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Research Paper

Estimation of Combining Ability in Maize Lines Using a Diallel Cross

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Abstract: *The objective was to select maize (zea mays L.) lines, based on the effects of general combining ability (GCA) and specific combining ability (SCA). During spring and autumn 2013, 20 single crosses with the combination of five lines of maize were evaluated, to estimate the GCA and SCA effect, the method 2 model (1) of Griffing was used in randomize complete block design with three replication. The results revealed that there are lines with good GCA, as DKC648 and Thal-A1059 for traits, leaf area, No. of kernels row^{-1}, 3000 kernel weight, kernels yield plant^{-1} and protein percent. The cross ATha7AAX ATha-132, pak. X DK C648, ATha-132x ATha-7AA and pak. x Thaal-A1059 showed the greatest effect of SCA for traits, Leaf area, No. of rows ear^{-1}, No. of kernels row^{-1}, 300 kernel weight, kernels yield plant^{-1} and oil percent, considering that there is greater additive gene action. The crosses DKC648X pak., ATha7AAXATha-133, ATha7AAX DKC648, ATha-132X DCC648 exhibited maximum yield plant^{-1} with values, 162.99, 158.78, 156.38 and 155.50g respectively. The uses of diallel design to estimate GCA and SCA in bred lines and their crosses allowed knowing the most efficient breeding method.*

Keywords: Combining ability, 5×5 diallel Field crops department Duhok.

Introduction

Maize (*Zea mays L.*), a multipurpose crop, plays an important role in cropping systems throughout the word. Advance in genomics breeding and production had significant impact on the lives of a large proportion of the world's population (Xu and Crouch, 2008). Balancing consumer demand for various end-uses of maize and different production practices will be critical for maintaining sustainability of cropping system, food security, feed and fodder supply, and bio-energy demands (Ortiz et al., 2006).

Maize is widely spread and cultivated crop through-out the word due to its ability to grow in divers climates. In 2010/ 2011, the global area planted with maize was 162.72 million hectares with a total production of 820.02 million tons with average of 5.04 ton per hectares. The United States of America alone has the largest area under it's cultivation with 32.96 million hectares producing 173.00 million tons with an average of 5.33 ton per hectare (USDA, 2011).

Corn production in Iraq saw a sharp decline between the years of 2006 and 2011, currently, Iraq requires approximately 300.000, metric tons of corn per year to satisfy the feed consumption of its growing poultry sector. In 2010, Iraq produced 150.000 metric tons of corn with an average yield of two metric tons per hectare, but imported the other 150.000 metric tons to meet the feed consumption requirement. The new hybrid seed corn varieties have the potential to raise productively to a level of 6 metric ton per hectare (www.inmairaq.com). Maize possesses extravagant variation for all traits that can be easily used by the plant breeders to develop high yielding and early maturing genotypes. It has been estimated that more than half of the increased demand in the world's food in term of cereals as a whole will be produced from maize (Yan et al., 2011). Considerable genotypic variability among various maize genotypes for different traits was reported by Ihsan et al., (2005). This variability can be of great importance to corn improvement.

The primary objective of most maize breeding program is the development of high yielding and well adapted cultivars (Saleem et al., 2002). Because of very wide utilization of maize, the main goal of all maize breeding programs is to obtain new inbreeds and hybrids that will outperform the existing hybrids with respect to a number of traits. For this purpose, particular attention is paid to grain yield as the most important agronomic traits beside gene effects, breeder would also like to know how much of the variation in genetic and to what extent this variation is heritable, because efficiency of selection depends mainly on additive genetic variance, influence of the environment and interaction between genotype and environment (Novoselovic et al., (2004).

Conventional diallel analysis is limited to partitioning the total variation of the data in to general combining ability (GCA) of each parent and specific combining ability (SCA) of each cross (Yan and Hunt, 2002). Further, advancement in the yield of corn requires certain information regarding the nature of combining parents available for use in the hybridization program and also the nature of gene action involved in expression of quantitative and qualitative traits of economic importance. General and specific combining ability effect is very important in constructing the next phase of breeding program. To the objective of this study to estimate the general and specific combining ability in bred lines and their crosses allowed knowing the most efficient breeding method.

Materials and Methods:

The material under study consisted of five maize inbred lines, (1) DKC648, (2) Thal-A 1059, (3) ATha7AA, (4) ATha7A-132 and (5) pak which selected based on different agronomic traits. These lines were sown to perform full diallel cross in all possible combination Schame in 15 March, 2012. The resulting 20 F_1 progenies along with their parents were arranged in randomize complete block design with three replications. Each genotype was planted in a plot of 3m long, 0.75m between rows with a spacing of 0.25m between plants in row. 400 kg/ha of N_{27}, P_{27}, Ko were applied with planting, later 200 kg/ ha urea (46%) were also used. Weed control and other cultural practices were performed to plant requirement. Five plants from the middle of each row were sampled and the following traits were recorded for each cross: days to 50% tasseling and silking plant and ear height, leaf area, number of row ear^{-1}, number of kernels row^{-1}, 300 kernel / weight, grain yield plant^{-1}, protein and oil percent. The data were analyzed by using RCBD design and DMRT was used to compare the mean square of genotypes (Gomez and Gomez, 1983) means of genotypes. The genetic analysis was based on Griffing method 2-fixed model to determine the variance and effects of general and specific combining ability.

Results and Discussion:

The mean square of genotypes (Parents and hybrids) were highly significant for all studied traits while the general combining ability (GCA) was highly significant for all studied traits except No. of row ear^{-1} also the mean square for specific and reciprocal combining ability were also significantly different for all traits, indicating that there was enough variation for a successful in selection of the desirable cross combinations (table 1).

Table 1: Mean square of variance analysis for general and specific combining ability for the parents, F_1 diallel crosses and reciprocal crosses of the studied traits

S.O.V.	d.f	Days to 50% tasseling	Days to 50% silking	Plant height cm	Ear height cm	Leaf area cm^2	No. of rows ear^{-1}	No. of kernels row^{-1}	300 kernel weight	Kernel yield plant (g)	Oil parent	Protein percent
replication	2	1.29	4.44	4.72	14.40	20.62	0.15	10.04	3.42	82.84	0.01	0.14
Genotypes	24	** 21.91	** 17.83	** 3409.02	** 747.30	** 20871.57	** 3.22	** 50.83	** 348.64	** 2933.50	** 3.18	** 4.63
GCA	4	** 13.12	** 9.19	** 1888.43	** 408.07	** 7587.27	1.05	** 44.09	** 400.41	** 2347.59	** 6.26	** 4.59
SCA	10	** 23.13	** 21.44	** 6130.45	** 1181.20	** 33315.71	** 2.42	** 62.02	** 18.905	** 2047.00	** 2.60	** 7.36
RCA	10	* 24.20	** 17.66	** 1295.83	** 449.10	** 13741.15	** 4.87	** 42.35	** 487.52	** 4054.38	** 2.53	** 1.92
Mse	10	3.29	2.48	19.68	17.70	517.60	0.6	2.61	12.87	35.29	0.05	0.07
VGCA/SCA	48	0.02	0.01	0.01	0.01	0.01	0.01	0.02	0.08	0.04	0.09	0.02

* and ** indicating significant at 5% and 1% level, respectively.

The mean performance of the five parents and the obtained diallel reciprocal hybrids of different traits are presented in table 2. Among the parental forms, parent I was the earliest with 55.66 days to 50% tasseling, while parent 2 the latest with 60.33 days. The differences in parent's days to 50% tasseling caused also the difference in their hybrids. Regarding the dialles, the hybrid (4×5) was the earliest compared to all genotypes including the earliest parent with 52.00 days. The diallel hybrids (1×3) and (1×4) were latest with 57.00 days. The reciprocal hybrid (5×3) expressed the shortest period to 50% tasseling with 52.66, whereas, the reciprocal (4×3) revealed the longest period with 63.00 days. Regarding the number of days to 50% silking, parent 5 that was introduced from Pakistan was the earliest with 59.66 days, whereas parent I was the latest with 63.33 days to silking. It seems that the differences between the crossed parental forms regarding the 50% tasseling and silking periods had influenced the phenology of the obtained hybrids. Concerning the diallel hybrids, the hybrid (4×5) was the earliest with 55.00 days to 50% silking, while the hybrid (2×5) was the latest with 60.00 days. Among the reciprocals, the hybrid (3×1) was the earliest with 56.00 days to 50% silking. These results were in agreement with results obtained by Haruna (2008) and Wattoo et al., (2009).

The maximum plant height among parents was noticed in parents 5 with 208.00 cm, while the minimum value (132.40 cm) was recorded for parent I. hybrids obtained from diallel crosses expressed plant values from a minimum of 222.00 cm for (4×5) to 244.00 cm for (1×2). Whereas, hybrids from reciprocal crosses manifested values between 156.66 cm to 265.33cm for hybrids (4×3) and (3×2), respectively.

For ear height, the maximum value exhibited by parent 1 with 112.00 cm and minimum value (76.66cm) was recorded for parent 3. Regarding the diallel hybrids, the maximum ear height was noticed for the hybrid (2×5) with 145.66cm and the minimum value was exhibited b×(1×5) with an ear height of 113.00cm. Hybrids of reciprocal crosses were restricted between 87.66cm to 130.00 cm for both reciprocal (4×3) and (5×3), respectively. Similar results were reported by (Haruna, 2008).

Maximum leaf area was exhibited by parent 5 with 588.50 cm^2, whereas the minimum value (425.50cm2) was recorded for parent I. The diallel crosses values ranged between 480.70 cm^2 to 733.87cm^2 for crosses (1×4) and (2×5), respectively. Regarding the reciprocal crosses, the maximum value of leaf area (665.60cm^2) was noticed for the cross (4×1), and the minimum value for reciprocal cross (5×3) with 476.67cm^2. Among parental forms, the greats number of row ear^{-1} was recorded by parent 4 with 16.14 and the minimum was noticed by parent I) 14.66). Among diallel hybrids, the greatest value was recorded for the hybrid (1×2) with rows 18.26. Concerning the reciprocal crosses, the cross (3×1) showed maximum value with 18.26, while minimum value (14.73) was recorded for combination (5×2).

The greatest number of kernels row^{-1} (33.06) was noticed for parents 5, whereas parent 4 expressed the smallest number with 26.44 kernels row^{-1}. Among the diallel crosses, the crossing combination (1×5) showed the highest value with 37.66 kernels row^{-1}, while the minimum (26.73) was observed in the diallel cross (1×4). The hybrid of reciprocal crosses ranged between 25.53 to 36.00 kernels row^{-1} for crosses (4×2) and (3×1), respectively.

The kernels size is an important yield component which may significantly contribute to yield increase in cereal crops including corn. In our experiment, among the parental forms, parent 2 had the greatest kernel size with 300-kernel weight of 76.91g whereas parent 3 exhibited the lowest value with 67.20g. diallel cross expressed the maximum value for the combination (1×5) with 95.00g, while the minimum size was noticed for cross (3×5) with 67.26g. The hybrid of reciprocal crosses ranged between results 48.23 to 89.41g for crosses (4×3) and (3×2), respectively. Similar results were obtained by researchers (Wattoo et al., 2009; Amanullah et al., 2011). For the practical exploitation of hybrid vigor, the grain yield $plant^{-1}$ remains the most important quantitative trait in corn breeding. In our experiment, the parent 2 was the highest yielding genotypes producing 126.279g $plant^{-1}$, while parent 4, yielded only 67.33g to rank fifth among the parental forms. The cross (3×4) exhibited the maximum yield with 158.73g, while the minimum yield (105.5^{-1}g) was noticed for cross (1×3). Regarding the reciprocal crosses, grain yield varied between 47.98 to 156.39g for crosses (4×2) and (3×1), respectively. Concerning the most important quality trait of corn, table 2 shows that parent 5 was superior to other parents for oil content with an average of 6.86% and the lowest value was noticed by parent 2 scoring 5.22%. Regarding diallel crosses, the combination (1×3) expressed the highest oil content (8.13%), while the, lowest percentage was shown by the hybrid (2×4) with 5.4%. The reciprocal crosses ranged between 4.82 to 8.23% for crosses (5×2) and (2×1), respectively. In table 2, it is shown that parent 5 was highest in protein content (7.87%), whereas the lowest was noticed for parent 4 with 6.21%. The diallel cross (1×4) exhibited the highest protein content with 10.29% while the diallel cross (4×5) exhibited the lower percentage which was almost equivalent to the worst parent with 5.99% .The reciprocal crosses ranged between 6.72 to 10.28% for crosses (5×4) and (2×1) respectively.

The general combining ability effects of parents for studied traits are presented in table 3. From this table we can notice that the highest positive value (0.466) was for parent 2, which predicts the contribution of this parent increasing the number of days to 50% tasseling in its hybrids, while the parents 5 exhibited negative value of ĝij reaching – 1.13, which indicates the contribution of this parent in decreasing the number of days to 50 % tasselling in its hybrids. The general combining ability effect for days to 50% silking was recorded for parent 2 with 0.613.

Table 2: Mean of parents, hybrids and reciprocal hybrids for studied traits

Parents and hybrids	Days to 50% tasseling	Days to 50% silking	Plant height cm	Ear height cm	Leaf area cm^2	No. of rows ear^{-1}	No. of kernels row^{-1}	300 kernel weight/g	Kernel yield plant/ g	Oil percent	Protein percent
1	58.33bcd	63.33ab	132.40m	112.00e-g	425.50n	14.66g	29.66g-j	73.38h-k	99.22gh	6.38f	6.62j-k
2	60.33ab	62.33a-d	177.06k	102.33h	539.10jk	15.26e-g	31.74d-h	76.91h-k	126.26c-f	5.22gh	6.44k-m
3	60.00abc	62.66a-c	162.66L	76.66j	438.73mn	15.40e-g	29.93L	67.20k	104.77g	6.84de	6.91ij
4	56.66cdef	62.00a-e	161.60L	107.00gh	463.53m-l	16.40b-e	26.44jk	72.92i-k	67.32L	5.24gh	6.21Lm
5	55.66d-i	59.66e-i	208.00j	91.00i	588.50g-i	15.03e-g	33.06c-f	71.40jk	86.86ij	6.86de	7.87ef
1×2	54.33e-i	58.33g-i	244.00bc	127.00bc	647.37b-d	18.26a	32.53d-g	84.88c-f	135.18c	7.64b	8.60cd
1×3	57.00b-e	58.33g-i	241.33b-d	142.00a	664.77b-e	16.00c-g	32.95d-f	72.92i-k	105.50g	8.139	7.78f
1×4	57.00b-e	59.00e-j	222.66gn	119.66c-e	480.70L	16.13c-g	26.73i-k	90.32a-c	120.01ef	6.35f	10.29a
1×5	53.00h-j	56.66i-k	226.66fg	113.00e-g	679.93bc	17.16a-d	37.66a	94.99a	162.99a	7.31bc	7.70f
2×3	53.33h-j	57.00h-j	214.00ij	119.53c-e	591.60g-i	16.40b-e	26.8i-k	83.08e-g	130.57c-e	6.51ef	8.69b-d
2×4	52.33ij	56.66i-k	242.00b-d	125.00bc	529.93k	16.33b-e	36.53ab	89.10a-d	149.57b	5.47g	9.11b
2×5	57.00b-e	60.00c-h	236.00c-f	145.66a	733.87a	17.40a-c	33.60b-e	79.42f-h	129.83c-e	6.38f	7.22hi
3×4	53.33h-j	56.00jk	224.00gh	121.00cd	700.00ab	17.73ab	36.33ab	92.18ab	158.72ab	7.01d	9.83a
3×5	54.33e-j	57.00h-k	243.33bc	125.00bc	562.00h-k	17.46a-c	36.40ab	67.25k	130.79c-e	7.23b-d	6.96ij
4×5	52.00j	55.00k	222.00gh	123.66bc	536.47jk	15.13e-g	27.04i-k	83.02d-g	124.65c-f	6.27ef	5.99m
2×1	56.00e-h	59.33e-i	248.66b	108.00f-h	641.80c-f	15.60e-g	33.53b-e	86.62b-e	151.57b	8.23a	10.28a
3×1	53.33f-j	56.00jk	232.00ef	115.66d-f	577.50h-j	18.26a	36.00a-c	89.41a-d	156.38ab	7.65b	9.15b
4×1	57.00b-e	59.00e-j	238.66c-e	123.66bc	665.60b-e	16.26b-f	32.73d-g	86.50b-e	155.50ab	7.21b-d	8.70b-d
5×1	54.00e-j	57.66g-k	240.66b-d	127.33bc	602.50f-h	15.00e-g	34.66b-d	87.66b-d	79.01jk	8.25gh	7.00ij
3×2	56.00d-h	60.33c-g	265.33q	127.33bc	625.63e-g	15.16e-g	31.11e-h	80.12e-g	122.65d-f	6.15f	7.04ij
4×2	57.00b-e	61.00b-f	242.00b-d	125.00bc	553.00i-k	15.86d-g	25.53k	66.64k	47.98m	6.20f	8.28de
5×2	56.66c-f	60.00c-h	227.00fg	126.00bc	563.25h-k	14.73fg	30.93e-h	86.44b-e	116.98f	4.82hi	7.68f-n
4×3	63.00a	64.00a	156.66L	87.66i	634.33d-f	16.00c-g	32.48e-h	48.23L	132.08cd	7.44bc	8.93bc
5×3	52.66h-j	57.66g-k	217.33hi	130.00b	476.67mL	15.16e-g	28.96h-j	78.117g-i	89.88ij	5.10g-i	7.30g-i
5×4	56.33d-g	59.00e-i	234.33d-f	108.00f-h	557.27j-L	15.66e0g	30.25f-h	66.64k	70.44kl	4.70i	6.72jk

Values for each having the same letters are not significantly different.

While parent 5 had the maximum negative GCA effect value with -0.886. In this manner, the right choice of parental pairs based on their general combining ability might be of great importance in reducing the flowering periods of both male and female in florescence plant height could be exclusively important for increasing the dry matter production especially in fodder corn. Therefore, the study of general combining ability of inbred lines to be crossed is quite important for the expression of maximum hybrid vigor. In our experiment, the maximum positive GCA effect was exhibited by parent 2 with 8.897 followed by parent 5 with 7.917, predicting their high contribution in the inheritance of plant height of the hybrids. The maximum negative general combining ability was noticed for parent 4(-7.862).

For ear height, parent 2 showed the highest positive value of 3.758, while maximum negative GCA effect was recorded for parent 3 with -4.974. Considering general combining ability effect for leaf area, the estimated effects of general combining ability for yield, yield components and quality characters are presented in table 3. From this table we can see that, the greatest positive effect of parent 3 with equal to 0.158 may have a large contribution of this parent to increase the expression of this trait in its hybrids, whereas maximum negative GCA effect (-0.308) was noticed for parent 5. Considering the number of kernels row^{-1} only parent I and 5 may have a certain positive influence.

For 300-kernel weight, grain yield plant^{-1}, oil and protein content, parent I show the highest positive value with 4.946, 8.264, 0.577 and 0.381, respectively. Such values may indicate that parent I could be chosen to be used in crossing for the production of high yielding heterosis hybrids with high oil and protein content. Similar results were obtained by Shams et al., (2010) and Bocanski et al., (2011).

Table 3: Estimation of GCA effects of parents for phenology, plant stature, yield, yield components and quality traits

Traits / Parents	Days to 50% tasseling	Days to 50% silking	Plant height cm	Ear height cm	Leaf area cm^2	No. of row ear^{-1}	No. of kernels row^{-1}	300-kernels weight (g)	Kernel yield plant (g)	Oil percent	Protein percent
1	-0.033	-0.020	-2.460	-2.905	3.630	0.062	1.228	4.946	8.264	0.577	0.381
2	0.466	0.613	8.847	3.758	18.979	-0.038	0.020	2.025	5.500	-0.291	0.085
3	0.433	0.046	-6.482	-4.974	-9.169	0.158	-1.095	-4.485	5.416	0.414	0.059
4	0.266	0.246	-7.862	-2.528	-21.94	0.125	-1.333	-2.140	-8.824	-0.332	0.134
5	-1.130	-0.886	7.917	0.838	8.509	-0.308	1.179	-0.346	-10.356	-0.368	-0.661
S.E()	0.296	0.257	0.724	0.687	3.715	0.126	0.263	0.585	0.970	0.039	0.043

Values of the estimated specific combining ability effects of hybrids for studied traits are presented in table (4). Pertaining the SCA effect of the hybrids, the maximum SCA effect value (1.633) was noticed for diallel hybrid (2×5), while the highest negative SCA effect value (-2.100) was shown by the diallel cross (2×3) for days to 50% tasseling. Maximum positive SCA effect for days to 50% silking was also exhibited by the hybrid (2×5) indicating its ability to increase the required days to silking. The maximum negative value of SCA effect (-1.980) recorded by the hybrid (1×3), demonstrates the ability of this hybrid in decreasing the number of days to 50% silking compared to its parents.

The data in the same table reveal the estimation of SCA effects for plant height. The maximum positive SCA effect value was recorded by the cross (1×3) followed by the hybrids 1×4 and 2×4 with respective values of 27.202, 22.582 and 22.549, while the maximum negative effect was -13.737 exhibited by diallel cross (3×4). Regarding the SCA for ear height positive SCA effect value recorded by the diallel cross (3×5) was 14.508, whereas the lowest negative effect was -6.292 exhibited by cross (1×2). For leaf area, the diallel hybrid (3×5) exhibited the highest positive value (118.099).In the same table we can see that the SCA effect for yield and yield components the hybrids (1×5) gave the positive value of SCA effects. Regarding some of the quality character of corn, we found that the hybrids 1×2 and 3×4 were recorded the highest values for SCA effect for oil and protein. Pshdary, (2011); Zare et al., (2011) and Bocanski et al., (2011) reported significant SCA effects for grain yield and yield components in a diallel crosses of inbred lines. The estimated SCA effects of reciprocal hybrids, the data in the same table indicated that the hybrid (4×3) exhibited maximum negative effect for days to 50% tasseling and silking with respective value of -4.883 and -4.000 and the same hybrid gave the maximum positive value with 33.666 and 6.666 for plant and ear height while the cross (5×2) gave the maximum positive value for leaf area with 83.308.

For yield and yield components, the data in presented in table 4. The crosses (5×1), (4×2) and (4×3) were recorded positive value due to SCA for No. of rows^{-1}, No. of kernels rows^{-1}, 300 – kernel weight and kernel yield plant^{-1}. For oil and protein content the reciprocal (5×3) and (3×2) exhibited the maximum values with 1.066 and 0.828, respectively, while the cross (4×1) and (2×1) recorded the maximum negative value with -0.426 and -0.841. Similarly, in earlier studies were recorded significant of SCA effect by Bidhendi et al., (2011) and Zare et al., (2011).

Table 4: Estimation of SCA effects of hybrids and reciprocal hybrids for phenology, plant stature, yield, yield components and quality characters

hybrids	Day to 50% tasseling	Days to 50% silking	Plant height cm	Ear height cm	Leaf area cm^2	No. of rows ear^{-1}	No. of kernels row^{-1}	300 kernel weight/g	Kernel yield plant/ g	Oil percent	Protein percent
1×2	-1.133	-0.880	21.489	-6.292	55.287	0.821	0.398	-0.206	11.42	1.172	1.079
1×3	-1.100	-1.980	27.202	13.774	46.486	0.558	2.955	1.349	-0.975	0.421	0.133
1×4	0.900	-0.346	22.582	4.161	11.282	-0.075	-1.548	6.616	20.132	0.059	1.083
1×5	-1.200	-1.046	9.802	-0.705	48.891	0.241	2.371	7.739	4.905	-0.403	-0.264
2×3	-2.100	-1.113	18.836	7.521	18.621	-0.425	-1.356	5.071	-2.490	-0.267	-0.172
2×4	-1.933	-1.146	22.549	6.641	-35.749	0.024	0.960	-1.001	-16.087	-0.016	0.584
2×5	1.633	1.153	-3.730	14.441	40.884	0.324	-0.319	2.264	10.072	-0.215	0.133
3×4	1.600	0.586	-13.737	-5.292	118.099	0.494	5.450	-2.157	30.624	0.669	1.294
3×5	-1.666	-0.946	10.482	14.508	-60.192	0.378	1.212	-1.445	-2.911	-0.357	-0.158
4×5	-0.833	-1.480	9.696	-0.438	-20.879	-0.505	-2.586	-1.667	-1.457	-0.142	-1.013
E.S(sij-sij)	0.610	0.530	1.493	1.417	7.659	0.261	0.543	1.207	1.999	-0.081	0.089
2×1	-0.833	-0.500	-2.337	9.500	16.283	1.330	-0.500	-0.870	-8.190	0.300	-0.840
3×1	1.833	1.166	4.666	13.166	43.633	-0.870	-1.530	-8.610	-25.39	0.240	-0.690
4×1	0.000	0.000	-8.000	-2.000	-92.450	-0.070	-3.000	1.910	-17.75	-0.43	0.800
5×1	-0.500	-0.500	-7.000	-7.166	38.716	1.080	1.500	3.670	41.990	1.030	0.350
3×2	-1.333	-1.666	-25.666	-3.900	-17.016	0.620	-2.160	1.480	3.960	0.180	0.830
4×2	-2.333	-2.166	0.000	0.000	-11.533	0.330	-5.500	11.230	50.800	-0.360	0.420

5×2	0.166	0.000	4.500	9.500	85.308	1.330	1.330	-3.510	6.430	0.780	-0.230
4×3	-4.833	-4.000	33.666	16.666	32.833	0.870	1.930	21.980	13.320	-0.210	0.450
5×3	0.833	-0.333	13.000	-2.500	42.666	1.150	3.720	-5.460	20.450	1.070	-0.170
5×4	-2.160	-2.000	-6.1666	6.333	-9.400	-0.270	-1.600	8.190	27.100	0.940	-0.370
E.S(rij-rij)	0.740	0.643	1.811	1.719	9.288	0.320	0.660	1.460	2.430	0.100	0.110

Conclusion

Greater yield of crosses DKC648 x Pak., ATha7AA x Tha-132 and ATha7AA x DKC648 indicates the best of SCA, thus the non-additive dene action in involved in these crosses and grain yield can increase through hybridization. The inbred KC648, Pak., ATa7AA and Tha- 132 had the greatest effect in GCA. So that it can be use these inbreds in hybridization program to produce a good hybrid with high potential yield.

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