STUDIES ON THE EXPRESION OF GENERAL AND SPECIFIC COMBINATION CAPACITY AT SEVERAL INBRED LINES IN A DIALLEL SYSTEM AND THE MANIFESTATION OF HETEROSIS IN NEW MAIZE HYBRIDS OBTAINED

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Abstract: *Of great importance for the extension of the practice of corn amelioration, of quantitative genetic analysis methods, was the enunciation of the general combination capacity (CGC) and specific combination (CCS) concept. By CGC, according to the concept, is meant the additive genetic component transmitted by the crossing of all the descendants by a parent. By CCS is meant that genetic component that is transmitted to the descendants only when a genitor is specifically crossed with a particular partner. The two components equate to the effect of the action of the aditive genes in the genetic point of view, in the case of the general combinatorial capacity, and in the case of the specific combining capacity, it is equivalent to the effect of the interactions of nonadjusted dominant genes and epistaxis. In the second half of the 20th century, in the creation of maize hybrids, this concept had some remarkable results (Căbulea 2004). The overall ability to combine inbred lines is particularly important in making valuable corn hybrids. Crossing known inbred lines through the general combination ability (for production or other character) in a dialell system, it is normal to perform a hierarchy of the respective inbred lines. The study of the effects of the general combining ability in the expression of heterosis in the characters: the height of insertion, the total height, the length of the ear, the number of grains per row, the grain weight, the weight of the ear, the dry matter, the MMB, the number of erect plants, using experimental data from a dialel system of type p (p-1) / 2. Regarding the analysis of variants of hybrid combinations obtained in the dialell system, it is observed that for all the studied characters the ratio between the specific combining capacity and the overall combinaton capacity is superunit, which means that in these cases the effect of nonadjusted dominant gene interactions and epistasis is stronger than the additive effect. High values for heritability coefficient were recorded for the number of rows per ear, grain production, and the percentage of erect plants, which means that transmission of these characters to other genotypes can be done efficiently. The majority of characters are mainly dominated by dominant genes, with a dominance ratio greater than 1, except for the percentage of erect plants.*

Keywords: *inbred lines, dialell system, additive genetic component, heritability coefficient, general combination capacity, specific combination capacity*

INTRODUCTION

The heredity of quantitative characters, expressed by polygenic quantitative (continuous) and not qualitative variability, is controlled by the simultaneous action of many genes, called polygene.

In the practice of improving corn, the concept of general and specific combining capability (CGC) and (CSC) (Spraque and Tatum 1942) is of great importance.

By CGC, according to the concept, is meant the additive genetic component transmitted by the crossing of all the descendants by a parent. By CCS is meant that genetic component that is transmitted to the descendants only when a genitor is specifically crossed with a particular partner.

The two components equate to the effect of the action of the aditive genes in the genetic point of view, in the case of the general combinatorial capacity, and in the case of the specific combining capacity, it is equivalent to the effect of the interactions of nonadjusted dominant genes and epistasis.

In the second half of the 20th century, in the creation of maize hybrids, this concept had some remarkable results. (CĂBULEA 2004)

MATERIAL AND METHODS

The biological material that was the subject of experimentation was the 21 simple hybrids resulting from direct crosses made in a diallel system between a number of seven inherited lines differentiated from the phenotypic and genetic point of view.

Years of simple hybrid testing were between 2017 and 2018, in a randomized three-reel trial. The comparative crops were placed in experimental soil belonging to the Corn Amelioration Laboratory at the Lovrin Agricultural Research and Development Station, on a well prepared ground by autumn plowing with a fertilization of 80 kg / ha P2O5 and 180 kg / ha N active substance. In all cases the pre-plant was autumn wheat. Maintenance work was carried out on the experimental field of maize improvement.

Study of the effects of general and specific combining ability in the expression of heterosis at the height of insertion, total height, length of ear, number of seeds per row, number of rows on ear, grain weight, weight of ear, dry matter, MMB, number of erect plants , grain production was performed using experimental data through a diallel crossing system of type p (p-1) / 2.

The highlight of the variance for the general and specific combination ability of the diallel system as well as the genetic effects involved was based on the genetic model IV (fixed) proposed by Griffing (1956)

Heterosis or hybrid vigor is the superiority of hybrids. The most quantitative measure is the relationship with parents' media.

RESULTS AND DISCUSSIONS

The variance of the genotypes obtained from the direct crossing of the 7 inbred lines is presented in Table 1. The variance decomposition according to model IV (fixed) proposed by Griffing (1956). By performing variance analysis, it is found that for all the studied characters, the ratio between the specific combining capacity and the overall combining capacity is superunit.

Table 1

Variance decomposition for a diallel cross-linking system of inbred lines

Cause of variability	Variance (s^2)			
	Genotypes	(CGC)	(CSC)	Eroare
Character GL	20,0	6,0	14,0	98,0
Height of insertion	9911,83	3200,84	12787,97	1,03
Total height	100799,16	32159,84	130216,01	3,67
Length of ear	1181,19	381,92	1523,74	0,26
Nr. of seeds per row	5214,21	16,84,93	6726,77	1,43
Nr. of rows on ear	686,63	223,65	885,06	0,01
Grain weight	109517,87	30776,58	143264,14	14,79
Weight of ear	159425,02	46960,44	207624,13	214,48
MMB	325923,60	104324,80	420894,51	28,14
Nr. erect plants	22650,21	7373,54	29197,36	4,07
Grain production	12054,37	3874,64	15559,97	9,78

Based on these results, it can be argued that in these cases the effect of non-dominant dominant gene interactions and epistatics is stronger than the additive effect.

Additive genes can be fixed in pure homozygous lines, as a consequence, knowing and calculating the heritability of different quantitative characters is of great importance for amelioration. By appropriate statistical methods it is possible to separate the genetic parameters of the genotypic variant. Knowing these basic parameters, it is possible to determine the heredity coefficient in a narrow sense and the degree of average dominance.

Among the components of genetic variation, the additive variance and variance determined by the interaction of homozygous locus (Vaa) is transmissible and fixable of offspring. Therefore "h2" represents a statistic value of the quantitative characters (CĂBULEA, 1975).

Using the parameters of the genetic variants the narrower heritability coefficient and the dominance quota for each character taken into study were calculated.

Table 2.

Analysis of variance for diallel crossing system

Character	$\bar{x}$	S^2g	S^2_s	S^2_e	h^2	ā
Height of insertion	55,42	294,50	2456,68	1,03	0,39	4,17
Total height	178,26	6537,07	43133,58	3,67	0,47	3,30
Length of ear	19,28	76,12	503,81	0,26	0,46	3,31
Nr. of seeds per row	40,53	336,12	2231,16	1,43	0,46	3,32
Nr. of rows on ear	14,49	44,09	293,06	0,01	0,65	3,62
Grain weight	179,40	7499,17	67495,46	14,79	0,48	3,14
Weight of ear	218,67	10710,91	47140,91	214,48	0,34	6,15
MMB	320,00	2140,65	138449,9	28,14	0,47	3,28
Nr. erect plants	84,70	1454,92	9707,66	4,07	0,52	0,77
Grain production	60,42	779,02	4800,99	9,78	0,59	3,08

A first observation that can be made is that the hereditary transmission of the number of rows per ear (h2 = 0,65), the production of grains (h2 = 0,59) and the percentage of erect plants (h2 = 0,52) Genotypes can be done efficiently.

The mean of hereditary transmission and amelioration is represented by the characters: the height of the ear insertion, (h2 = 0,39), the height of the plant (h2 = 0,47), the length of the ear (h2 = 0,46) (h2 = 0.46), the weight of the grain on the cobs (h2 = 0.48), the weight of the ear (h2 = 0.34), and MMB (h2 = 0.47).

The study of the effects of the general combining ability in the expression of heterosis in the 11 characters studied was performed using experimental data from a p (p-1) / 2 diallel system.

Table 3 shows the additive effects values for the lines: Lv 1700, Lv 92, C103, TA 409, Lv 86, TA 403 and B73. Regarding the expression of the specific combining ability, any F1 hybrid within the diallel system accumulates in average the mean effects, the effects of the combined parenting capacity of the two parents, the specific combining effects, the effects of the years of experimentation, the interplay between the experimentation years and the specific combining ability of hybrid combinations or error. Analyzing the data in Table 4, it can be noticed that in the combinations with Lv 1700 there were non-aditive effects, significant for the characters:

- The height of the cage insertion in the hybrid (LV 1700xC103) (7.16
- Number of grains per line on the hybrid (Lv 1700xTA 403) (4.90)
- The number of rows per ear on the hybrid (Lv 1700xTA 409) (1.48) and (Lv 1700xLv 92) (0.95).
- Grain weight on the hybrid (Lv 1700xC103) (17,84)
- Grain production at (Lv 1700xLv 86) (12.87)

Hybrids that shared the Lv 92 line showed significant nonadjacent effects on the characters:

- The height of the ear - (Lv 92xC 103) (6,13),
- Number of rows per ear - - (Lv 92xLv 86) (0.49) and (Lv 92xB 73) (0.49)
- Grain weight - (Lv 92xTA 403) (17,12) and (Lv 92xB 73) (31,90),
- Weight of the cow - (Lv 92xTA 403) (35.84) and (Lv 92xB73) (42.09),
- MMB - (Lv 92xLv86) (30.81),

In combinations with line C 103, significant non-additive effects were found for the following characters:

- Total plant height - (C 103xB 73) (7,27),
- Number of rows per ear - (C 103x TA 409) (0.76) and (C 103xB 73) (2.99),

- MMB - (C103xLv 86) (7.27)

For hybrids comprised of the TA 409 line, the characters with significant nonadditive effects were as follows: the height of insertion of the ear (TA 409xB 73) (6,78), the total plant height (TA 409xB 73) (8,84), number of rows per ear - (TA 409xLv 86) (0.91), grain weight - (TA 409xLv 86) (14.90), weight of the ear - (TA 409xB 73) (36,17), percentage of erect plants - (TA 409xB 73) (2.78), grain production - (TA 409xLv 86) (12,08).

In the hybrid combinations with the Lv 86 line, significant nonadditive effects were determined only for the character: the number of rows per ear - (Lv 86xTA 403) (1.07). Hybrids made with the TA 403 line showed significant nonadditive effects for the characters: crow insertion height - (TA 403xB 73) (6.04), weight of the cob - (TA 403xB 73) (23.01). The hybrid combinations to which most of the non-additive effects have accumulated were: (TA 409xLv 86), (Lv 1700xLv 86), (Lv 92xB 73), (TA 409xB 73).

Concerning the expression of heterosis in hybrid combinations performed in a diallel system, the results are presented in Table 5. and refer to the heterosis effect obtained as the difference between the value of the hybrid combination and the average of the two inbred parental forms for the 10 characters traced in this study.

Table 3

Non-additive genetic effects of inbred lines in dialleic system

The line	Character	Lv 92	C103	TA 409	Lv 86	TA 403	B 73	DL 5%
Lv 1700	Height of insertion	3,59	7,16	-6,03	2,38	-4,53	-1,96	3,83
	Total height	0,66	0,85	2,19	-6,77	-1,24	-3,73	7,23
	Length of ear	0,02	1,36	-0,32	-0,11	-1,12	-0,63	1,92
	Nr. of seeds per row	-1,22	-1,04	-1,33	-0,83	**4,90**	-1,97	4,5
	Nr. of rows on ear	**0,95**	-1,03	**1,48**	-1,48	-0,39	0,30	0,44
	Grain weight	-39,60	7,04	-3,74	10,09	**17,84**	1,12	14,5
	Weight of ear	-63,64	3,65	-3,71	2,23	7,54	31,62	35,23
	MMB	-20,42	-26,11	8,44	1,72	1,86	15,92	20,0
	Nr. erect plants	1,70	-3,38	-0,61	1,20	2,31	-0,58	7,61
	Grain production	-4,52	2,83	-12,45	**12,87**	2,79	5,65	11,79
Lv 92	Height of insertion		**6,13**	-1,61	-1,63	-2,65	-4,54	3,83
	Total height		2,12	-1,06	-2,68	6,01	-11,46	7,23
	Length of ear		-0,54	0,15	-1,26	0,99	0,43	1,92
	Nr. of seeds per row		-0,05	3,00	-0,03	-1,05	-1,94	4,5
	Nr. of rows on ear		-2,79	0,32	**0,49**	-1,58	**2,01**	0,44
	Grain weight		5,31	-21,13	-3,63	**17,12**	**31,90**	14,5
	Weight of ear		-3,55	-14,13	-8,46	35,48	**42,09**	35,23
	MMB		-34,86	-0,31	**30,81**	4,11	10,83	20,0
	Nr. erect plants		0,78	-0,61	1,37	0,48	-2,41	7,61
	Grain production		4,53	8,24	-3,73	-1,19	-5,69	11,79
C103	Height of insertion			-5,92	-0,74	0,81	-1,65	3,83
	Total height			-5,93	1,26	0,07	**7,27**	7,23
	Length of ear			-0,39	0,23	-1,49	1,81	1,92
	Nr. of seeds per row			1,64	1,47	-1,55	1,11	4,5
	Nr. of rows on ear			**0,76**	-0,07	**2,99**	-0,36	0,44
	Grain weight			7,67	5,84	-17,08	-17,46	14,5
	Weight of ear			33,26	-16,08	4,90	-25,85	35,23
	MMB			3,00	**20,61**	17,75	17,47	20,0
	Nr. erect plants			2,31	2,62	1,56	-4,83	7,61
	Grain production			-8,00	-1,55	1,57	3,93	11,79
TA 409	Height of insertion				3,10	0,85	**6,78**	3,83
	Total height				2,22	-7,69	**8,84**	7,23
	Length of ear				-0,33	1,41	-0,25	1,92
	Nr. of seeds per row				-2,17	-3,02	1,32	4,5
	Nr. of rows on ear				**0,91**	-1,07	-0,46	0,44
	Grain weight				**14,90**	-24,69	5,76	14,5
	Weight of ear				**36,17**	-29,35	-15,27	35,23
	MMB				-12,67	10,47	-6,31	20,0
	Nr. erect plants				-1,27	-3,33	**2,78**	7,61
	Grain production				**12,08**	8,20	0,51	11,79
Lv 86	Height of insertion					3,10	-3,84	3,83
	Total height					-0,98	6,00	7,23
	Length of ear					0,93	-0,04	1,92
	Nr. of seeds per row					0,34	1,82	4,5
	Nr. of rows on ear					1,07	-1,19	0,44
	Grain weight					-22,69	2,42	14,5
	Weight of ear					-23,52	10,73	35,23
	MMB					-19,25	-17,36	20,0
	Nr. erect plants					-5,52	2,25	7,61
	Grain production					-13,80	-0,80	11,79
TA 403	Height of insertion						**6,04**	3,83
	Total height						4,06	7,23
	Length of ear						-0,85	1,92
	Nr. of seeds per row						0,60	4,5
	Nr. of rows on ear						-0,24	0,44
	Grain weight						**23,01**	14,5
	Weight of ear						-4,80	35,23
	MMB						-5,72	20,0
	Nr. erect plants						3,20	7,61
	Grain production						-1,46	11,79

Table 4.

The effect of heterosis on hybrid combinations made in the diallel system

Character / Combination	Height of insertion	Total height	Lenght of ear	Number of seeds per row	Number of rows on ear	Grain weight	Weight of ear	MMB	Erect plants %	Grain production
	Heterosis effect (h)									
Lv 1700x Lv 92	1,34	1,12	1,34	8,55	1,05	14,31	7,36	16,54	4,32	11,88
Lv 1700x C 103	2,38	**5,30**	1,12	6,24	0,42	**28,70**	14,61	14,25	1,21	34,42
Lv 1700x TA 409	1,14	1,15	0,55	9,37	2,02	17,20	8,22	21,31	1,68	6,52
Lv 1700x Lv 86	0,14	4,28	0,21	4,33	0,21	21,40	16,34	19,56	3,35	16,40
Lv 1700x Lv 403	0,82	3,19	0,12	18,25	0,42	16,48	19,22	25,63	7,84	18,38
Lv 1700x B 73	0,56	2,14	0,13	2,37	1,87	21,20	**24,56**	12,40	1,15	33,27
Lv 92 x C103	**2,40**	2,21	0,15	10,20	0,12	10,80	8,25	15,78	2,76	34,38
Lv 92 x TA 409	2,31	2,21	0,87	**23,20**	1,69	14,32	7,41	24,65	1,18	**44,97**
Lv 92 x Lv 86	0,15	1,17	0,11	10,90	1,87	15,22	9,36	17,49	6,47	5,57
Lv 92 x Lv 403	0,78	4,25	0,71	6,25	0,23	18,90	18,55	21,03	6,48	10,67
Lv 92 x B 73	0,12	1,12	0,64	4,38	**2,41**	21,31	21,66	19,47	1,12	9,70
C103 x TA 409	0,85	1,80	0,14	21,01	1,75	17,22	22,88	27,50	6,54	13,12
C103 x Lv 86	1,12	2,01	0,19	19,30	0,23	18,93	14,20	24,90	4,88	11,93
C103 x TA 403	0,11	3,17	0,08	8,42	2,10	10,28	22,31	26,45	**7,48**	24,92
C103 x B73	2,04	4,87	1,34	17,50	0,24	9,37	10,24	**34,30**	0,77	20,80
TA 409 x Lv 86	1,12	4,22	0,19	2,32	1,74	21,36	24,31	14,55	2,74	43,73
TA 409 x TA 403	0,04	1,80	1,57	3,25	0,16	9,34	10,28	24,87	1,89	44,02
TA 409 x B73	1,93	2,25	1,54	15,22	0,24	16,62	14,56	17,00	4,84	32,75
Lv 86 x TA 403	0,21	0,75	**1,67**	16,30	1,87	8,22	12,37	10,27	0,56	1,48
Lv 86 x B73	2,06	1,16	0,34	20,10	0,11	14,35	16,28	12,65	6,23	18,12
TA 403 x B73	1,88	1,55	0,12	16,21	0,15	24,36	10,64	12,37	6,54	21,02

Observing these data, it can be noted that heterosis generally had high values for the number of grains in a row, grain weight, ear weight, MMB, and grain production.

For the height of insertion, the strongest heterosis effect was recorded at the combination (Lv 92xC 103) (2.40); for the height of the plant, the highest value was within the combination (Lv 1700xC103) (5.30); for the length of the ear, the hybrid combination (Lv 86xTA 403) (1.67) had the largest heterosis.

In the case of the number of grains per row, a maximum heterosis effect on the hybrid (Lv 92xTA 409) (23,20) was recorded; in the case of the number of rows per ear, the heterosis manifested itself most strongly at the combination (Lv 92xB 73) (2.41); for grain weight, the highest level of heterosis was at (Lv 1700xC103) (28.70); for the weight of the ear, the hybrid combination (Lv 1700xB 73) (24.56) recorded the strongest heterosis effect.

The most powerful heterosis effect calculated for MMB belonged to the hybrid combination (C 103x B 73) (34,30), the hybrid with the highest heterosis effect (C 103xTA 403) and the heterosis effect the highest grain yield was obtained in the combination (Lv 92xLv 409).

The hybrid combinations at which most of the maximum heterosis effects were observed (Lv 1700xC 103) and (Lv 92xTA 409).

CONCLUSIONS

1. With respect to the analysis of variants of hybrid combinations obtained in the diallel system, it is observed that for all the studied characters, the ratio between the specific combinatorial capacity and the general combinatorial capacity is superunit, which means that in these cases the effect of nonadjusted dominant gene interactions and of epistasis is stronger than the additive effect;

2. High values for the limited heritability coefficient were recorded for the number of rows per ear, the production of grains and the percentage of erects, which means that transmission of these characters to other genotypes can be done with efficiency.

3. Most of the characters are mainly dominated by dominant genes, with a dominant ratio greater than 1; exception makes the percentage of erect plants.

4. The highest overall combining capacity for the height of the ear was the C 103 line; for plant height - C103; for the length of the C 103 ear; for the number of grains per row - C 103; for the number of rows per ear - TA 409; for grain weight - B 73; for the weight of the ear - B 73; for MMB - C 103; for the percentage of erect plants - Lv 92; for grain production - TA 409.

5. Lines C 103, B 73, TA 409 and Lv 92 have been identified as having a good overall combining capacity, which can be used as parental forms or in breeding programs for inbred maize lines.

6. From the perspective of the specific combination potential, the hybrid combinations with the most non-admissible effects for the studied characters were: (TA 409x Lv 86), (Lv 1700xLv 86), (Lv 92xB 73), (TA 409xB 73).

7. The hybrid combinations with the highest number of maximum heterosis effects were: (Lv 1700xC103) and (Lv92xTA 409).

8. Considering that in the practice of amelioration it is desirable that situations where both parents with high combining ability (positive additive effects) and gene interactions that enhance the favorable expression of genetic potential (favorable favorable effects) can be found in the same cross, we recommend hybrid combinations with the C103, B73, TA409 and Lv92 lines.

9. We also recommend hybrid combinations between lines belonging to the groups of the following combinations: (TA 409xLv 86), (Lv 1700xLv 86), (Lv 92xB 73), (TA 409xb73), given that this specificity of interaction can be largely attributed to the degree of genetic diversity of the two parental forms in the sense that a pronounced positive effect corresponds to a pronounced differentiation between the lines.

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