hungarian	College of Agriculture - University of Duhok (UOD)
8	ZP505	Yugoslavia	College of Agriculture - University of Duhok (UOD)
9	ZP670	Yugoslavia	College of Agriculture - University of Duhok (UOD)
10	ZP197	Yugoslavia	College of Agriculture - University of Duhok (UOD)

2.1. The Hybridization Program and Comparison Method

Autumn Season (2022). The seeds of the ten purebred lines were planted in the experimental field, where all soil management operations were carried out. The planting was done on three different dates, spaced seven days apart, starting from July 1st, to ensure flowering synchronization and maintain high pollen viability during the hybridization period. Each line was planted in two rows, each 4 meters long, with a distance of 0.75 meters between the rows and 0.25 meters between the plants. Two seeds were placed in each hole and later thinned to one plant. During the flowering stage of the lines, all half-diallel crosses were performed ($N = P(p-1)/2$) to obtain 21 individual hybrids, according to the second method of Griffing (1956). Pollination was controlled by bagging male and female inflorescences as described by [35]. Self-pollination was also carried out for the pure lines to preserve their genetic purity and to multiply their seeds. At the end of the season, when the plants reached full maturity, the hybrid ears and self-pollinated parent ears were harvested separately for each line. The ears were husked, threshed, and dried for planting in the second season.

Spring Season (2023): Seeds of the parents and individual hybrids (10 pure lines + 45 individual hybrids) were planted on three different dates. The first planting was on March 15th, the second one week after the first, and the third one week after the second to ensure flowering synchronization and the continued availability of high-viability pollen during the hybridization period. Two rows were planted for each genetic material (pure line + individual hybrid), each 4 meters long, with a spacing of 0.75 meters between rows and 0.25 meters between holes. Two seeds were placed in each hole and later thinned to one plant. All soil and crop management operations were outlined for the previous season.

2.2. Genetic Statistical Analysis

The data collected from the ten purebred lines and their diallel hybrids (excluding reciprocal hybrids) were analyzed according to the second random model (Random Model) proposed by Griffing (1956)[8], as described by [10]. The number of genetic materials under study was calculated as n(n+1)/2, equaling 55 genetic combinations. General combining ability (GCA) and specific combining ability (SCA) were studied according to the second random model (Random Model) proposed by Griffing (1956)[8]. The random model was used because the genetic materials in the study were considered not as a fixed sample but as a random sample from a population. Consequently, the environmental effects on the genetic materials were treated as random, and the effects of general combining ability (GCA) and specific combining ability (SCA) were estimated. The effects were tested, and the variances of the general and specific combining ability effects for each parent were estimated.

$$\sigma^2{}_{si}$$

$$\sigma^2_{gi} = \left(\hat{gi}\right)^2 - \frac{r(n-1)}{n(n+2)}\hat{\sigma}^2_e$$

$$S.E(\hat{gi}) = \sqrt{\frac{(n-1)\sigma^2 e}{n(n+2)}}$$

$$\sigma^2_{si} = \sum S\hat{i}^2 j - \frac{rn(n-1)}{(n+1)(n+2)}\hat{\sigma}^2_e$$

$$S.E(\widehat{sij}) = \sqrt{\frac{n(n-1)\sigma^2 e}{(n+1)(n+2)}}$$

3. Results and Discussion

It can be observed from the results in Table (2) regarding the general combining ability (GCA) and specific combining ability (SCA) that the ratio of the variance components attributed to GCA to the variance components attributed to SCA was more significant than one for all the studied traits. This indicates the importance of additive genetic effects. This result is consistent with [36] and [37] findings. This result makes it clear that these traits can be improved through a recurrent selection program. If there are traits with a ratio of less than one, they can be improved by producing hybrids and benefiting from hybrid vigour for commercial production [38].

Table 2 Analysis of GCA and SCA for the studied traits according to the first method of the random model (Griffing, 1956)

Variances	Number of corns/Plant	Corn Length	corn Diameter	Number of Rows/corn	Number of grains/Row	Number of grains/corn	Weight of 300 grains	Single Plant Yield
$\sigma^2_{G.C.A}$	**0.164	**11.758	**5.873	**10.688	**20.264	**9542.666	**187.628	**484.730
$\sigma^2_{S.C.A}$	**0.014	**0.767	**0.230	**0.630	**3.955	**920.598	**20.220	**139.277
σ^2_E	0.009	0.491	0.180	0.425	0.437	411.727	14.378	58.167
$\sigma^2_{G.C.A}$ / $\sigma^2_{S.C.A}$	11.714	15.329	25.534	16.965	5.123	10.365	9.279	3.480

3.1. Effects of General Combining Ability (GCA) of the Parents

The ignificance of the general combining ability indicates the importance of additive genetic variance in the inheritance of the studied traits. The effects of the general combining ability for each parent were estimated to evaluate the genetic performance of the parents, as shown in Table (3). The general combining ability effect for the trait "number of ears per plant" was observed to be significantly positive and in the desired direction for parent (8), with a value of 0.322. For the trait "ear length," the effect was significant and in the desired direction for parent (8), with a value of 2.728. For the trait "ear diameter," the effect was significant for parent (8), with a value of 1.986, respectively. For the trait "number of rows per ear," the effect was significant and in the desired direction for parent (8), with a value of 2.528. For the trait "several kernels per row," the effect was significant and in the desired direction for parents (4), (5), (8), and (9), with value of 0.395, 0.559, 2.836, and 0.289, respectively. For the trait "number of kernels per ear," the effect was significant and in the desired direction for parent (8), with a value of 74.107. For the trait "300-kernel weight," the effect was significant and in the desired direction for parent (8), with a value of 10.890. For the trait "individual plant yield," the effect was significant and in the desired direction for parent (8), with a value of 15.855.

In light of the above results, it is noted that parent (8) showed a significant general combining ability effect in the desired direction for all traits. Additionally, parents (4), (5), and (9) had a significant effect on the general combining ability in the desired direction for the trait "number of kernels per row" only.

Table 3 Estimates of general combining ability effects for each parent (genetic structures) for the studied traits

Parents	Number of corn/Plant	corn Length	Corn Diameter	Number of Rows/corn	Number of grains/Row	Number of grains/corn	Weight of 300 grains	Single Plant Yield
1	0.000	-0.500	-0.199	-0.402	-0.687	-5.212	-0.083	1.241
2	-0.084	-0.752	-0.150	-1.054	-2.330	-36.768	-3.652	-5.999
3	-0.067	-0.186	-0.276	-0.009	-0.664	-9.122	-0.494	0.252
4	0.016	-0.013	-0.137	-0.062	0.395	4.071	-0.741	0.146
5	-0.035	-0.019	-0.280	-0.109	0.559	-2.118	-1.495	-2.431
6	-0.033	-0.366	-0.244	0.058	-0.097	-7.818	-1.755	-7.578
7	-0.042	-0.146	-0.249	-0.214	0.170	-2.555	-0.740	-2.816
8	0.322	2.728	1.986	2.528	2.836	74.107	10.890	15.855
9	-0.023	-0.155	-0.232	-0.286	0.289	-5.321	-1.333	1.761
10	-0.054	-0.590	-0.219	-0.451	-0.471	-9.263	-0.595	-0.432
$S.E(\hat{gi})$	0.025	0.191	0.116	0.178	0.181	5.55	1.03	2.08

3.2. Specific Combining Ability for Each Hybrid of the Half Diallel Hybrids

Table (4) shows the estimates of specific combining ability effects for each hybrid and the studied traits. It is observed that the specific combining ability effect for the trait "number of ears/plant" was positive and significant in the desired direction for hybrids (1×3), (1×4), (1×8), (2×4), (2×8), (2×9), (3×7), (3×8), (4×5), (4×8), (6×8), (5×8), and (6×8), ranging from (0.238) in hybrid (2×9) to (0.092) in hybrid (1×4).

The specific combining ability effect for the trait "ear length" was also positive, significant, and desirable for the following hybrids: (1×3), (1×4), (1×5), (1×8), (2×4), (2×5), (2×6), (2×8), (2×9), (3×8), (3×9), (3×10), (4×5), (7×8), (7×10), and (9×10), ranging from (1.629) in hybrid (2×5) to (0.588) in hybrid (3×9).

The specific combining ability effect for the trait "ear diameter" was positive and significant in the desired direction for the following hybrids: (1×8), (2×3), (2×8), (3×8), (8×9), and (8×10), ranging from (1.077) in hybrid (4×8) to (0.560) in hybrid (8×9).

The specific combining ability effect for the trait "number of rows/ear" was positive, significant, and desirable for the following hybrids: (1×8), (2×4), (2×5), (2×6), (2×8), (3×5), (3×6), (6×8), (7×9), and (9×10), ranging from (1.405) in hybrid (2×5) to (0.593) in hybrid (3×5).

The hybrids for the trait "number of kernels/row" exhibited desirable and significant specific combining ability effects, which were (1×3), (1×4), (1×6), (1×8), (1×9), (1×10), (2×4), (2×5), (2×6), (2×7), (2×8), (2×9), (2×10), (3×8), (3×9), (3×10), (4×8), (6×7), and (7×10), ranging from (3.753) in hybrid (2×5) to (0.547) in hybrid (1×9).

The specific combining ability effects for the trait "number of kernels/ear" were positive and significant for hybrids (1×3), (1×8), (1×10), (2×5), (2×6), (2×7), (2×8), (2×9), (2×10), (4×6), (6×8), (7×9), (7×10), (8×9), and (8×10), ranging from (3.25) in hybrid (7×10) to (16.907) in hybrid (8×10).

The specific combining ability effects for the trait "number of pods/plant" were in the desired direction and significant for hybrids (1×3), (1×4), (2×8), (2×10), (3×8), (3×9), (4×8), and (7×10), ranging from (14.690) in hybrid (7×10) to (3.153) in hybrid (1×4).

It is observed that the specific combining ability effect for the trait "number of seeds/pod" was significant and positive in the desired direction for hybrids (1×4), (1×10), (2×6), (3×6), (4×7), (7×10), and (9×10), ranging from (43.256) in hybrid (7×10) to (6.314) in hybrid (2×6). These results align with the findings of [14], [15], [12],[16] ,[17]and [18] .

Table 4 Present the estimate of the specific combining ability effect for each individual hybrid in the hal- diallel crosses for the studied traits

traits / **Hybrids**	**Number of corn/Plant**	**corn Length**	**corn Diameter**	**Number of Rows/corn**	**Number of Grains/Row**	**Number of Grains/corn**	**Weight of 300 Grains**	**Individual Plant Yield**
2×1	-0.241	-1.668	-0.075	-2.280	-5.589	-68.293	-0.123	1.577
3×1	0.106	0.855	-0.089	0.108	2.222	22.174	4.985	-4.596
4×1	0.092	0.704	0.082	-0.094	1.286	-3.812	3.153	11.827
5×1	-0.064	0.810	0.095	0.264	0.098	-5.315	0.953	1.336
6×1	-0.053	0.291	0.130	-0.236	0.977	-21.216	-3.300	-1.135
7×1	-0.085	-0.274	-0.178	-0.330	0.133	-28.367	-0.555	-14.266
8×1	0.134	0.838	0.713	0.916	0.730	31.889	1.940	11.766
9×1	-0.041	-0.442	-0.183	-0.470	0.547	7.522	-5.073	-14.201
10×1	0.070	0.414	-0.091	0.651	1.240	27.697	1.551	8.230
3×2	-0.035	-1.748	-0.014	-1.562	-5.557	-59.093	1.359	0.077

4×2	0.133	0.846	-0.157	1.058	2.429	5.518	0.681	-4.515
5×2	0.031	1.629	-0.022	1.405	3.753	23.780	2.700	4.340
6×2	0.031	1.221	-0.012	0.705	3.209	31.420	1.480	6.314
7×2	0.011	0.490	-0.062	0.510	1.121	20.161	-1.518	-9.568
8×2	0.229	1.549	0.599	1.268	2.921	52.556	5.364	1.703
9×2	0.238	0.888	0.052	-0.018	2.612	17.248	2.127	3.212
10×2	0.029	0.266	0.009	0.458	2.017	45.025	5.971	5.790
4×3	-0.102	-0.721	0.002	-0.998	-0.104	-32.835	-6.864	-26.544
5×3	-0.013	-0.648	0.115	0.593	-1.080	0.505	-1.772	-7.695
6×3	-0.010	-0.057	0.187	0.993	-1.480	13.286	2.095	7.160
7×3	0.150	-0.188	0.041	-0.202	0.009	-6.958	-1.519	-2.899
8×3	0.167	0.827	0.735	0.500	1.154	3.684	5.354	9.752
9×3	0.071	0.588	-0.106	-0.541	1.468	2.005	1.913	10.904
10×3	0.028	0.922	-0.061	-0.343	1.084	2.948	-0.715	-4.592
5×4	0.105	0.645	-0.048	0.247	-0.294	0.938	-0.028	4.983
6×4	-0.015	-0.274	-0.059	-0.487	-0.905	20.281	2.766	-1.765
7×4	-0.082	0.228	-0.045	0.296	-0.027	10.000	-0.499	9.548
8×4	0.151	0.232	1.077	0.532	0.696	0.352	4.531	-0.081
9×4	-0.007	-0.285	-0.153	-0.087	-0.035	-12.085	-0.880	1.854
10×4	-0.060	-0.629	-0.240	-0.756	-0.653	-30.325	-6.382	-16.353
6×5	-0.063	-0.323	-0.072	-0.463	-0.147	-7.414	-2.210	-1.252
7×5	-0.005	-0.244	-0.111	-1.258	0.208	-36.343	-0.729	-6.694
8×5	0.124	0.505	-0.073	-0.311	-0.102	3.408	1.128	-4.657
9×5	0.004	-0.401	-0.217	-0.352	-0.011	-4.729	0.698	-0.638
10×5	-0.041	-0.833	0.153	-0.110	-0.728	2.740	-1.562	-9.060
7×6	0.015	-0.408	-0.391	-0.202	0.798	13.784	-0.696	-6.868
8×6	0.100	-0.448	0.232	0.700	-0.212	35.696	2.943	-6.005
9×6	0.002	-0.087	0.000	-0.019	-0.744	-11.432	-1.495	-4.842
10×6	-0.021	-0.186	-0.105	-0.376	-2.672	-53.885	-6.513	-22.975
8×7	0.031	0.587	0.313	0.172	0.021	-4.586	-12.704	-9.925
9×7	0.005	-0.252	0.138	0.743	-0.221	21.742	1.006	-10.640
10×7	-0.034	1.271	0.098	0.530	2.006	35.396	14.690	43.256
9×8	-0.258	0.163	0.560	-0.267	0.012	25.387	1.018	-5.037
10×8	-0.123	-1.058	0.694	-0.213	-0.016	16.907	1.131	-12.913
10×9	-0.004	0.914	-0.025	0.846	0.053	1.791	-1.189	10.621

$S.E.(\hat{S}_{ij})$	0.077	0.578	0.350	0.538	0.545	16.75	3.13	6.29

3.3. Estimating the Variance of General and Specific Combining Ability Effects for Each Parent on the Studied Traits:

Table (5) shows the variance in the general and specific combining ability effects for each parent across all traits. This is crucial to understanding how these parents achieve their effects, as explained in Table (4), and identifying which of the studied parents is most useful in trait improvement.

For the trait of the number of ears per plant, the general combining ability effect for parent (8) was significantly high in the desired direction, reaching (0.322), with its specific combining ability variance at (0.193). This indicates that parent (8) consistently transmitted the genetic traits for this characteristic to most of its progeny. The variance of general combining ability effects among the ten genotypes ranged from (0.103) for parent (8) to (0.000) for parents (4), (6), and (9).For ear ear length, the general combining ability effect was significant and favourable, with parent (8) showing superiority, reaching (2.728). The specific combining ability variance for this parent was (4.08), indicating that parent (8) consistently transmitted this trait to most of its offspring. The variance of general combining ability effects among the ten genotypes ranged from (7.403) for parent (8) to (-0.037) for parent (4).

The ear diameter, the general combining ability effect was significant, with parent (8) showing the highest value at (1.986), while the specific combining ability variance for this parent was (2.643). This suggests that parent (8) reliably transmitted this trait to most of its progeny, with general combining ability variance values for the ten genotypes ranging from (3.932) for parent (8) to (0.005) for parent (4). For the number of rows per ear, the general combining ability effect was significantly high for parent (8) in the desired positive direction, reaching (2.528). This parent's specific combining ability variance was (2.001), indicating that parent (8) consistently passed on this trait to most of its hybrids. The general combining ability variance values for the ten genotypes ranged from (6.361) for parent (8) to (-0.020) for parent (5).

Parents (4), (5), (8), and (9) had considerably higher values for the number of grains per row, measuring (0.395), (0.559), (2.836), and (0.289), respectively. The specific combining ability variances for these parents were (6.834), (15.048), (9.509), and (8.689), respectively. This indicates that parents (5) and (8) reliably transmitted this trait to most of their progeny, while parents (4) and (9) transmitted it to some of their offspring but not others. The general combining ability variance values for the ten genotypes ranged from (8.010) for parent (8) to (-0.023) for parent (6). For the number of grains per ear, the effect was significant and positive for parent (8), reaching (74.107). This parent's specific combining ability variance was (4170.839), indicating that parent (8) reliably transmitted this trait to most of its hybrids. The general combining ability variance values for the ten genotypes ranged from (5461.019) for parent (8) to (26.392) for parent (5). For the 300-grain weight trait, the effect was significant and in the desired direction for parent (8), reaching (10.890). The specific combining ability variance for this parent was (222.195), suggesting that parent (8) reliably passed on this trait to most of its hybrids. The general combining ability variance values for the ten genotypes ranged from (117.507) for parent (8) to (-1.071) for parent (1).

Regarding individual plant yield, the effect was significant and positive for parent (8), reaching (15.855). The specific combining ability variance for this parent was (327.397), indicating that parent (8) reliably transmitted this trait to most of its hybrids. The general combining ability variance values for the ten genotypes ranged from (247.021) for parent (8) to (-4.299) for parent (3). Based on these findings, it becomes clear that parents with high general combining ability and low specific combining ability variance could benefit breeding programs aiming for superior segregating populations in isolation generations. Some of these parents transmitted the genetic traits for these characteristics to most of the hybrids to which they contributed. Hybrids with high specific combining ability resulted from crosses involving one parent with high general combining ability, suggesting that these hybrids can be exploited in trait improvement programs. Consequently, we recommend conducting further studies to utilize these superior hybrids to achieve the second and isolated generations and perform selection to derive new genetic configurations [39],[40].

Table 5 Estimation of Variance in General and Specific Combining Ability Effects for Each Parent on Studied Traits

Parent	Variance	Number of corns/Plant	corn Length	Corn Diameter	Number of Rows/corn	Grains/Row	Grains/corn	300-Grain Weight	Individual Plant Yield
1	σ_g^2	-0.001	0.213	0.026	0.130	0.439	-3.712	-1.071	-2.823
	σ_s^2	0.098	4.88	0.259	6.064	40.289	7451.699	49.407	658.936
2	σ_g^2	0.006	0.529	0.009	1.079	5.397	1321.010	12.262	31.625
	σ_s^2	0.113	10.41	0.022	7.236	80.949	9726.288	53.637	98.395
3	σ_g^2	0.004	-0.002	0.063	-0.032	0.408	52.340	-0.835	-4.299
	σ_s^2	0.049	4.91	0.236	4.603	38.017	3979.438	62.219	939.577
4	σ_g^2	0.000	-0.037	0.005	-0.028	0.123	-14.309	-0.529	-4.341
	σ_s^2	0.054	1.30	0.905	2.492	6.834	1844.431	88.099	995.960
5	σ_g^2	0.001	-0.036	0.065	-0.020	0.280	-26.392	1.157	1.548
	σ_s^2	0.015	3.76	-0.259	3.542	15.048	1141.669	-9.362	134.467
6	σ_g^2	0.000	0.097	0.046	-0.029	-0.023	30.234	2.003	53.064
	σ_s^2	-0.002	1.07	-0.106	1.735	20.811	5286.286	43.501	611.379
7	σ_g^2	0.001	-0.015	0.049	0.014	-0.004	-24.354	-0.530	3.565
	σ_s^2	0.013	1.57	-0.069	2.002	5.115	2970.130	354.659	2246.886
8	σ_g^2	0.103	7.403	3.932	6.361	8.010	5461.019	117.507	247.021
	σ_s^2	0.193	4.08	2.643	2.001	9.509	4170.839	222.195	327.397
9	σ_g^2	0.000	-0.013	0.040	0.050	0.051	-2.565	0.698	-1.261
	σ_s^2	0.110	1.30	0.049	0.892	8.689	878.865	-14.272	288.902
10	σ_g^2	0.002	0.311	0.034	0.172	0.189	54.932	-0.724	-4.176
	σ_s^2	0.005	4.61	0.219	1.223	16.469	6566.331	310.830	2963.598

4. Conclusions

The results showed that the effect of specific combining ability (SCA) for the trait of seed number/pod was significant and positive in the desired direction for the hybrids (1×4), (1×10), (2×6), (3×6), (4×7), (7×10), and (9×10), ranging from 43.256 in the hybrid (7×10) to 6.314 in the hybrid (2×6). Significant effects of general combining ability (GCA) were observed in parent (8) for all the studied traits, with GCA variance components being greater than SCA components for all traits. These hybrids can be used to select individuals who combine the desired traits in segregating generations.

Compliance with ethical standards

Disclosure of conflict of interest

The author declares no conflict of interest.

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