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ESTIMATE OF HETEROSIS AND COMBINING ABILITY OF SOME WHITE INBRED LINES OF MAIZE (*Zea mays* L.)

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ABSTRACT

This research was carried out at the Experimental Farm, Faculty of Agric., Kafr El-Sheikh Univ. The aim of the experiment was to study heterosis and combining ability for the most important traits of maize (Tasselling and silking dates, plant and ear heights, ear length, ear diameter, number of rows/ear, number of kernels/row, 100 grain weight and grain yield (ardab/fed.) Seven inbred lines of corn were crossed in one half diallel cross in 2004. The resulted 21 single crosses in addition to three recommended commercial crosses, were grown in a randomized complete block design in 2005 season. The variation among single crosses were partitioned into gca and sca, using griffing's method 4 model 1. The results are summarized as follows:

1. Highly significant differences were found among the studied inbred lines, also the gca effects were significant for all studied traits and the sca effects also, were, significant, except for 100-grain weight.
2. The cross (P_5 x P_6) was the earliest for tasseling and silking dates. The crosses (P_3 x P_7) and (P_5 x P_7) were of desirable performance for plant and ear heights. Mean while the cross (P_1 x P_2) was the best cross for ear length and number of kernels per row and grain yield/fed. and cross (P_4 x P_6) for ear diameter and number of rows/ear and the single cross (P_1 x P_4) for 100-grain weight.
3. The gca/sca ratio revealed that importance of additive genetic variance in the inheritance of all studied traits, except plant height and number of rows/ear.
4. The best general combining ability for earliness were lines P_3, P_4, P_5, P_6 and P_7, while for grain yield ardab/fed. were lines P_1, P_2 and P_3.
5. Estimate of specific combining ability effects indicated that the best crosses were 3 x 4 for tasseling date, silking date and ear height, the cross P_2 x P_7 for plant height, the crosses P_3 x P_6, P_4 x P_7, P_4 x P_6, P_6 x P_7 and (P_1 x P_3) for ear length, ear diameter, number of rows per ear, number of kernels per row and weight and 100-kernels, respectively, while the cross (1 x 2) showed the best desirable sca effects for grain yield ard./fed.
6. The cross (P_5 x P_6) showed negative and significant useful heterosis for tasseling and silking dates relative to the earlier check, while the crosses (P_3 x P_7) and (P_5 x P_7) had negative and significant useful heterosis relative to the shortest check for plant and ear heights, respectively. The cross (P_1 x P_2) for ear length and number of kernels per row, (P_4 x P_6) for ear diameter and number of rows per ear, (P_1 x P_4) for weight of 100 kernels, and (P_1 x P_2) for grain yield ardab/fed. showed positive and significant heterosis relative to superior check in these traits.
7. The best cross (P_1 x P_2) was the superior one which significantly outyielded the three checks.

INTRODUCTION

Corn (*Zea mays* L.) is one of the major cereal crops in Egypt and the world, which ranks the third one surpassed only by wheat and rice.

In recent years, the major objective of maize breeding program in Egypt is to develop high yielding maize hybrids to cover the increasing consumption of maize in food, animal feeding and poultry industry. Estimation of genetic variance and its components are of great importance for the improvement of maize. The technique used extensively in maize breeding programs is aiming to classify parental lines in terms of their ability in the combination for producing hybrid of corn. The total genetic variation is portioned into the effects of general and specific combining ability (g.c.a. and s.c.a.) in this respect. General and specific combining abilities were first defined by Sparague and Tatum (1942) also Hallauer and Miranda (1981) stated that both general and specific combining ability effects should be taken in consideration when planning maize program to produce and release new inbreds and crosses. Several investigators studied the general and specific combining ability of growth yield and its attributes. Hassaballa *et al.* (1980), El-Hosary (989), Beck *et al.* (1991), El-Absawy (2000), Amer *et al.* (2003) and Abd El-Aal and Abdallah (2006), reported that gca was more important than sca. On the contrary Nawar *et al.* (1981), Sedhom (1992), Mostafa *et al.* (1996), Gaber (1997), Amer (2005) and Abd El-Aty and Darwish (2006) reported that sca was more important than g.c.a.

The main objectives of the present investigation are:

1. Identifying the best lines and their single crosses to be used in maize breeding programs.
2. Estimating general and specific combining abilities effects for newly developed inbred lines of white maize.
3. Estimating magnitude of heterosis (useful heterosis) relative to the best recommended commercial hybrids as checks.

MATERIALS AND METHODS

The present investigation was carried out at the Experimental Farm, Faculty of Agric., Kafr El-Sheikh University during 2004 and 2005 seasons, seven white maize inbred lines isolated from diverse origin of maize varieties and composites in the breeding program of Agronomy department. Faculty of Agric. Kafr El-Sheikh Univ. and also from the national maize program, A.R.C. named as; Line 101 (P_1), line 102 (P_2), line 103 (P_3), line 104 (P_4), line 105 (P_5), line 106 (P_6) and line 107 (P_7) were used in this study.

In 2004 season, all possible cross combinations without reciprocals were made between the seven inbred lines giving a total of 21 crosses. In 2005, the 21 F_1 crosses and three checks (S.C.10, T.W.C. 310 and T.W.C. 324) were grown in a randomized complete block design with four replications. Plot size was two rows, 5 m long and 70 cm part with 25 cm hill spacing.

All cultural practices were applied as recommended. Random samples of 10 guarded plants in each plot which is designated as field plot were taken to evaluate; tasseling date, silking date (day). Plant height (cm), ear height (cm), ear length (cm), ear diameter (cm), number of rows/ear, number of kernels/row, weight of 100-grains (gm) and grain yield/plot which was transferred later to (ardab/fed.) (one ardab = 140 kg of grains) adjusted to 15.5% moisture content. General and specific combining ability estimates were measured using Griffing's (1956) diallel cross analysis designated as method-4, model-1. Agronomical or the useful heterosis (superiority) was measured by comparing each cross with each of the check having the best desired trait in comparison (i.e. earliness, shortness …. etc.).

RESULTS AND DISCUSSION

Analysis of variance for all the studied traits are presented in Table (1) indicating that there were highly significant differences within all the studied traits indicating the presence of genetic variability in the material under study which lead to estimate combining ability. The mean squares associated with general (gca) and specific (sca) combining abilities were highly significant for all the studied traits except sca for 100-grain weight, indicating that both additive and non-additive gene action were involved in the inheritance of these traits.

The ratios of gca/sca exceeded the unit for all studied traits except of plant height (cm) and number of rows/ear, showing that additive gene effects were more important than that of dominance gene effects in the inheritance of these traits. These results are similar with those obtained by Nawar *et al.* (1988), Gomaa and Shaheen (1994), El-Sherbieny *et al*. (1996).

Mean performance of the 21 F_1 crosses and the three checks for all the studied traits are presented in Table (2). The cross (P_5 x P_6) was the earlier cross, while the crosses (P_1 x P_2) and (P_1 x P_4) were the latest out of 21 F_1 crosses.

Regarding to plant height, twelve single crosses were more shorter than the three checks and the shorter cross was the single cross (P_3 x P_7), while eight single crosses have lower ear placement than the three cheeks (lowest ear) for ear height and the best cross for lowest ear placement was the single cross (P_5 x P_7).

The mean values of ear length for the F_1 crosses ranged from 16.3 cm for cross (P_5 x P_6) to 21.7 cm for cross (P_1 x P_2) with an average of 19.6 cm. While the mean of the three checks was 20.45 cm which is larger than the grand mean of the crosses.

With respect to ear diameter (cm), the mean values varied from 4.4 cm for crosses (P_5 x P_7) and (P_2 x P_3) to 5.4 cm for cross (P_4 x P_6) with an average of 4.8 cm while the mean of the three checks were 4.86 cm which is larger than the mean of the crosses. Regarding to number of rows/ear, the highest mean value of the F_1 crosses was obtained from the cross (P_4 x P_6) (16.0), while the lowest mean value was obtained from the cross (P_5 x P_6) (12.3). The mean values of number of kernels/row varied from 35.8 for cross (P_3 x P_4) to 47.0 for cross (P_1 x P_2) with an average of 41.6 while the mean of the three checks were 42.7 which is larger than the grand mean of the crosses. The mean values of 100-grain weight ranged from 28.4 gm for cross (P_5 x P_7) to 37.0 gm for cross (P_1 x P_4) with an average of 32.6 gm while the mean of the three checks was 34.3 gm which is larger than the grand mean of the crosses, also the crosses (P_1 x P_2) and (P_1 x P_6) were superior in weight of 100-grain than the three checks.

Regarding to grain yield (ardab/fed.), the mean values for the F_1 crosses ranged from 27.4 (ardab/fed.) for cross (P_5 x P_6) to 40.75 (ardab/fed.) for cross (P_1 x P_2), also nine out of 21 crosses outyielded the grand mean.

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However, only three crosses significantly surpassed the best commercial cheek SC10 (37.6 ardab/fed.) and these crosses are P_1 x P_2 (40.75 ardab/fed.), P_1 x P_4 (38.1 ardab/fed.) and P_1 x P_7 (37.8 ardab/fed.), where the differences among the first cross and the three checks were only significant while the other two crosses have no significant differences with the three checks.

The estimates of the general combining ability effects of the parental inbreds for all studied traits are presented in Table (3).

The results revealed that gca effects showed desirable significant negative values for tasseling date, for the inbreeds 3, 5, 6, and 7 toward earliness. While the inbred lines 2, 3, 5, 6 and 7 exhibited significant negative gca effects for silking date. These inbred lines were considered the best, combiners for earliness.

The gca effects for plant height ranged from -11.97 for the line 3 to 15.23 for the line 1, and the inbreds 2, 3 and 6 showed significant negative desirable gca effects for plant height (toward shortness). On the other hand, the line P_3, P_5, P_6 and P_7 showed desirable significant negative gca values for ear height (toward lower ear placement). These inbred lines were considered the best combiners for the above-mentioned traits.

The parental lines P_1 and P_2 expressed highly significant positive gca effects for ear length and number of kernels/row.

For number of rows/ear; lines 2, 4 and 7 were considered the good combiners, as they exhibited significant positive gca effects. Inbred lines 1 and 4 showed highly significant positive gca effects for 100-grain weight.

Regarding to grain yield (ardab/fed.), the lines P_1, P_2 and P_4 had significant positive gca effects, these lines possessed favorable breeding estimates (good combiner) and it could be used as good breeding materials in hybrid breeding program. These findings were also found by El-Shamarka (2000), Amer *et al.* (2003), Devi and Prodhan (2004), Amer (2005) and Abd El-Aal and Abdallah (2006) and Abd El-Aty and Darwish (2006).

The estimates of specific combining ability effects (sca) for the F_1 crosses for all the studied traits are shown in Table 4. Significant desirable sca effects were detected for the 21 crosses where for tasseling date 4 crosses, silking date 6 crosses, plant height 6 crosses, ear height 3 crosses, ear length 4 crosses, number of rows/ear 4 crosses, number of kernels/row 3 crosses, 100-grain weight one cross and 6 crosses for grain yield ard./fed. However, it could be concluded that the best desirable crosses for each trait could be mentioned as; the crosses (P_3 x P_4) for tasseling and silking dates towards earliness, (P_2 x P_7) for plant height, (P_5 x P_7) for ear height, (P_3 x P_6) for ear length, (P_4 x P_6) for number of rows/ear, (P_6 x P_7) for number of kernels/row, (P_1 x P_3) for 100-grain weight and (P_1 x P_2) for grain yield ardab/fed. These crosses can be of practical importance in maize breeding programs.

Useful heterosis relative to the superior check for all the studied traits are presented in Table 5.

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The useful or agronomic or economic heterosis refer to the superiority of any cross under study over the best check (or all cheeks) relative to the desired trait (i.e. earliness, shortness of plant or ear height …. etc.). so, with respect to tasselling and silking dates, useful heterosis relative to the earlier check (T.W.C. 310) ranged from -8.10 and -8.50 for cross P_5 x P_6 to 6.50 and 5.70 for cross P_1 x P_2, respectively. Also there were 9 crosses showed desirable significant negative useful heterotic effects.

Highly significant negative desirable heterotic effect values relative to the shortest check (T.W.C. 324) were shown in single crosses (P_2 x P_7), (P_3 x P_4), (P_3 x P_7) and (P_4 P_6) for plant height, the crosses (P_3 x P_7), (P_5 x P_6) and (P_5 x P_7) for ear height. The crosses (P_2 x P_4), (P_4 x P_5), (P_4 x P_6) and (P_4 x P_7) gave desirable heterotic effects for ear diameter. The crosses (P_1 x P_2) and (P_4 x P_6) gave the highest desirable and significant positive values of economic heterosis for number of rows/ear relative to the superior check (T.W.C. 310).

With regard to number of kernels/row, the best crosses were (P_1 x P_2) and (P_1 x P_3) where they gave significant positive useful heterosis relative to the superior check (S.C. 10).

Concerning the grain yield ardab/fed., the useful heterosis of each cross of the 21 crosses relative to each of the three checks were calculated and the results are presented in Table (5).

It could be concluded from the Table 5, the best superior cross under study is (P_1 x P_2) which outyielded by percentages of 8.37, 10.37 and 10.13% over three checks SC10, TWC310 and 324 respectively.

This result indicates that this cross (hybrid) must be evaluated more comparing with the highest yielded commercial hybrids (single or three crosses) to confirm its superiority which leads to be useful hybrid and could be added to the commercial hybrids.

Significant negative heterosis effects for earlines was previously detected by Abd El-Aty (1987), El-Hosary *et al.* (1999), El-Absawy (2000) and Abd El-Aty and Darwish (2006), while significant positive heterotic effects for grain yield/plant ardab/fed. and other agronomic traits was previously detected by Nawar *et al.* (1990); El-Hosary *et al.* (1999); El-El-Absay (2000); Abd El-Aty and Darwish (2006).

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تقدير قدرة التآلف وقوة الهجين لبعض سلالات الذرة الشامية البيضاء

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أجريت هذه الدراسة بالمزرعة البحثية بكلية الزراعة ـ جامعة كفرالشيخ بهدف دراسة القدرة على الإئتلاف وقوة الهجين لمجموعة من سلالات الذرة الشامية. وتم فى الموسم الأول ٢٠٠٤ التهجين الدورى فيما بينها وفى الموسم الثانى ٢٠٠٥ تم زراعة نباتات الجيل الأول الهجين بالإضافة إلى ثلاثة هجن تجارية للمقارنة (هجين فردى ١٠ ، هجين ثلاثى ٣١٠ ، وهجين ثلاثى ٣٢٤) فى نظام القطاعات الكاملة العشوائية فى أربعة مكررات. حيث تمت دراسة الصفات التالية: عدد الأيام حتى ظهور ٥٠% من النورة المذكرة وعدد الأيام حتى ظهور ٥٠% من الحراير وارتفاع النبات (سم) وارتفاع الكوز (سم) ، وطول الكوز (سم) ، وقطر الكوز (سم) ، وعدد السطور بالكوز ، وعدد الحبوب فى السطر ، ووزن المائة حبة (جم) بالإضافة إلى محصول الحبوب (أردب/فدان).

ويمكن تلخيص النتائج فيما يلى:

١- وجود اختلافات عالية المعنوية بين التراكيب الوراثية وكان تباين القدرة العامة على الخلط معنوى وكذلك القدرة الخاصة كانت معنوية لجميع الصفات ماعدا صفة وزن المائة حبة.

٢- كان الهجين الفردى (٥ × ٦) من أبكر الهجن ، والهجينان (٣ × ٧) ، (٥ × ٧) من أفضل الهجن لصفتى قصر ارتفاع النبات والكوز ، أما الهجين (١ × ٢) فكان من أفضل الهجن فى صفات طول الكوز وعدد حبوب الصف ومحصول الحبوب للفدان وتفوق الهجين الفردى (٤ × ٦) فى صفتى قطر الكوز وعدد الصفوف للكوز وكان الهجين (١ × ٤) الأعلى فى صفة وزن المائة حبة.

٣- كانت نسبة القدرة العامة إلى القدرة الخاصة أكبر من الواحد مما يشير إلى زيادة أهمية الفعل المضيف لجميع الصفات المدروسة عدا صفتى ارتفاع النبات وعدد صفوف الكوز حيث كان الفعل غير المضيف هو الأكثر أهمية.

٤- كانت أحسن السلالات للقدرة العامة على الإئتلاف لصفة التبكير هى السلالات ٣ ، ٤ ، ٥ ، ٦ ، ٧ فى حين كانت السلالات ١ ، ٢ ، ٤ الأفضل فى القدرة العامة على الإئتلاف لصفة محصول الفدان من الحبوب.

٥- أظهرت نتائج القدرة الخاصة على الإئتلاف المرغوبة أن الهجين (٣ × ٤) كان الأفضل فى التبكير وقصر ارتفاع الكوز والهجين (٢ × ٧) لصفة قطر النبات والهجن (٣ × ٦) ، (٤ × ٧) ، (٤ × ٦) ، (٦ × ٧) ، (١ × ٣) لصفات طول الكوز ، قطر الكوز ، عدد الصفوف للكوز ، عدد الحبوب للصف وصفة وزن المائة حبة على الترتيب. فى حين كان الهجين الفردى (١ × ٢) أفضل الهجن فى القدرة الخاصة على الإئتلاف لصفة محصول الحبوب (أردب/فدان).

٦- أظهرت النتائج أن الهجين (٥ × ٦) أعطى قوة هجين معنوية وسالبة منسوبة إلى هجين المقارنة المبكر بالنسبه لصفات عدد الأيام حتى ظهور ٥٠% من النورة المذكرة ، ٥٠% من الحراير بينما أظهرت الهجن (٣ × ٧) ، (٥ × ٧) قوة هجين معنوية وسالبة كنسبة إلى هجين المقارنة القصير لارتفاع النبات (سم) وارتفاع الكوز (سم) على الترتيب بينما الهجين (١ × ٢) لصفة طول الكوز وعدد الحبوب بالسطر والهجين (٤ × ٦) بالنسبه لصفة قطر الكوز وعدد الصفوف بالكوز والهجين (١ × ٤) بالنسبه لصفة وزن المائة حبة والهجين (١ × ٢) لصفة محصول الفدان من الحبوب فقد أعطوا قوة هجين موجبة ومعنوية منسوبة إلى هجين المقارنة المتفوق فى هذه الصفات.

٧- يعتبر الهجين (١ × ٢) من أفضل الهجن مقارنة بجميع الهجن المستخدمة فى المقارنة لصفة محصول الحبوب.

Table (1): Observed mean squares for genotypes as well as general and specific combining ability and their ratio in diallel analysis for all the studied traits.

S.O.V	d.F	Tasseling date (day)	Silking date (day)	Plant height (cm)	Ear Height (cm)	Ear length (cm)	Ear diameter (cm)	No of rows /ear	No. of kernels/ row	100-grain weight	Grain yield ardab /fed.
Replication	3	27.90**	26.28**	1099.65**	366.94**	3.38*	0.192**	1.85*	17.64**	18.58**	9.14*
Genotypes	23	31.94**	36.51**	2438.86**	850.44**	7.40**	0.260	3.89**	42.50**	25.48**	81.79**
Crosses	20	31.25**	31.47**	1000.41**	826.99**	6.76**	0.294**	4.16**	44.34**	20.73*	43.19**
g.c.a	6	84.95**	77.9**	1868.92**	1849**	15.58**	0.732**	8.49**	107.37**	61.02**	106.67**
s.c.ca	14	8.24**	11.56**	628.2**	388.96**	2.97**	0.108*	2.30**	17.33**	3.46	15.98**
Checks	2	8.07**	16.74**	15972.7**	739.72*	1.93	0.043	0.84	9.02	19.87**	3.12
cr.v.ch.	1	93.6**	176.9**	4140.2**	1540.9	31.20**	0.015	4.80**	72.61**	131.79**	1011.36**
Error	69	1.31	0.822	195.19	173.28	0.616	0.052	0.413	4.18	2.65	1.92
g.c.a/s.c.a		2.13	1.36	0.628	1.04	1.09	1.51	0.76	1.30	4.3	1.4

***, ** Significant and highly significant at 0.05 and 0.01, respectively**

Table (2): Mean performance of 21 crosses resulted from seven inbred lines of maize and three cheeks for all the studied traits.

Crosses	Tasseling date (day)	Silking date (day)	Plant height (cm)	Ear height (cm)	Ear length (cm)	Ear diameter (cm)	No of rows/ear	No. of kernels/ row	100-grain weight	Grain yield ardab/fed.
P_1 x P_2	68.4	70.5	298.2	173.7	21.7	4.9	15.6	47.0	36.20	40.75
P_1 x P_3	65.3	68.2	271.3	165.0	20.9	4.8	15.2	46.8	33.40	32.30
P_1 x P_4	68.3	70.2	305.6	178.3	19.4	5.0	14.4	43.6	37.00	38.10
P_1 x P_5	64.0	66.0	295.7	162.3	20.7	4.7	14.7	44.5	31.80	31.90
P_1 x P_6	67.0	67.8	272.9	154.5	18.4	5.0	13.8	41.5	36.60	33.40
P_1 x P_7	67.4	69.1	303.0	164.9	21.6	4.8	15.3	46.2	35.50	37.80
P_2 x P_3	61.2	63.3	286.8	175.8	20.4	4.4	13.3	44.6	32.20	31.40
P_2 x P_4	66.2	68.3	292.7	171.9	20.5	5.3	15.3	42.3	34.10	34.10
P_2 x P_5	61.0	62.3	282.9	167.1	20.9	4.7	14.5	45.0	30.00	31.40
P_2 x P_6	61.2	62.3	283.6	164.6	19.2	4.8	14.6	41.0	31.50	31.50
P_2 x P_7	62.0	63.0	257.0	158.0	19.2	4.9	14.8	39.7	30.70	30.90
P_3 x P_4	60.5	63.5	259.3	140.1	18.8	4.9	14.8	35.8	33.10	28.60
P_3 x P_5	61.5	64.4	267.0	150.0	19.9	4.5	14.1	40.5	30.30	29.30
P_3 x P_6	62.9	65.0	271.7	149.5	19.4	4.6	13.2	41.5	32.50	31.60
P_3 x P_7	60.3	62.4	254.6	134.8	19.4	4.9	13.6	39.3	31.40	28.70
P_4 x P_5	62.7	65.0	287.0	159.1	19.2	5.2	15.5	38.1	32.30	32.40
P_4 x P_6	63.2	65.9	259.0	145.1	18.2	5.4	16.0	35.9	32.70	31.80
P_4 x P_7	63.3	66.0	293.8	170.9	20.2	5.2	15.7	39.0	33.00	32.10
P_5 x P_6	59.0	61.0	264.9	132.5	16.3	4.7	12.3	39.3	30.20	27.40
P_5 x P_7	60.8	63.0	272.4	131.8	18.7	4.4	14.5	38.7	28.40	27.80
P_6 x P_7	64.0	67.2	268.5	150.1	18.0	4.7	14.3	42.9	31.60	33.00
Checks										
S.C. 10	66.0	68.3	297.1	171.7	20.4	4.8	14.2	44.0	36.0	37.60
T.W.C. 310	64.2	67.5	290.7	163.7	20.6	4.9	14.5	43.2	34.0	36.80
T.W.C. 324	64.3	66.7	283.2	154.2	20.3	4.9	14.2	41.0	33.1	37.00
L.S.D. 0.05	1.85	2.35	23.36	17.09	1.50	0.32	1.12	2.82	3.22	3.20
0.01	2.46	3.13	31.03	22.70	2.00	0.42	1.49	3.75	4.28	4.37

Table (3): Estimates of general combining ability effects of parental inbred lines for all studied traits.

Inbreeds		Tasseling date (day)	Silking date (day)	Plant height (cm)	Ear height (cm)	Ear length (cm)	Ear diameter (cm)	No of rows/ear	No. of kernels/ row	100-grain weight	Grain yield ardab/fed.
Line 101 (P_1)		4.071**	3.822**	15.23**	11.17**	1.05**	0.017	-0.039	4.015**	2.98**	4.126*
Line 102 (P_2)		-0.008	-0.597**	-6.01*	13.65**	0.897**	-0.023	0.316*	2.018**	-0.174	1.295**
Line 103 (P_3)		-1.668**	-1.177**	-11.97*	-5.53*	-0.2374	-0.0203**	-1.004**	-0.182	-0.534	-2.223**
Line 104 (P_4)		0.831**	1.243**	-5.33	-4.51	-0.225	0.377**	1.035**	-2.964**	1.326**	0.805**
Line 105 (P_5)		-2.219**	-2.197**	-0.196	-8.01**	-0.345*	-0.183**	-0.184	-0.659	-2.514**	-2.575**
Line 106 (P_6)		-0.548*	-0.697**	-10.11**	-9.31**	-1.585**	0.037	-0.464**	-1.484**	-0.094	-0.875**
Line 107 (P_7)		-0.459*	-0.397*	-4.32	-6.47*	-0.065	-0.023	0.340*	-0.745	-0.099	-0.555
L.S.D. g_i	0.05	0.473	0.375	5.78	5.45	0.324	0.094	0.266	0.846	0.673	0.570
	0.01	0.497	0.497	7.69	7.21	0.432	0.125	0.353	1.120	0.896	0.760
L.S.D. g_i-g_j	0.05	0.722	0.573	8.83	8.32	0.496	0.144	0.406	1.29	1.029	0.870
	0.01	0.961	0.762	11.75	11.00	0.660	0.191	0.504	1.71	1.369	1.160

***, ** Significant and highly significant at 0.05 and 0.01, respectively**

Table (4): Estimates of specific combining ability effects for F_1 crosses in all the studied traits.

Crosses	Tasseling date (day)	Silking date (day)	Plant height (cm)	Ear height (cm)	Ear length (cm)	Ear diameter (cm)	No of rows /ear	No. of kernels/ row	100-grain weight	Grain yield ardab/fed.
P_1 x P_2	0.997*	1.827**	-1.50	-8.26	0.10	0.053	0.903**	-0.621	0.793	2.599**
P_1 x P_3	-0.443	0.107	-10.22**	2.22	0.001	0.133	-0.877**	1.379	1.647*	-1.775**
P_1 x P_4	0.057	-0.313	6.58*	5.48	-1300**	-0.247**	-1.017**	0.962	0.093	0.989
P_1 x P_5	-1.193*	-1.079**	2.21	2.00	0.42	0.013	0.503	-0.440	-1.267	-1.831**
P_1 x P_6	0.137	-0.773	-10.68**	-4.50	-0.64*	0.093	-0.117	-2.619**	1.113	-2.031**
P_1 x P_7	0.447	0.227	13.63**	3.06	1.04**	0.047	0.603*	1.342	0.913	2.049**
P_2 x P_3	-0.463	-0.373	14.30**	10.54*	-0.34	-0.227*	-0.432	1.176	0.313	0.199
P_2 x P_4	2.037**	2.207**	2.90	-3.40	0.26	0.093	-0.472	1.660*	0.353	-0.180
P_2 x P_5	-0.113	-0.353	-1.37	4.32	0.78*	0.053	-0.052	2.069**	0.093	0.501
P_2 x P_6	-1.583**	-1.853**	8.84**	3.12	0.32	-0.067	0.328	-1.122	-0.827	-1.130*
P_2 x P_7	-0.873	-1.453**	-23.15**	-6.32	-1.20**	0.093	-0.277	-3.161**	-0.737	-2.02**
P_3 x P_4	-2.003**	-2.013**	-12.52**	-16.02**	-0.82	-0.127	0.348	-2.641**	-0.287	-2.161**
P_3 x P_5	2.047**	2.327**	0.71	6.40	0.40	0.033	0.868**	0.134	0.753	1.919**
P_3 x P_6	1.77**	1.427**	15.32**	7.20	1.14**	-0.087	0.248	1.581	0.533	2.519**
P_3 x P_7	-0.913	-1.473**	-7.57*	-10.34*	-0.38	0.273**	-0.157	-1.361	0.333	-0.701
P_4 x P_5	0.747	0.507	3.413**	5.46	0.20	0.153	0.228	0.137	0.893	1.990**
P_4 x P_6	-0.423	-0.093	-14.68**	-7.24	0.44	0.133	1.008**	-1.239	-1.127	-0.310
P_4 x P_7	-0.413	-0.293	14.33**	15.72**	0.92**	0.007	-0.097	1.122	0.073	-0.330
P_5 x P_6	-1.573**	-1.553**	-3.25	-7.32	-1.34**	-0.007	-1.472*	-0.144	0.213	-1.330*
P_5 x P_7	0.087	0.147	-1.69	-10.86**	0.46	-0.247**	-0.077	-1.484	-0.687	-1.250*
P_6 x P_7	1.667**	2.847**	4.47	8.74*	0.08	-0.067	0.003	3.542**	0.093	2.250**
L.S.D. Sij 0.05	0.933	0.740	5.780	8.32	0.640	0.185	0.524	1.66	1.321	1.130
0.01	1.241	0.984	7.690	11.00	0.852	0.247	0.691	2.21	1.767	1.500
L.S.D.Sij-Sij 0.05	1.252	0.993	15.30	14.40	0.859	0.249	0.704	2.23	1.783	1.520
0.01	1.665	1.321	20.35	19.10	1.143	0.331	0.936	2.97	2.371	2.020

***, ** Significant and highly significant at 0.05 and 0.01, respectively**

Table (5): Percentage of useful heterosis (superiority) relative to the superior check (between brackets) for the desired trait for all the studied traits.

Characters Crosses	Tasseling date TWC (310)	Silking date TWC (324)	Plant height (cm) TWC (324)	Ear height (cm) TWC (324)	Ear length (cm) TWC (310)	Ear diameter (cm) TWC (310)	No of rows TWC (310)	No. of kernels row SC (10)	100-grain weight (SC10)	Grain yield ardab/fed.		
										SC(10)	TWC(310)	TWC(324)
P_1 x P_2	6.50**	5.70**	5.30	12.60	5.30	0.00	7.60*	6.80*	0.60	8.37*	10.73*	10.13
P_1 x P_3	1.70	2.20	-4.20	7.00	1.50	-2.00	-13.8**	6.40*	-7.20	-14.1**	-12.2**	-12.7**
P_1 x P_4	6.40**	5.20**	7.90	15.66**	-5.80	2.00	-0.70	-0.90	2.80	1.3	3.5	3.0
P_1 x P_5	-0.30	1.00	4.40	5.30	0.50	-4.10	1.40	1.10	-11.70**	-15.2**	-13.3**	-13.8**
P_1 x P_6	4.40**	1.60	-3.60	0.20	-10.7**	2.00	-4.80	-5.70	1.70	-11.2*	-9.2*	-9.7*
P_1 x P_7	5.00**	3.60**	7.00	6.90	4.90	-2.00	5.50	5.00	-1.40	0.5	2.2	2.2
P_2 x P_3	-4.70**	-5.10**	1.30	14.0**	-1.00	-10.2**	-8.30*	1.40	-10.60*	-16.5**	-14.7**	-15.1
P_2 x P_4	3.10*	2.140	3.40	11.50*	-0.500	8.20**	5.50	-3.90	-5.030	-9.3*	-7.3	-7.8
P_2 x P_5	-5.00**	-6.60**	-0.10	8.410	1.50	-2.10	0.00	2.30	-16.7**	-16.5**	-14.7**	-15.1**
P_2 x P_6	-4.470**	-6.60**	0.10	6.740	-6.80	-2.00	0.70	-6.80*	-12.5**	-16.2**	-14.4**	-14.9**
P_2 x P_7	-3.40*	-5.50**	-9.30*	2.50	-6.80	0.00	2.10	-9.80**	-14.7**	-17.2**	-16.0**	-16.5**
P_3 x P_4	-5.80**	-4.80**	-8.40*	-9.10	-8.70*	0.00	2.10	-18.60**	-8.10	-23.9*	-22.3**	-22.7**
P_3 x P_5	-4.20**	-3.40*	-5.70	-2.70	-3.40	-8.20**	-2.80	-7.90*	-15.8**	-22.1**	-20.4**	-20.8**
P_3 x P_6	-2.30	-2.50	-4.10	-3.00	-5.80	-6.10*	-8.90*	-5.70	-9.70*	-16.0**	-14.1**	-14.6**
P_3 x P_7	-6.10**	-6.40**	-10.1**	-12.96*	-5.80	0.00	-6.20	-10.70**	-12.8**	-23.7*	-22.0**	-22.4**
P_4 x P_5	-2.30	-2.50	1.30	3.20	-6.80	6.10*	6.90	-13.40**	-10.30*	-13.8**	-12.0**	12.4**
P_4 x P_6	-1.70	-1.20	-8.50*	-5.90	-11.7**	11.20**	10.3**	-18.40**	-9.20**	-15.4**	-13.6**	-14.1**
P_4 x P_7	-1.60	-1.00	3.70	10.80	-1.90	6.10*	8.30	-11.40*	-8.30	-14.6**	-12.8**	-13.2**
P_5 x P_6	-8.10**	-8.50**	-6.50	-14.1*	-20.9**	-4.10	-15.2**	-10.70**	-16.1**	-27.1**	-25.5**	-25.9**
P_5 x P_7	-5.50**	-5.50**	-3.80	-14.5*	-9.20*	-10.20**	0.00	-12.00***	-21.1**	-26.1**	-24.5**	24.9**
P_6 x P_7	-0.30	0.70	-5.20	-2.70	-12.6**	-4.10	-1.40	-2.50	-12.20*	-12.2**	-10.3*	-10.8*

***, ** Significant and highly significant at 0.05 and 0.01, respectively**

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