ESTIMATION OF HYBRID VIGOUR, COMBINING ABILITY AND GENE ACTION USING (LINE × TESTER) ANALYSIS IN MAIZE

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ABSTRACT

Field experiment was conducted at field of Fallujah- Anbar Governorate/ Iraq, during the two seasons of 2017. Seeds of eight maize inbred lines were cultivated, and line × tester method was used to produce 16 crosses. The seeds of parents were cultivated and crosses in the fall season of 2017 in a randomized complete block design with three replicates. The objectives of the study were to estimate gene action, hybrid vigour, and the effects of general and specific combination abilities of the inbred lines and to evaluate test cross performance of the hybrids for grain yields and yield related traits. There were significant differences between parents and their crosses for all studied traits. The results showed that crosses (ZM12 x ZM51W) and (ZM12 x ZM43W) gave the highest hybrid vigour in grain yield (39.32% and 31.62% respectively) to the best parents. The two crosses also were superior in the plant grain yield (222.29 and 217.15 gm. plant $^{-1}$).The specific combination ability components were larger than the general combination ability components. The dominance genetic variation was more important than the genetic variation additive. The heritability in its narrow sense was low ranging between 2.17% for grain yield.plant^{-1} and 25% for Leaf area, and this led to a high degree of dominance on the one for all the studied traits except leaf area. It can be concluded that it is possible to use some parents which outperformed others of crosses, because most of traits were under the influence of dominant and over dominant gene effects.

Key words:hybrid vigour, line × tester, gene action, degree of dominance.

تقدير قوة الهجين وقابلية الائتلاف والفعل الجيني باستخدام تحليل (السلالة × الفاحص) للذرة الصفراء

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المستخلص

أجريت تجربة حقلية في حقول أحد المزارعين في الفلوجة ـ محافظة الأنبار- العراق خلال موسمين في عام 2017، زرعت بذور ثمان سلالات نقية من محصول الذرة الصفراء ثم هجنت السلالات بموجب طريقة (السلالة × الفاحص) لإنتاج 16 هجيناً فردياً. زرعت بذور الآباء وهجنها الفردية في الموسم الخريفي 2017 وفق تصميم القطاعات الكاملة المعشاة وبثلاثة مكررات بهدف دراسة الفعل الجيني وتقدير قوة الهجين وتأثيرات قابلية الائتلاف العامة والخاصة وتقييم حاصل النبات ومكوناته للسلالات والهجن. وجدت فروق عالية المعنوية بين الآباء وهجنها لجميع الصفات المدروسة. أظهرت النتائج بان الهجينين (ZM12 x ZM51W) و(ZM12 x ZM43W) قد أعطيا أعلى قوة هجين في حاصل الحبوب (39.32% و31.62% بالتتابع) نسبة إلى أفضل الأبوين وكذلك تفوق الهجينان في حاصل حبوب النبات وأعطيا حاصلاً قدره 222.29 و217.15 غم.نبات$^{-1}$. كانت مكونات تباين القدرة الخاصة على الائتلاف أكبر من مكونات تباين القدرة العامة على الائتلاف، التباين الوراثي السيادي أكثر أهمية من التباين الوراثي المضيف، وكانت نسبة التوريث في معناها الضيق منخفضة حيث تراوحت بين 2.17% لحاصل الحبوب و25% في المساحة الورقية. أدى ذلك إلى ارتفاع درجة السيادة عن واحد لجميع الصفات المدروسة باستثناء المساحة الورقية. يستنتج من الدراسة أمكانية استخدام بعض الإباء المتفوقة في تضريباتها في استنباط هجن فردية ذات قابلية اتحاد خاصة لإنتاج حاصل حبوب عال لأن معظم صفاتها كانت تحت تأثير السيادة والسيادة الفائقة.

الكلمات المفتاحية: قوة الهجين، السلالة × الفاحص الفعل الجيني، درجة السيادة.

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INTRODUCTION

Maize (*zea mays* L.) is one of the most important field crops grown in the word as well as in Iraq for the purpose of grain production and also known as queen of cereals this crop comes third in terms of economic importance after the wheat and barley crops(1,9,11), also for the purpose of evaluation of several lines to produce a high yield after crossing with other line (3). The line × tester was used to determine the phenomenon of hybrid vigour which is expressed by the rate of increase in size, weight or growth of the first generation compared to its parents, and this phenomenon attracted plant breeders for the purpose of studying and applying them in many field crops (4), with the aim of raising its productivity in the unit area and improving its quality traits. When adopting this phenomenon, the first step includes testing of different lines from different origins to expand the genetic base of hybrid production which have the desired traits (8,17). The value of any genotype is estimated through its productivity and desirable traits, its genetic behavior and its ability to combine (13). Therefore, attention is focused on selecting appropriate line that has specific combination ability with genetically diverged lines to produce crosses, because it expresses the ability of the line to produce a superior hybrid by pairing with another line(16). The general combining ability is under the additive effect of genes which gives a clear indication of line on the hybrid combine, as well as the specific combination ability which are under dominant effects of gene which gives special indication to the breeds in their ability to combine with other breeds(20), and for the purpose of identifying the genetic behavior some genetic parameters are estimated through partitioning of components, and calculating the degree of inheritance with its broad and narrow sense heritability which means the amount transferred to the offspring resulting from them in the first generation because each parent has a general effect to improve the number of attributes, as well as estimate the degree of dominant through which we can find out what kind of gene controls the traits to determine the appropriate breeding method to improve them (25). Many researchers were interested in maize crop such as Suadi(24) and Wuhaib (26) they found a significant effect on general and specific combining abilities and that the effects of specific combining ability was more than the general combining ability in most of the studied traits. There for the objectives of the research were to estimate the effects of general and specific combination abilities, gene action and hybrid vigour of the inbred lines and to evaluate test cross performance of the hybrids for grain yields and yield related traits.

MATERIALS AND METHODS

Eight inbred line of maize were used in this study. They were numbered from 1 - 8 as follow: (1- ZM12, 2- ZM49W, 3- ZP607, 4- M19R, 5- HS, 6- ZM51W, 7- ZM43W and 8 - ZM 7) Table (1). Inbred lines were cultivated in Anbar governorate/, Fallujah in the spring and autumn seasons of 2017 on furrow length of each 5m, in 16 and 25 March 2017 respectively to ensure compatibility between flowering breeds and to obtain high-vitality pollens throughout the duration of the hybridization. Hybridization was carried out between inbred lines to obtain seeds of the F1 crosses according to line × tester method which was proposed by (13). The total inbred lines was 16, the breeds were used (1, 2, 3, 4) as parents of the testers and inbred lines (5, 6, 7, 8) as female line, selfing was carried out for inbred lines. at the end of the season, ears were harvested from each of the eight parents and the sixteen crosses. Seeds were obtained by manual isolation for planting in the followed season. Hybrid seeds were cultivated with the parents in mid-July at the same site, a randomized complete block design was used in the experiment with three replicates. The experimental unit was 4 furrow with a length of 6_m and a distance of 0.75_m between each two furrows, 0.25_m between the hills and the rate of (3) seeds in each hill, Then were thinned to one plant. All agricultural practices were carried out according to the prescribed recommendations. Phosphate fertilizer was added at rate of 160 kg $P_2O_5.h^{-1}$ before plantin,. and nitrogen fertilizer was add at a rate of 200 $kgN.h^{-1}$ at two times. Studied traits were taken as means of 10 plants that were taken from each experimental unit apart from guard lines traits were:

1- The number of days from planting to 50% silking

2- Leaf area. cm^2.

3- Number of rows. ear^{-1}.

4- The number of grains. ear^{-1}.

5- 1000 kernel weight. gm.

6- Grain yield. $Plant^{-1}$.

Table 1. The origin of inbreds used

	Line number	Line name	Origin
Male	1	ZM12	Yugoslavian
	2	ZM49W	Yugoslavian
	3	ZP607	Produced by a Yugoslav hybrid
	4	M19R	American
Female	5	HS	American
	6	ZM51W	Yugoslavian
	7	ZM43W	Yugoslavian
	8	ZM7	Yugoslavian

The data were statistically analyzed in the method of Line × Tester, analysis which suggested by (15) as mentioned (22), where the parents are divided into two groups, the first group representing the parents to be evaluated, Lines (L=4) and The second group of parents used tester (T= 4). The number of crosses will be equal to the number of crosses (L) × number of testers (T), which is equal to sixteen crosses and accordingly the number of genotypes is equal (8+16) =24. The effects of general and specific combination ability were tested as follows:

General Combination Ability (GCA) for the lines to be tested:

$$\hat{g}L = \frac{xL...}{tr} - \frac{x...}{Ltr}$$

General Combination Ability (GCA) For the testers to be tested:

$$\hat{g}t = \frac{x.j}{Lt} - \frac{x...}{Ltr}$$

Effects of Specific Combination Ability (SCA) for the hybrid (i, j):

$$\hat{S}ij = \frac{xij}{Ltr} - \frac{xi...}{Lr} - \frac{x.j.}{tr} + \frac{x...}{r}$$

The components of the phenotypic variation were estimated ($б^2$p) which include the additional variance ($б^2$A), the dominant variation ($б^2$D) and the environmental variance ($б^2$E) and so on of the expected means variance values of EMS of the fixed model as follows, as the:

Mse = $б^2$E

$$б2L = \frac{MsL - Ms(L \times t)}{rt}$$

$$б2t = \frac{Mst - Ms(L \times t)}{rL}$$

$$\sigma2Sca = \frac{Ms(L \times t) - mse}{r}$$

$$Cov\ H.s\ (average) = \frac{1}{R(2Lt - L - t)}\left[\frac{(L-1)\ MSL + (t-1)\ MSL}{L + t - 2} - MSL \times t\right] =$$

$$б2\ Gca = Cov\ H.s = \left(\frac{F+1}{4}\right)^2 б2A$$

$б^2$ A = 2 $б^2$ Gca

$$б2\ Sca = \left(\frac{F+1}{2}\right)^2 б2D$$

$б^2$G = $б^2$A + $б^2$D

$б^2$P = $б^2$G + $б^2$E

dominant variation = $б^2$D

Variance return to general combining ability=$б^2$Gca

Variance return to specific combining ability=$б^2$Sca = Phenotypic variation = $б^2$p

Genetic variation= $б^2$G

As the, Environmental variation = $б^2$E

Additional variance due to Lines line = $б^2$L

Additional variance due to Testers = $б^2$t

The degree of inheritance in the broad sense (h^2.b.s) and narrowness (h^2.n.s) and the Dominant (ā) rate were estimated as follows:

$$\%H^2_{B.S} = \frac{б2G}{б2P} \times 100$$

$$\%H^2_{n.s} = \frac{б2A}{б2P} \times 100$$

$$ā = \sqrt{\frac{2б2D}{б2A}}$$

Hybrid vigour %: was estimated for all studied traits from of the mean replication by using the following equation:

$$Heterobeletiosis\ \% = \frac{F1^- - BP^-}{BP^-} \times 100$$

As the, Hybrid vigour = Heterobeletiosis

$F1^-$ = The first generation rate

BP^- = Best rate of parents

Standard errors for the effect of combining ability was estimated in method which explained by (20).

S.E. ($\hat{g}i - \hat{g}j$) Line

$$S.E.(g\hat{\ }i - g\hat{\ }j)\ Tester = \sqrt{\frac{2mse}{rL}}$$

$$S.E.(S\hat{\ }ij - S\hat{\ }ik) = \sqrt{\frac{2mse}{r}}$$

RESULTS AND DISCUSSION

Table 2 analysis of variance showed that mean highly significant for traits such as grain yield, 50% silking, leaf area_(cm^2), number of rows .ear^{-1}, number of grains. ear^{-1}, 1000 kernel weight.gm, plant yield. gm^{-1} as for the mean values of the parents against the crosses which were significant at (P<0.01)for 50% silking and grain yield but the mean squares of crosses varied with a significant difference (P<0.01) for all studied traits, mean squares tester varied at (P<0.01)for all traits except number of grains. row^{-1} was not significant, aswellas the differences between the lines × tester interaction varied in the mean squares at (P<0.01)for all traits. Mustafa(18) and Ramadhan (19) have study confirmed that there were significant differences between genotypes, This allows us to continue to study their genetic behavior. Table (3) showed the mean squares for parents and single crosses for those studied traits, there were significant differences between the genotypes and their single crosses, parent (1) was superior which gave the lowest value among the parents in the days to 50% silking and number of rows.ear^{-1}. The parent (7) was superior in the number of grains per row and number of grains yield per plant while the parent (6) is superior in 1000 kernel weight, hybrid (3 × 8) gave it the least time for silking was 51.66 day, while hybrid (1 x 7) gave the highest number of grains. row^{-1} equal 40.26 and the hybrid (3 × 7) gave the highest number of rows.ear^{-1} was 17.73. The hybrid (1×6) showed a superiority in leaf area equal 585.28 cm^2, 1000 kernel weight 343.68 gm and plant yield 222.29 gm. this hybrid did not differ significantly with the crosses (1 × 7) and (3 × 7) this is consistent with the findings of both (10, 12) showed significant differences between single crosses and their parents for several studied traits.

Table 2. Analysis of variance of growth and yield traits

		(Mean Squares) M.S					
S.O.V	**Df**	**number of days to 50% silking**	**leaf area (cm^2)**	**Number of rows.ear^{-1}**	**Number of kernel. ear^{-1}**	**1000 kernel weight (gm)**	**Yield. plant^{-1}**
Replication	2	0.43	1016.7	8.62	2.33	183.9	4.22
Genotypes	23	** 13.79	** 18849.0	** 3.88	** 19.84	** 2864.5	** 1556.9
Parents	7	** 5.75	** 4959.2	1.08	** 7.75	** 432.2	** 78.7
Parent× crosses	1	** 75.11	** 182027.3	** 25.84	** 258.24	** 48696.7	** 31844.7
Crosses	15	** 13.46	** 14452.3	** 3.72	** 9.60	** 944.1	** 227.5
Lines	3	** 14.30	** 21865.8	* 2.71	** 20.64	** 1842.92	** 237.7
Tester	3	** 27.36	** 6962.9	** 5.61	1.15	** 1693.5	** 117.5
Line×Tester	9	** 8.54	** 14477.6	** 3.43	** 8.72	** 394.8	** 260.7
Residual	46	0.43	308.68	0.55	2.19	11.71	24.79

***and **Significant at level of probability(P<0.05) and (P<0.01)Sequentially.**

Table 3. means of varieties

Parents and crosses	Number of days to 50 silking	leaf area (cm^2)	Number of rows.ear^{-1}	Number of kernel.ear^{-1}	1000 kernel weight (gm)	Yield.plant^{-1}
1	51.66	330.31	15.53	31.56	264.88	159.55
2	55.00	417.12	14.56	32.33	273.37	162.21
3	54.33	353.93	14.43	33.49	264.86	161.94
4	53.66	415.45	14.90	34.53	254.56	160.84
5	52.66	424.73	14.86	31.88	278.44	158.05
6	55.66	347.95	13.43	30.34	294.56	147.86
7	54.33	359.37	14.26	35.24	273.63	164.98
8	52.33	326.56	14.53	32.94	264.64	160.43
1 x 5	50.33	315.93	16.23	36.67	311.79	203.15
1 x 6	53.00	407.28	17.46	36.51	327.68	222.29
1 x 7	53.00	478.23	17.03	40.26	307.53	217.15
1 x 8	50.66	466.09	15.40	38.25	316.84	198.24
2 x 5	52.33	489.88	14.30	36.78	345.97	193.51
2 x 6	50.33	487.46	16.03	37.26	341.57	203.87
2 x 7	58.33	441.42	16.56	33.70	329.05	195.59
2 x 8	50.66	529.60	16.10	34.44	349.03	206.05
3 x 5	51.33	430.26	15.40	35.84	335.64	202.90
3 x 6	49.66	471.58	14.16	38.02	315.52	191.57
3 x 7	51.33	570.27	17.73	39.42	300.71	216.64
3 x 8	48.66	585.63	14.90	38.56	313.50	198.06
4 x 5	50.33	593.00	16.76	36.77	331.47	210.75
4 x 6	51.00	474.77	14.56	34.82	353.14	202.50
4 x 7	53.33	467.39	16.00	35.53	297.26	202.55
4 x 8	51.33	448.65	14.73	36.10	343.90	200.73
L.S.D%5	1.15	28.84	1.21	2.43	5.61	8.17

Table 4 showed hybrid vigours for single crosses in the studied traits and combining ability on the basis of the best parents. Differences have emerged in Hybrid vigour values, as it was positive in some crosses and negative in others and that some of the crosses showed hybrid vigour desirable for some traits, It gave thirteen crosses negative hybrid vigour and to the significant of silking where the hybrid (1 × 6) gave the highest negative value of hybrid vigour of -8.52%, while the leaf area of all the crosses gave positive and significant hybrid vigour reached highest value (65.45%) at the hybrid (3 × 8) except for the hybrid (1 × 5) where it gave a negative Hybrid vigour, the hybrid (1 × 5) gave the highest positive Hybrid vigour to the number of rows. ear^{-1} (40.50%) while in the number of grains. row^{-1} the hybrid (1 × 8) was distinguished by giving higher positive hybrid vigour (16.12%) as for the weight of the 1000 kernel. Gm. The cross (2 x 5) gave higher positive hybrid vigour of 24.25%, on single plant bases, all the crosses gave positive hybrid vigour. The crosses(1 × 6) and (1 × 7) gave the higher value of hybrid vigour 39.32% and 31.62%, respectively for the best parents. It implies that hybrid vigour varies according to the parents, and it is not necessary to obtain a high hybrid vigour from high-value parents, that is, no consistent relationship between grain yield for parents and hybrid vigour (12, 21). The parents were evaluated by estimating the effects of the general combined ability (Table 5). It is noted that the parent (1) was combined by the significant and desirable direction of the number of rows. ear^{-1} and plant yield reached 0.70 and 6.11 sequentially, while the parent 2 combined in the desired direction and significant of 1000 kernel weight .plant^{-1} while the parent 3 showed a significant combined in the desired direction 50% silking, leaf area and number of grains per row , parent 5 showed combined in the undesirable direction of most of the traits while parent 6 combined in the unwanted direction except for the 1000 kernel weight. The parent 7 combined in the desired direction of all traits except for 50% silking, parent 8 showed a general combined ability and significant coalition desirable for 50% silking and leaf area. When estimating the specific combined ability (Table 6). The crosses 3 × 7 and 4 × 5 showed a special effect in combining the desired direction of all the studied traits, while the hybrid 3 × 6 showed a special combining with the unwanted trend of most Traits, and the hybrid 1 × 6 gave a desirable and general combined ability significant coalition in the grain yield. plant^{-1}. The cross 1 × 7 showed a specific combining ability in the desired direction of most studied traits and showed a positive trend for leaf area traits, weight 1000 kernel and plant yield. These results are consistent with the findings of (6, 7). These crosses showed a positive significant effect, while others show a negative and significant effect on the specific combined ability in the studied traits. As shown before, there are a variation between crosses in specific combining ability. The parents that have a positive and significant effect of general combining ability had given a significant effects in the same direction in the effects of their specific combined ability, Means the emergence of the dominant influence of the genes. If the general combination ability positive and significant for a characteristic and did not have any positive effect on the specific combining ability that is due to the additive effect of the genes in these traits, which is consistent with what it found (2,14), if the specific combined ability is more important than general combination ability and this means that genetic control is due to the dominant gene. Table 7 showed the values of variance components and heritability in the broad and narrow sense and the means of dominant degree of the studied traits. The ratio between components of the general combination ability to the components of the special combing ability was less than one in all the traits except for the leaf area; this confirms the importance of the dominant action of genes in controlling the inheritance of traits. As for heritability in broad sense, was high for the traits of the plant yield , the 1000 kernel weight and the 50% silking as it ranged between (76.56%, 95.09%) respectively, this was due to the increase in the genetic variation and the decrease in the value of environmental variability, which makes trait transmission to the F1 are more likely and heritability values ranged from 2.17% to (P<0.05) for plant yield and leaf area. This was due to a decrease in additive genetic variation, so it can be improved by hybridization. The dominant genetic variation values greater than additive genetic variation values in all studied traits except for the leaf area, it has been shown that the degree of dominance has increased in value to one true for all studied traits except leaf area, this indicates the presence effect of over dominance of genes that control inherited adjectives this is consistent with what they findings of (14). whose found that the ratio of the components of the variation of the general combination ability to the variation of the specific combing ability is less than one and the inheritance ratio is some high in the broad sense and low in the narrow sense and the degree of dominance is greater than one, which confirm the existence of the effect of over dominance controls of traits.

Conclusion

It is clear from these results that the components of the specific combining ability was larger than components of the general combined ability of all the studied traits, the parents (1, 6, and 7) were the best parents of the combination of grain yield by achieving the high values of the general combined ability for two lines (1, 7)**,** also that it is possible to use some parents which outperformed in their crosses development of crosses related to a specific combination ability to produce high grain yield, crosses (ZM12 x ZM51W) and (ZM12 x ZM43W) gave the highest hybrid vigour in grain yield also were superior in the plant grain yield and the dominance genetic variation was more important than the genetic variation additive.

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Table 4. Hybrid vigour for the best parents of the traits studied in maize

	Hybrid vigour %					
crosses	days to 50% silking	leaf area (cm^2)	rows.ear^{-1}	kernel.ear^{-1}	1000 kernel weight	Yield.plant^{-1}
1 x 5	-2.57	-25.61	40.50	15.02	11.97	28.53
1 x 6	2.59	17.05	12.42	15.68	11.24	39.32
1 x 7	2.59	33.07	9.65	14.24	12.38	31.62
1 x 8	-1.93	41.10	-0.83	16.12	19.61	23.56
2 x 5	-0.62	15.33	-3.76	13.76	24.25	19.29
2 x 6	-9.75	16.86	10.09	15.24	15.95	25.68
2 x 7	7.36	5.82	13.73	-4.37	20.25	18.55
2 x 8	-3.19	26.96	10.57	4.55	27.67	27.02
3 x 5	-2.52	1.30	3.63	7.01	20.54	25.29
3 x 6	-8.59	35.53	-1.87	13.52	7.11	18.29
3 x 7	-5.52	58.68	22.86	11.86	9.89	31.31
3 x 8	-7.01	65.46	2.54	15.13	18.36	22.30
4 x 5	-4.42	39.61	12.48	6.48	19.04	31.03
4 x 6	-4.95	14.27	-2.28	0.83	19.88	25.90
4 x 7	-0.61	12.50	7.38	0.82	8.63	22.77
4 x 8	-1.91	7.99	-1.14	4.54	29.95	24.80
S.E	1.09	10.84	2.28	3.15	4.47	7.17

Table 5. Effect of (GCA) of each parent of the studied traits

Varieties Parents	days to 50% silking	leaf area (cm^2)	rows.ear^{-1}	grains.ear^{-1}	1000 kernel weight	Yield.plant^{-1}
1	0.145	.61.7	0.70	1.11	-10.32	6.11
2	1.312	8.5	-0.09	-1.26	15.12	-4.34
3	-1. 352	35.8	-0.29	1.15	-9.95	-1.80
4	-0.104	17.3	-0.32	-1.00	5.15	0.03
S.E. Line	0.20	5.07	0.22	0.43	0.98	1.43
5	-0. 520	-21.3	-0.16	-0.30	4.93	-1.52
6	-0.604	-18.3	-0.27	-0.15	8.19	0.96
7	2.395	10.7	0.10	0.42	-17.65	3.88
8	-1.270	28.9	-0.56	0.03	4.53	-3.32
S.E. Tester	0.20	5.07	0.22	0.43	0.98	1.43

Table 6. Effect of (SCA) for each hybrid on the studied traits

crosses	days to 50% silking	leaf area (cm2)	Number of rows.ear^{-1}	of grains. ear^{-1}	1000 kernel weight	Yield. plant^{-1}
1×5	-0.87	-79.62	-0.13	-0.95	-9.10	-5.53
1×6	1.87	8.71	1.21	-1.26	3.53	11.12
1×7	-1.20	50.60	-0.50	1.92	9.22	3.06
1×8	0.20	20.30	-0.57	0.30	-3.65	8.64
2×5	-0.04	24.11	-1.28	1.53	-0.36	-4.72
2×6	-1.95	18.68	0.56	1.87	-8.02	3.15
2×7	2.96	-56.40	-0.17	-2.27	5.30	8.05
2×8	-0.95	13.60	0.90	-1.13	3.10	9.62
3×5	1.62	-62.85	0.01	-1.82	14.36	2.12
3×6	0.04	-24.53	-1.10	0.21	-9.01	11.68
3×7	-1.37	45.09	1.18	1.04	2.02	0.46
3×8	-0.29	42.29	-0.09	0.57	-7.37	0.90
4×5	-0.71	118.36	1.41	1.25	-4.90	3.13
4×6	0.04	-2.86	-0.67	-0.83	13.50	2.59
4×7	-0.37	-39.29	-0.51	-0.70	-16.53	5.47
4×8	1.04	-76.20	-0.23	0.26	7.92	0.07
S.E.(sij.ski)	0.53	14.34	0.61	1.21	2.80	4.06

Table 7. Values of genetic variation of studied traits

varieties Parent	days to 50% to silking	leaf area (cm^2)	rows.ear^{-1}	grains.ear^{-1}	1000 kernel weight	yield. plant^{-1}
σ2 Gca	0.17	0.02	0.01	0.03	19.07	1.15
σ2 Sca	2.70	0.01	0.958	2.17	127.7	78.66
σ2 Gca σ2 Sca	0.06	1.5	0.01	0.01	0.15	0.01
σ2 A	0.34	0.04	0.02	0.06	38.14	2.30
σ2D	2.70	0.01	0.958	2.17	127.7	78.66
σ2 G	3.04	0.05	0.978	2.23	168.84	30.96
σ2 E	0.43	0.11	0.557	2.19	11.71	14.79
σ2 P	3.47	0.16	1.535	4.42	177.55	25.73
h^2b.s	87.6	31.25	63.71	50.4	95.09	16.56
h^2n.s	9.80	25.0	1.30	1.35	21.48	.17
ā	4.24	0.70	9.78	80.50	3.66	3.27

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