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HETEROSIS AND COMBINING ABILITY FOR YIELD AND YIELD COMPONENTS IN MAIZE (*Zea mays* L.)

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ABSTRACT

This study was conducted at the Experimental Farm , of the Agricultural Research, Faculty of Agriculture , Omer Al-Mukhtar University , Libya, during summer of the two growing seasons 2013 and 2014 . A half diallel crosses comprising six inbred lines yielding 15 hybrids were studied for nine traits to estimate heterosis and the nature of gene action associated with it in both parents and their hybrids. The analysis of variance for combining ability revealed that both general combining ability (gca) and specific combining ability (sca) variances were highly significant for most of the studied traits indicating the importance of additive as well as non-additive types of gene action in controlling these traits. However , variances due to sca were higher in magnitudes than gca for all the studied traits except plant height . GCA to SCA ratios were less than one for most of the traits except for plant height indicating a preponderance of non additive genetic effects over additive effects .

Parent P_5 among the parental lines was identified as the best general combiner for ear weight /plant (g), kernel weight /plant (g), ear weight and grain yield/ha (ton) , P_2 was the best general combiner for 100-kernal weight and P3 for oil (%) and P_1 was identified as the best general combiner for number of ears .

Four crosses ($p_2 \times p_3$, $p_2 \times p_4$, $p_3 \times p_4$ and $p_4 \times p_6$) showed significant positive SCA effects for ear yield (ton) **/**ha and seven crosses ($p_1 \times p_2$, $p_1 \times p_5$, $p_2 \times p_5$, $p_3 \times p_4$, $p_3 \times p_6$ and $p_4 \times p_5$) showed significant positive SCA effect for grain yield (ton) **/**ha.

Heterosis was measured as a deviation from the midparents. The heterobeltiosis of the different crosses was ranged from 13.13 %to 88.40% for grain yield/ha (ton) . The crosses involving $p_2 \times p_5$, $p_2 \times p_3$, $p_1 \times p_2$ and P4 × P6 produced the highest positive heterosis for grain yield /ha(ton). It would be concluded that these parentalal combinations could be desirable to produce high yielding hybrids. Therefore ,this parents would be involved in the breeding programs to further improve these parents and to produce high yielding hybrids.

INTRODUCTION

Maize (*Zea mays* L.) is one of the most important cereal crop used for both human and animal consumption. Successful cultivation markedly depend on the right choice of varieties .Variety selection trails to identify the best suitable varieties have been directed on the physiological basis of maize growth and productivity (Koscielniek *et al*., 2005 and Malti *et al.,*2006).

Heterosis and Combining ability is prerequisite for developing a good economically viable maize variety. Informations on the heterotic pattern and combing ability among maize germplasm are essential in maximizing the effectiveness of hybrid development (Beck *et al* 1990). In maize, appreciable investigations on heterosis and combining ability for yield were studied by several workers (Roy *et al.,* 1998; Revilla *et al* 2006 ., Devi *et al* 2007).

Combining ability studies provide information on the genetic mechanisms controlling the inheritance of quantitive traits . It enables the breeders to select suitable parents for further improvement or to be used in hybrid breeding on commercial scale . In quantitative genetics, two types of combining abilities are considered i.e. general combining ability (GCA) and specific combining ability (SCA). General combining ability refers to the average performance of the genotype involved in series of hybrid combinations and is a measure of additive gene action (Sharief *et al*., 2009). SCA is due to genes showing, no additive effects including dominance effect, (Sprague and Tatum., 1942). Line x tester mating design was developed by Kempthorne (1957) which provides reliable information on the general and specific combining ability effects of parents and their hybrid combinations in applied breeding programs. The design has been widely used in maize breeding by several workers and continues to be applied in quantitative genetic studies in maize due to its significance (Sharma *et al*., 2004) in evaluating combining ability and estimating heterosis for yield and yield components of maize genotypes.

The objective of this investigation was to evaluate the combining abilities and heterosis effects for genotypes obtained from half diallel crosses among six lines . The study would involve the evaluation at , yield and yield components in attempt to produce high yielding single cross hybrids better than the commercial ones.

MATERIALS AND METHODS

This study was carried out at the Experimental Farm of the Agricultural Research , Faculty of Agriculture ,Omer AL-Mukhtar University (Libya) during the two growing seasons 2013 and 2014. The study involved six (*Zea Mays* L.) lines and their F_1 hybrids .

The parental genotypes were derived from maize breeding program of Al-Saryer and Egypt Research station as presented in Table 1.

All possible crosses between the six lines excluding reciprocals were obtained . At the first season, parents were planted on 24 April 2013 and utilized to make all the possible crosses to obtain seed of F_1 plants. In the second season, seeds of F_1 hybrids and their parents were planted on 24 April 2014. Plot area was 25 m^2 where it consists of 3 rows with 5 m in length and 0. 5 m in width. Each of genotypes was planted in 3 rows for parents and 4 rows for hybrids at 15 cm. apart.

Heterosis percentage in the F_1 was calculated according to the two following formulas (Mather and Jinks, 1971).

Heterosis (H) as percent deviation from the mid parents

$$\textbf{H (M.P), \%} = \frac{F1 - Mid\ parent}{Mid\ parent} \times 100$$

Heterosis (H) as percent deviation from the better parent

$$\textbf{H (B. P), \%} = \frac{F1 - Better\ parent}{Better\ parent} \times 100$$

The parents were subjected to techniques prescribed by Downey *et al*.(1980). A randomized complete blocks design was used. The data were obtained and analyzed according to Griffing (1956) method- 2 and model-1 (One set of parents and their 15 F_1 hybrid excluding reciprocals).

The following traits were studied in the parents and their F_1 hybrids:

- Plant height (cm)
- Number of ears per plant
- Ear weight per plant (g)
- Kernel weight per plant (g)
- 100- kernel weight (g)
- Protein (%)
- Oil (%).
- Ear weight per he (ten)
- Grain yield per ha (ten)

Data were statistically analyzed according to Snedecor and Cochran (1971). Least significant differences (LSD) were used to test the significance of the differences between means of the studied treatments. The pedigree of the six Zea mays parents showing their origin

Table 1 .Pedigree of the six Zea Mays genotypes and their origin

Parents	Code	Origin
P_1	PAC	CB - 9/10 # 47
P_2	1024	CB – 9/10 # 52
P_3	R-490	CB – 9/10 # 57
P_4	G507A	CB – 9/10 # 58
P_5	KG-38	CB – 9/10 # 68
P_6	RG-23	CB – 9/10 # 72

RESULTS AND DISCUSSION

Analysis of variance

Pooled analyses of variance to test the significance of differences among the genotypes are presented in Table 2 which revealed the presence at highly significant differences for all of the traits reflecting the presence of adequate diversity in the genetic material chosen for this study. These results were also supported by the earlier findings of Vasal *et al* (1992b) and Joshi *et al*.(1998).

Mean performance of parents and F_1 hybrids:

The mean performances for the parents shown in Table 3 ranged from 172.4 cm . for (P_3) to 183.71 cm . for (P_4) for plant height; 1.10 (P_2) to 1.83 (P_5) for number of ears /plant ; 90.51 (P_4) to 193.36(P_5) for ear weight /plant ; 171.75(P_4) to 270.18(P_5) for kernel weight /plant (g),19.18 (P_4) to 26.50 (P_2) for 100- kernel weight, 6.18 (P_5) to 6.76(P_2) for protein % ; 2.83 (P_6)to 4.13(P_3) for oil % ; 0.69 (P_4) to 1.26 (P_5) for ear weight (ton) /ha and finally from 1.13(P_4) to 1.85(P_5) for grain yield(ton) /ha.

2-3

The mean performances for the F_1 hybrids in Table 4 ranged from 172.53 cm. for (P_3 x P_5) to 186.2 (P_1 x P_4) for plant height ; 1.00 (P_2x P_6 and P4 x P6) to 1.66 (P_{1x} P_2) for no-of ears **/**plant ; 59.76 (P_{1x} P_3) to 151.51(P_2xP_3) for ear weight **/**plant; 240 (P_{1x} P_3) to 297.73($P_{1x}$$P_5$) for kernel weight **/**plant (g) ; 18.76 (P_{5x} P 6) to 29.73 (P_1 x P_6) for 100- kernel weight, 6.00 (P_2xP_6) to 8.11(P_{1x} P_2) for protein (%),3.83 ($P_{4x}$$P_6$) to 5.63(P_{2x} P_3) for oil (%) , 0.37 (P_1xP_3) to 0 .94 (P_2 xP_3) for ear weight (ton) **/**ha and finally from 1.53(P_1 xP_4) to 2.94(P_2 x P_5) for grain yield(ton) **/**ha.

Analysis of variances of combining ability

Analysis of variances of combining ability which are presented in Table 5 revealed that both gca and sca variances were highly significant for all the studied traits except plant height in both gca and sca and kernel weight/plant for gca . These results indicated the importance of additive as well as non-additive type of gene action in the inheritance of these traits. However, variances due to sca were much larger in their magnitudes than gca for all the traits , except plant height. This indicated the predominance of non additive gene action for all the traits except plant height. Ivy and Hawlader (2000) also found larger gca variances in plant height . The grain yield was predominantly controlled by non-additive gene action (dominance and epistasis). This results were in agreement with those of Sanghi *et al*. (1983) , Khotyleva *et al* (1986) Debnath *et al* . (1988), Das and Islam (1994),. Roy *et al*. (1998). Mathur and Bhatnagar 1995, Zelleke (2000) who reported the predominant role of non-additive gene actions for kernel yield in maize. Hussain *et al*. (2003) also reported the predominance of non-additive gene action for number of kernels per ear in maize. The presence of marked additive and non-additive gene effects indicated the need to exploit and fixed the components of genetic variances in new lines or hybrids for increasing the productivity in maize.

General combining ability (gca) effects:

The estimates of general combining ability effects of each parent are presented in Table 6. In the present study, parents were classified as high, average and low combiners based on their effects. Parents with desirable gca effect (significantly different from zero) were considered as high combiners, while parents showing insignificant estimates were classified as average combiners. Low or poor combiners had significant but negative (undesirable) gca effects. The good general combiners for all yield traits were: P_5 for ear weight**/**plant , kernel weight**/** plant , protein content, ear weight and kernel weight **/**ha ; P_2 for ear weight**/**plant , 100-Kernel weight ,protein content, Oil (%) and ear weight **/**ha ; P_3 for plant height and oil % and P_1 for number of ears**/** plant . Positive estimates for these traits are desirable since they directly contribute to yield in maize. Parent p_5 was the best general combiner for kernel yield and also showed significant positive gca effects all the yield components and simultaneously possessed high mean values indicating that per se performance of the parent would be proved as an useful index for combining ability. Ivy and hawlader (2000), Hussain *et al*. (2003) and Amiruzzaman, *et al* (2010). also observed the similar phenomenon.

4-

5-6

The overall study of gca effects suggested that parent p_5 was an excellent general combiner for yield and all the yield contributing traits and would be used extensively in hybrid breeding program with a view to increase the yield level. Parent P_2 was also good combiner for some of the important yield components. These parents would be used in the breeding program for obtaining higher yield and desirable traits

Specific Combining Ability (sca) Effects:

The sca effects of the hybrids for yield and different yield contributing traits are presented in Table 7. Significant positive sca effects were observed in three and two hybrids for number of ears and ear weight **/**plant, respectively . Significant positive sca represents dominance and epistatic component of variation . In case of kernels weight **/** plant six hybrids expressed significant positive sca effect. For 100-kernel weight, five hybrids showed their significant positive sca effects .Significant positive sca effect were observed in six hybrids for protein percent. In case of oil percent seven hybrids showed significant positive sca effects. Four hybrids reported significant positive sca effect for ear yield **/**ha and seven hybrids showed significant positive sca effect for grain yield **/**ha.

Out the 15 F s, three hybrids, viz. $P_1 \times P_2$, $P_1 \times P_6$ and $P_2 \times P_3$ showed significant positive sca effects for number of ears **/**plant and two hybrids ($P_2 \times P_3$ and $P_4 \times P_6$) for ear weight **/**plant. The significant positive sca effects for kernel weight **/**plant recorded for six crosses ($P_1 \times P_2$, $P_1 \times P_6$,$P_2 \times P_3$, $P_3 \times P_4$, $P_4 \times P_6$ and $P_5 \times P_{6)}$,five hybrids also possessed significant positive sca effects for 100-kernel weight ($P_1 \times P_6$, $P_2 \times P_3$, $P_2 \times P_4$, $P_2 \times P_5$ and $P_4 \times P_6$) . The significant positive sca effects for protein percent were recorded for ($P_1 \times P_2$, $P_1 \times P_5$, $P_2 \times P_5$, $P_3 \times P_4$, $P_3 \times P_6$ and $P_4 \times P_5$) . In case of oil percent seven hybrids ($P_1 \times P_4$, $P_1 \times P_6$, $P_2 \times P_3$, $P_2 \times P_6$, $P_3 \times P_6$ and $P_4 \times P_5$) had the significant positive SCA effect. Four hybrids ($P_2 \times P_3$, $P_2 \times P_4$, $P_3 \times P_4$ and $P_4 \times P_6$) reported significant positive SCA effect for ear yield **/**ha and seven hybrids ($P_1 \times P_2$, $P_1 \times P_5$, $P_2 \times P_5$, $P_3 \times P_4$, $P_3 \times P_6$ and $P_4 \times P_5$) had the significant positive sca effect for grain yield **/**ha.

The significant positive sca effects for kernels weight and ear weight were more frequent and associated with significant estimates of sca effects for grain yield. The positive relationship of sca effect of kernel weight and yield contributory traits were observed by Das and Islam (1994) ; Ivy, and Howlader (2000), and Amiruzzaman, *et al* (2010). Positive sca indicated that lines are in opposite heterotic groups. while negative sca effects indicates that lines are in the same heterotic group (Vasal, *et al* 1992a). Roy *et al*. (1998) observed high × high, high × low, high × average and low × average general combiners due to sca effects of yield in their components .

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Heterosis (%):

The percent standard heterosis expressed by the F_1 hybrids as percent deviation from the mid parents for yield and yield components are presented in Table 8. The degree of heterosis in F_1 hybrids varied from trait to another or from one hybrid to another. For number of ears plant , heterosis ranged from -35.23 to 22.22 % for the hybrid P_4 x P_5 and P_2 x P_3 respectively .

Three hybrids exhibited significant positive heterosis. The hybrid P_2 x P_3 showed maximum at 22.22 % heterosis for this trait. Sarwar (1983) and Mian *et al* (1988) reported significant positive heterosis for number of ears plant in maize. Heterosis for ear weight**/**plant ranged from -54.38 to 19.66 %. One hybrid (P_2 x P_3) showed significant positive heterosis for this trait . Atif *et al* (2012) also found significant positive heterosis for ear weight**/**plant.

The kernel weight **/** plant and 100 kernel weight both are important yield components. Therefore, significant positive heterosis is desirable for them. Most of the hybrids showed high heterosis (%) for kernel weight **/** plant . The percent of heterosis ranged from 1.75 in P_1 x P_3 to 83.93 % in P_4 x P_6. Ten hybrids (P_1 ×P_2 , P_1 × P_5 , P_1 × P_6 , P_2 ×P_3 ,P_2 × P_4 , P_2 × p_5 , P_2 × P_6 , P_3 × P_4, P_4 × P_6 and P_5 ×P_6) exhibited significant positive heterosis. Heterosis for 100-kernel weight was the highest showing 34.89 % in P_1 × P_6 followed by P_4 × P_6 (18.25%), and P_2 × P_4 (8.57%). The Lowest heterosis (-19.16) % was observed in P_5 × P_6 . Das and Islam (1994) also found significant positive heterosis for kernel weight.

On the other hand, two hybrids (P_2 × P_3 and P_4 × P_6) showed significant positive heterosis values of 1.45 and 1.85%), for ear weight (ton), respectively .

In case of grain yield (ton) **/**ha , heterosis values varied from 13.13% to 88.40 %. All the hybrids exhibited significant positive heterosis. The highest heterosis for grain yield was shown by the hybrid P_2 × P_5 (88.40%) followed by P_2 × P_3 (78.52%) . Izhar and Chakraborty (2013) reported increased heterosis for grain yield up to 84.60% . The results showed that three hybrids viz (P_1 × P_6 , P_2 × P_3 and P_4 × P_6 expressed significant positive heterosis for grain yield coupled with most of the other yield components. The other desirable hybrids were P_1 × P_2 and P_1 × P_5 which showed significant positive heterosis for kernel weight**/** plant and associated with number of ears **/**plant or 100-kernel weight for the two hybrids, respectively.

In generally, this study concluded that, parents (P_5 and P_2) showed good combining ability for yield would be used as donor for obtaining high yield for desirable traits. The hybrid combination P_1 ×P_2 , P_1 × P_5 and P_4 ×P_6 manifested significant high SCA effects coupled with excellent heterosis and would effectively be exploited in hybrid breeding programme in maize.

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قوة الهجين والقدرة علي الإئتلاف للمحصول ومكوناته في الذرة الشامية

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أجريت هذه الدراسة في المزرعة التجريبية بقسم المحاصيل ،كلية الزراعة جامعة عمر المختار ،البيضاء ، ليبيا خلال الموسم الصيفي للعامين 2013 و2014 حيث تم زراعة الآباء في الموسم الأول وتم عمل جميع الهجن الممكنة بين الستة آباء في اتجاه واحد ، وفي الموسم الثاني تم تقييم الآباء والهجن وذلك لصفات: إرتفاع النبات،عدد الكيزان /النبات، وزن الكيزان / النبات، وزن الحبوب / النبات،وزن ال100 حبة، نسبة البروتين،نسبة الزيت،وزن الكيزان (طن)/ هكتار، محصول الحبوب (طن)/ هكتار،وقد حللت النتائج وراثيا طبقا للموديل الأول الطريقة الثانية للعالم جرفنج 1956.

وقد تلخصت أهم النتائج فيما يلي:-

كان التباين الراجع لكل من القدرة العامة والخاصة علي التآلف معنويا لكل الصفات ما عدا صفة ارتفاع النبات لكل من القدرة العامة والخاصة علي التآلف ووزن الحبوب /النبات للقدرة العامة علي التآلف وكانت النسبة بين تباين القدرة العامة والقدرة الخاصة علي التآلف تقل عن الوحدة في كل الصفات المدروسة فيما عدا صفة ارتفاع النبات مما يدل علي أن الجزء الأكبر من الإختلافات الوراثية المرتبط بهذه الصفات كان راجعا إلي الفعل الجيني من النوع السيادي.

أظهرت السلالة P5 قدرة عامة عالية علي التآلف لصفة وزن الكوز/ النبات ، وزن الحبوب /النبات، وزن الكيزان ومحصول الحبوب (طن)/هكتار ، بينما تفوقت السلالة P2 في وزن ال100 حبة وسجلت السلالة الأبوية P3 أعلي نسبة للزيت فيما كانت السلالة الأبوية P1 هي الأفضل في نقل صفة عدد الكيزان/النبات.

أشارت نتائج القدرة الخاصة علي التآلف إلي إرتفاع قيم الهجن (P 2 × P 3 , P 2 × P 4 , P 3 × P 4 and P 4 × P 6) بالنسبة لصفة محصول الكيزان (طن) / هكتار والهجن (P 1 × P 2 , P 1 × P 5 , P 2 × P 5 , P 3 × P 4 , P 3 × P 6 and P 4 × P 5) لصفة محصول الحبوب (طن) /هكتار وقد لوحظت أيضا أعلي قدرة خاصة للتآلف في هجن (P 1 × P 2 , P 1 × P 6 , P2 × P 3 , P 3 × P 4 , P 4 × P 6 and P 5 × P 6) وذلك لصفة محصول حبوب النبات مما يدل علي أن التأثير غيرالمضيف له أهمية في توريث هذه الصفات.

إتضح من النتائج أهمية كلا من التأثير المضيف وغير المضيف في وراثة صفات المحصول ومكوناته في الذرة الشامية وكذلك في اختيار برامج التربية المناسبة لتحسين المحصول

كانت قوة الهجين بالنسبة الي متوسط الأبوين معنوية وموجبة لمعظم الصفات المدروسة في معظم الهجن وقد تراوحت ما بين 13.13الي88.40 لصفة محصول الحبوب (طن)/ هكتار وسجلت أعلي القيم لهذه الصفة للهجن P 2 × P 5 , P 2× P 3 , P1× P2 and P4 × P6 كما تراوحت قوة الهجين ما بين 1.75 للهجين (P 1 x P3) إلي 83.93 للهجين P4 x P6لصفة محصول حبوب النبات .

هذه المعلومات تعتبر هامة ومفيدة لمربي النبات للتخطيط لبرنامج تربية فعال للحصول علي الآباء التي يمكن إستخدامها في انتاج هجن من الذرة الشامية ذات انتاجية عالية.

Table 2 : Analysis of variance for all studied traits of parents (P), hybrids (F_1), and (P. VS. F_1)

Characters S.O.V	d .f	Plant height (cm)	N. of ear/plant	Ear weight/ Plant (g)	Kernel weight/plant (g)	100-Kernel weight (g)	Protein (%)	Oil (%)	Ear weight/ha (ten)	Grain yield /ha (ten)
Replications	2	84.14	0.05	526.05	2253.21	0.48	0.01	0.70	0.02	0.05
Genotypes	20	61.87**	0.20**	2679.70**	14686.14**	22.25**	1.56**	1.69**	0.12**	0.70**
Parents	5	55.97**	0.27**	3541.38**	4165.32**	18.29**	0.15**	0.88**	0.10**	0.20**
F_1	14	67.97**	0.14*	1932.33**	7910.55*	25.21**	2.02**	0.54**	0.07**	0.47**
P vs. F_1	1	6.01	0.69	8834.53**	162148.4	0.73**	2.07**	21.80	0.97**	6.39
Error	40	78.46	0.05	271.34	2871.93	1.56	0.04	0.16	0.009	0.11
Total	62									

***,** significant at 0.05 and 0.01 levels of probability, respectively**

Table 3: The mean performances of the six parents for all studied traits.

Genotype	Plant height (cm)	N. of ear/ plant	Ear weight/ Plant (g)	Kernel weight/ plant (g)	100-Kernel weight (g)	Protein (%)	Oil (%)	Ear weight/ha (ten)	Grain yield /ha (ten)
P1	177.78	1.63	146.69	227.12	22.00	6.22	2.91	1.03	1.52
P2	182.53	1.10	137.88	189.62	26.50	6.76	3.86	1.00	1.27
P3	172.40	1.30	115.35	244.58	23.26	6.59	4.13	0.85	1.60
P4	183.71	1.66	90.51	171.75	19.18	6.33	3.48	0.69	1.13
P5	178.91	1.83	193.36	270.18	24.35	6.18	3.90	1.26	1.85
P6	183.10	1.16	135.94	195.65	22.08	6.41	2.83	0.93	1.32
LSD 0.05	9.28	0.16	23.28	11.97	2.02	0.18	0.49	0.12	0.09
LSD 0.01	14.55	0.25	36.51	18.77	3.17	0.28	0.78	0.19	0.15

Table 4: Mean performances of the 15 hybrids for studied traits

Crosses	Plant height (cm)	N. of ear/ Plant	Ear weight/ Plant (g)	Kernel weight/ plant (g)	100-Kernel weight (g)	Protein (%)	Oil (%)	Ear weight(ton) /ha	Grain yield(ton) /ha
$P_{1\,x}$ P_2	182.60	1.66	131.76	344.13	21.56	8.11	4.70	0.82	2.44
$P_{1\,x}$ P_3	173.00	1.06	59.76	240.00	22.56	6.27	4.80	0.37	1.79
$P_{1\,x}$ P_4	186.20	1.13	85.22	246.16	21.50	6.58	4.33	0.53	1.53
$P_{1\,x}$ P_5	172.60	1.13	124.58	397.73	23.43	7.94	4.66	0.77	2.69
$P_{1\,x}$ P_6	180.66	1.60	126.55	359.43	29.73	6.20	4.90	0.79	2.24
P_{2x} P_3	174.73	1.46	151.51	397.63	26.80	6.16	5.63	0.94	2.56
P_{2x} P_4	180.60	1.13	126.07	323.63	24.80	6.42	4.63	0.78	2.02
$P_{2\,x}$ P_5	182.66	1.46	126.04	371.00	26.03	8.03	5.16	0.78	2.94
$P_{2\,x}$ P_6	176.26	1.00	65.49	318.00	22.30	6.00	5.03	0.41	1.98
$P_{3\,x}$ P_4	174.06	1.13	111.10	353.60	20.56	7.58	4.40	0.69	2.21
$P_{3\,x}$ P_5	172.53	1.06	101.97	314.50	19.60	6.68	5.03	0.63	1.96
P_{3x} P_6	181.46	1.20	102.88	264.66	23.63	7.07	5.16	0.64	1.65
$P_{4\,x}$ P_5	183.80	1.13	109.32	283.83	21.33	7.52	5.03	0.68	1.77
$P_{4\,x}$ P_6	179.73	1.00	132.58	337.90	24.40	6.68	3.83	0.82	2.11
P_{5x} P_6	184.93	1.06	101.30	379.56	18.76	6.04	5.03	0.63	2.37
LSD 0.05	9.19	0.26	13.91	63.43	1.10	0.21	0.41	0.08	0.39
LSD 0.01	12.76	0.36	19.31	88.03	1.53	0.29	0.57	0.12	0.54

****,* significant at 0.05 and 0.01 levels of probability, respective**

Table 5. Analysis of variance of the parental diallel crosses of combining ability of all the studied traits.

Characters S.O.V	d .f	Plant height (cm)	N. of ear/ plant	Ear weight/plant (g)	Kernel weight/plant (g)	100-Kernel weight (g)	Protein (%)	Oil (%)	Ear weight/ ha (ton)	Grain yield(ton)/ha (ten)
Genotypes	20	61.87**	0.20**	2679.70**	14686.14**	22.25**	1.56**	1.69**	0.12**	0.70**
G.C.A	5	43.43	0.24*	3716.77**	10627.31	37.54**	1.85**	2.49**	0.12**	0.93**
S.C.A	14	13.02	1.11**	14147.95**	87280.26**	110.84**	8.55**	8.79**	0.73**	3.74**
Error	40	26.15	0.05	271.34	2871.93	1.56	0.04	0.16	0.01	0.11
G.C.A/S.C.A		3.33	0.21	0.26	0.12	0.33	0.21	0.28	0.16	0.23

GCA = General Combining Ability, SCA = Specific Combining Ability

Table 6. Estimates of general combining ability effects (GCA) of the six parents for all studied traits .

Parent	Plant height (cm)	Number of Ear	Ear weight/ Plant (g)	Kernel weight/ plant (g)	100-Kernel weight (g)	Protein (%)	Oil (%)	Ear weight(ton)/ha	Grain yield(ton)/ha
P_1	-0.51	0.109*	- 0.50	-4.39	0.16	0.07	-0.24**	-0.001	0.01
P_2	0.89	-0.006	6.41*	7.09	1.62**	0.16**	0.21**	0.048*	0.10
P_3	-4.27*	-0.056	- 8.42**	-2.16	-0.22	0.0019	0.26**	-0.045*	-0.03
P_4	2.13	-0.015	-9.99**	-23.53*	-1.31**	-0.06	-0.24**	-0.057**	-0.22**
P_5	-0.05	0.068	15.58**	26.26*	-0.45	0.20**	0.19*	0.082**	0.22**
P_6	1.81	-0.098*	-3.07	-3.25	0.19	-0.39**	-0.19*	-0.027	-0.08
S.E (gi)	1.65	0.043	3.07	9.98	0.23	0.038	0.07	0.018	0.06
S.E (gi - gi)	2.55	0.068	4.75	15.47	0.36	0.06	0.11	0.028	0.09
LSD 0.05	3.33	0.088	6.20	20.17	0.47	0.078	0.15	0.036	0.12
LSD 0.01	4.45	0.118	8.28	26.96	0.63	0.10	0.20	0.048	0.16

****,* significant at 0.05 and 0.01 levels of probability, respectively**

Table 7. Estimates of specific combining ability effects (SCA) of 15 hybrids for all studied traits

Crosses	Plant height (cm)	N. of ears /plant	Ear weight/ Plant (g)	Kernel weight /plant (g)	100-Kernel weight (g)	Protein (%)	Oil (%)	Ear yield (ton)/ha	Grain yield (ton)/ha
P_1 x P_2	-2.96	0.28**	7.949	44.73	-3.29**	1.16**	0.27	0.007	0.37**
P_1 x P_3	-1.46	-0.27**	-49.21**	-50.13*	-0.44	-0.51**	0.32	-0.34**	-0.13
P_1 x P_4	5.33	- 0.24*	-22.17**	-22.60	-0.42	-0.13	0.36*	-0.17**	-0.20
P_1 x P_5	-6.08	-0.32**	-8.39	79.17**	0.65	0.95**	0.26	0.07	0.50**
P_1 x P_6	0.11	0.30**	12.23	70.38**	6.30**	-0.19*	0.88**	0.05	0.36*
P_2x P_3	-1.14	0.24*	35.61**	96.00**	2.32**	-0.71**	0.69**	0.17**	0.54**
P_2x P_4	-1.68	-0.12	11.75	43.37	1.41*	-0.39**	0.21	0.027*	0.18
P_2 x P_5	2.56	0.12	-13.85	40.94	1.78**	0.95**	0.30	-0.11**	0.66**
P_2 x P_6	-5.69	-0.17	-55.75**	17.46	-2.58**	-0.47**	0.55**	-0.38**	0.01
P_3 x P_4	-3.04	-0.07	11.62	82.59**	-0.96	0.93**	-0.07	0.028*	0.51**
P_3 x P_5	-2.39	-0.22*	-23.09**	-6.29	-2.79	-0.23**	0.11	-0.16**	-0.17
P_3x P_6	4.67	0.07	-3.52	-26.61	0.59	0.74**	0.63**	-0.05	-0.18
P_4 x P_5	2.46	- 0.20*	-14.16*	-15.59	0.029	0.66**	0.63**	-0.11**	-0.18
P_4 x P_6	-3.46	-0.17	27.75**	67.98**	2.45**	-0.57**	-0.18	0.14**	0.46**
P_5x P_6	3.91	-0.18	-29.10**	59.85*	-4.04**	-0.48**	0.57**	-0.19**	0.27
S.E (sij)	3.74	0.09	6.96	22.64	0.53	0.08	0.17	0.04	0.13
LSD 0.05	7.56	0.20	14.06	45.74	1.06	0.17	0.35	0.08	0.28
LSD 0.01	10.10	0.26	18.79	61.14	1.42	0.23	0.46	0.11	0.37

****, * significant at 0.05 and 0.01 levels of probability, respectively**

Table 8. Heterobeltiosis (%) of the hybrids from mid parents values for all studied traits .

Crosses	Plant height (cm)	No. of ears/plant	Ear weight/plant (g)	Kernel weight/plant (g)	100-Kernel weight (g)	Protein (%)	Oil (%)	Ear weight(ton)/ ha	Grain yield(ton)/ ha
P_1 x P_2	1.35	21.95*	-7.39	65.15*	-11.06**	24.96**	38.57**	-19.40**	74.53**
P_1 x P_3	-1.19	-27.27*	-54.38**	1.75	-0.29	-2.13**	36.17**	-60.57**	15.17**
P_1 x P_4	3.01	-31.31*	-28.14*	23.43	4.41**	4.92**	35.41**	-38.55**	15.97**
P_1 x P_5	-3.22	-34.61**	-26.72*	59.95*	1.11*	28.01**	36.92**	-32.19**	59.71**
P_1 x P_6	0.12	14.28*	-10.44	70.03*	34.89**	-1.88	70.43**	-19.51**	57.89**
P_2x P_3	-1.54	22.22*	19.66*	83.15*	7.70**	-7.75**	40.83**	1.45*	78.52**
P_2x P_4	-1.37	-18.07*	10.40	79.11*	8.57**	-1.92	26.07**	-7.61**	68.22**
P_2 x P_5	1.07	1.51	-23.89*	61.37*	2.39*	24.03**	33.04**	-30.55**	88.40**
P_2 x P_6	-3.58	-11.76*	-52.16**	65.07*	-8.19**	-8.86**	50.24**	-57.74**	53.05**
P_3 x P_4	-2.24	-23.59*	7.94	69.86*	-3.10**	17.36**	15.53**	-10.79**	61.81**
P_3 x P_5	-1.77	-31.91*	-33.93**	22.19	-17.67**	4.51**	25.31**	-39.87**	13.89**
P_3x P_6	2.09	-2.70*	-18.12*	20.24	4.22**	8.62**	48.32**	-28.10**	13.13**
P_4 x P_5	1.37	-35.23**	-22.98*	28.44	-1.99*	20.14**	36.34**	-30.24**	19.08**
P_4 x P_6	-2.00	-29.41*	17.09	83.93*	18.25**	-10.82**	21.37**	1.81**	72.27**
P_5x P_6	2.16	-21.66*	-38.47**	62.96*	-19.16**	-13.04**	83.33**	-23.11**	39.32**
LSD 0.05	5.31	0.14	9.90	32.17	0.75	0.12	0.24	0.21	0.19
LSD 0.01	15.10	29.90	28.09	91.38	2.13	0.35	0.70	0.61	0.56

***, ** significant at 0.05 and 0.01 levels of probability, respectivel**