Genetic Analysis for Combining Ability and the Gene Action in Sunflower (*Helianthus annuus* L.) Using Half Diallel Cross

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Abstract. A field experiment was carried out in the right side of the Euphrates in Ramadi city Anbar province - Iraq, used in the research six pure varieties of Sunflower. These items introduced one-way half diallel in the 2018 spring season to produce 15 single crosses. The seeds of the parents and their hybrid were planted in the fall season 2018 in the design of R.C.B.D with three replicates. To estimate the effects of GCA, SCA and the gene action and some genetic parameters in the Sunflower. The results showed that there were significant differences between the hybrids and its parents in all studied traits. Note that the GCA and SCA variation on the union was highly significant for all studied traits. It was found that the parent (5) is the best parent in terms of GCA in the individual plant yield, gave an effect of (8.83) while the hybrid (3 × 4) is the best hybrid in the effect of SCA for the weight of 1000 seeds and the individual plant yield, (28.84 and 28.46) respectively. While the highest value of the heterosis in the trait of the individual plant yield of the hybrid (4 × 6) gave a value of (57.29%). The GCA variance to SCA was less than one for all studied traits except plant height indicating that there is a dominance gene action controls heredity of traits. This was reflected in the increase in the degree of dominance of one for most of the studied traits. The percentage of inheritance in the broad sense ranged from (97.74%) for the individual plant status to (99.81%) for the number of seeds per disc, this is due to the high genetic variation and low environmental variability. The highest value of genetic improvement was given to the number of seeds disk with a value of 249.15. The new combinations can be used in the production of individual hybrids with high specific combining ability to produce high yields because most of their traits were controlled by the dominance gene.

1. Introduction

Sunflower (*Helianthus annuus* L.) is one of the world's most important oil-producing crops. To contain the seeds of a high proportion of oil up to 15% as well as it contains a percentage of unsaturated fatty acids [1].

Hybridization is one of the basic ways to breeding and improve the characteristics of the sunflower for the purpose of testing its GCA and SCA to obtain the genetic differences that are used in the selection of genotypes. So, the researchers turned to take advantage of the phenomenon of hybridization by producing hybrid seeds. The difficulties faced by many breeders are the of obtaining superiority pure lines in the yield to conduct hybridization between them and to obtain superior hybrids.

A number of researchers have adopted the method of half diallel hybridization [2, 3, 4, 5] to improve the varieties of the sunflower in order to identify the nature of the gene action in the individual hybrids that controls the inheritance of studied traits. One of the difficulties faced by plant breeders in testing the appropriate parents in their general combining ability to reach positive results is the compatibility of parents. The results obtained by [6,7] showed a positive hybridization based on the best parents of all crosses for seed Yield plant -¹.

The aim of this study is to evaluate the genetic behavior of the Sun Flower varieties with different origins by studying the general and specific combining ability, hybridization, gene action and some genetic parameters.
2. Materials and methods

2.1. Plant materials
In this study, six varieties of the sunflower crop were given. Numbers were given from 1 - 6: Enflower, Flower Iraq, Coban, Royal, Flamme and Shamus. The varieties were grown on lines in the spring season 20/2/2018 in the fields of one of at latitude °33.28 north and longitude ° 43.33, with six lines for each variety and a length of 5 m. Seeds were planted at a distance of 0.75 m between one line and another, and a distance of 0.20 m between plant and another [8].

At the beginning of the petals, use a 25 ml g L⁻¹ solution to spray the floral discs of the plants used as mothers and spray until full wetness. After three days, the procedure was repeated again to ensure that all the pollen found in the flower disc are killed. The floral tablets of the used plants covered mothers using insulating bags made of mulch cloth [7]. For this purpose, several brushes were used to transport the pollen from parents to mothers, by using the brush on the floral disc used to parent and scan the discs used as mothers, for each cross by using the one-way half diallel. Self-pollination was also carried out for parents to multiply their seeds. At the end of the season, 15 individual crosses and 6 parents were obtained, bringing the number of genotypes to 21, the road explained by [9, 10].

2.2. Field experiment
In the fall season 18/7/2018, the seeds of the parents and their hybrids were planted in the same location using the RCBD design and three replicates. So that the single replicate contains (21) genotypes and the experimental unit included two lines guarded for each genotype [11]. The seeds were planted with 3 seeds hole single and the same distances in the previous season, and the plants were reduced to one plant at the stage of four leaves. The experiment was fertilized with DAP fertilizer containing (P2O5 46%) before planting and 240 kg h⁻¹ and urea fertilizer (N% 46) at rate 280 kg/h [6]. Fertilizer was added in two doses.

2.3. Phenotypic data were collected
A random sample consisting of 10 plants from the middle lines of each experimental unit was studied at the beginning of the composition of the flowers discs, to study the following traits: Plant height (cm), Leaf area (cm), Diameter disc (cm), No. of seeds / disc, Weight of 1000 seed (gm), Yield per plant (gm).

2.4. Equations
used estimation the sum of general combining as in the following equation

\[ SS \text{ gca} = \frac{1}{p+2} \left( \frac{\sum (x_i + x_j)^2}{p} - \frac{4}{p} (X..)^2 \right) \]

\[ SS \text{ sca} = \left( \frac{\sum x_{ij}^2}{p} - \frac{1}{p+2} \left( \frac{\sum x_i + x_j}{p} \right)^2 \right) + \frac{2}{(p+1)(p+2)} (x..)^2 \]

estimates the variance of the GCA and SCA of the calculated as follows

\[ 2^2 \text{ gca} = (MSgca-MS^)/P+2 \]

\[ 2^2 \text{ Sca} = MS \text{ sca} - MS e \]

The values of additive variance \(2^2A\), dominance \(2^2D\) and environmental \(2^2E\) were estimated as follows

\[ 2^2e = MS e \]

\[ 2^2D = 2^2\text{ sca} \]

\[ 2^2A = 2^2\text{ gca} \]

The values of in the broad and narrow sense and the degree of dominance were estimated by the mean variance expected from [11] analysis

\[ h^b,s = \frac{\sigma^2 G}{\sigma^2 P} \times 100 \]

\[ h^n,s = \frac{\sigma^2 A}{\sigma^2 P} \times 100 \]

\[ a^s = \sqrt{2\sigma^2D/\sigma^2A} \]

Where \(P\) = number of parents
MS \text{ gca} = mean variance of the general combining ability
MS \text{ sca} = The mean variance of the specific general combining ability
Data from parents and their hybrids were analyzed for the studied traits according to the design used. The data were analyzed according to the first model of the second method [12].

3. Results and Discussion

Table (1) shows that there are significant differences in all the studied traits. This indicates the importance of both the additive and Non additive effects in the studied traits. This indicates that dominance effects were more important than the additive effects of most traits. This indicates that there is a dominance gene action that controls inheritance of traits [4, 12, 13, 14].

Table 1. Analysis of variance of General and specific combining ability, for all studied traits.

| SOV    | DF | Plant height (cm) | Leaf area (cm) | Diameter disc (cm) | No. of seeds/disc | Weight of 1000 seed (gm) | yield per plant (gm) |
|--------|----|-------------------|----------------|--------------------|-------------------|--------------------------|----------------------|
| REP.   | 2  | 30.5              | 62.13          | 14.22              | 235.4             | 52.41                    | 55.2                 |
| Genotypes | 20 | 520               | 1645           | 10.92              | 42152.6           | 855                      | 869.12               |
|         |    | **                | **             | **                 | **                | **                       | **                   |
|         | 5  | **                | **             | **                 | **                | **                       | **                   |
| G.C. A | 5  | 761.250           | 8230.110       | 46.050             | 45620.000         | 380.160                  | 338.240              |
| S.C. A | 15 | 52.420            | 6425.220       | 12.200             | 10582.200         | 215.620                  | 230.140              |
| MSE    | 40 | 12.6              | 152.21         | 1.31               | 122.5             | 12.6                     | 21.15                |
| 2Gca/δ  |   | 1.962             | 0.160          | 0.485              | 0.540             | 0.222                    | 0.186                |
| 2Sca δ  |   |                   |                |                    |                   |                          |                      |

Table (2) shows the average values of the parents and the hybrids resulting from the studied traits. There are significant differences between parents and hybrids. The parent (1) was the least value among the parents in the height of the plant and diameter of the disc if given values of (152.4) cm and (15) cm. respectively. While the superiority of the parent (6) in the trait of plant height and gave a height of (185.2 cm). parent (5) superiority the leave area and gave a value of (345.8 cm). While in the number of seeds in the disk superiority the parent (6) and gave a number of seeds amounted to (1068.2 seed). The seed weight and the plant yield (g) superiority the parent (2) gave the values (85.4 g) and (83.55 g) respectively. While the hybrid (3 × 4) recorded the highest average for the two traits, weight of 100 grains (92.2 g) and the seed yield was (92.016 g). This superiority is due to the superiority of both lines in most of the growth, yield and components. This is consistent with the findings [3, 4, 15]. This is due to the genetic diversity between the parents involved in the crossing.
Table 2. Means of parents and their F1s for different traits in half diallel cross

| Characters | Genotypes | Plant height (cm) | Leaf area (cm) | Diameter disc (cm) | No. of seeds/disc | Weight of 1000 seed (gm) | yield per plant (gm) |
|------------|-----------|------------------|----------------|-------------------|------------------|------------------------|---------------------|
| 1          | 152.4     | 338.2            | 15             | 1022.1            | 50.2             | 51.309                 |
| 2          | 168.2     | 309.4            | 15.2           | 978.4             | 85.4             | 83.555                 |
| 3          | 165.6     | 295              | 16.3           | 899.12            | 54               | 48.552                 |
| 4          | 178.2     | 333.2            | 16             | 1023.1            | 47.3             | 48.393                 |
| 5          | 175.4     | 345.8            | 17.2           | 1025.6            | 63.7             | 65.331                 |
| 6          | 185.2     | 315.4            | 15.8           | 1068.2            | 45.8             | 48.924                 |
| 1x2        | 172.1     | 345              | 17.5           | 1096.9            | 50.8             | 55.723                 |
| 1x3        | 160.2     | 316.9            | 17.2           | 1013.2            | 49.2             | 49.849                 |
| 1x4        | 180       | 360.4            | 18.4           | 1031.8            | 53.1             | 54.789                 |
| 1x5        | 188.4     | 362.4            | 20.4           | 1032.6            | 47.2             | 48.739                 |
| 1x6        | 177.5     | 330              | 20.2           | 1118.4            | 51.3             | 57.374                 |
| 2x3        | 180.2     | 315              | 16.8           | 898.2             | 38.5             | 34.581                 |
| 2x4        | 169.21    | 350.3            | 14.7           | 1015.4            | 60.2             | 61.127                 |
| 2x5        | 186.2     | 365.2            | 16.9           | 998.2             | 85.3             | 85.146                 |
| 2x6        | 172.5     | 315.4            | 18.2           | 1005.2            | 60.1             | 60.413                 |
| 3x4        | 184.6     | 320.2            | 19.8           | 998               | 92.2             | 92.016                 |
| 3x5        | 192.3     | 360.4            | 20.3           | 1012.4            | 76.6             | 77.55                  |
| 3x6        | 175.1     | 290.4            | 21.5           | 1045.1            | 70.4             | 73.575                 |
| 4x5        | 185.9     | 207.3            | 18.3           | 1230.6            | 72.2             | 88.849                 |
| 4x6        | 186.6     | 342.4            | 17.6           | 1128.4            | 68.2             | 76.957                 |
| 5x6        | 196.3     | 375.3            | 16.9           | 1332.4            | 68.3             | 91.003                 |
| Means      | 177.719   | 328.266          | 17.628         | 1046.349          | 61.428           | 64.464                 |
| L.S.D      | 2.212     | 7.693            | 0.713          | 6.901             | 2.212            | 2.867                  |

Table (3) shows the Heterobeltiosis for the hybrids of the basis of the first-generation deviation from the best parents in the hybrids diallel of the studied traits. Note that hybridization ranged between positive and negative values for most studied traits. Where the hybridization to the plant high significant and the desired direction of ten crosses, For the leave area, nine hybrids reached the highest value (8.53%) in the hybrid (5 × 6). The values of the hybridization for the number of seeds per disc ranged between positive and negative values. Seven hybrids showed positively values (24.73%) for the hybrid (5 × 6).

While in the weight of 1000 seeds showed seven positive hybrids with the highest value (70.74%) for the hybrid (3 × 4). As for seed yield, nine hybrids showed positive was highest values (89.52%) for the hybrid (3 × 4). Researchers from previous studies have obtained hybrids characterized by high hybrid hybridization and desirable for some of them [1, 13, 16, 17].
Table 3. Estimates of heterosis over best parent for all studied traits

| Characters          | Hybrids | Yield per plant (gm) | Weight of 1000 seed (gm) | No. of seeds/disc | Diameter disc (cm) | Leaf area (cm) | Plant height (cm) |
|--------------------|---------|----------------------|--------------------------|-------------------|--------------------|----------------|------------------|
|                    | 1x2     | 2.318                | -40.515                  | 15.131            | 7.318              | 2.011          | 2.318            |
|                    | 1x3     | -3.261               | -8.888                   | 5.521             | -0.871             | 4.8            | 4.8              |
|                    | 1x4     | 1.01                 | 5.776                    | 15                | 0.85               | 6.564          | 6.782            |
|                    | 1x5     | 7.412                | 25.902                   | 18.604            | 0.682              | 4.8            | 15.131           |
|                    | 1x6     | -4.157               | 2.191                    | 27.848            | 4.699              | 1.01           | 2.318            |
|                    | 2x3     | 7.134                | -54.918                  | 3.067             | -8.197             | 1.809          | 11.82            |
|                    | 2x4     | -5.044               | -29.508                  | -8.125            | -0.752             | 5.132          | -5.87            |
|                    | 2x5     | 6.157                | -2.671                   | -1.744            | -1.112             | 5.61           | 5.521            |
|                    | 2x6     | -6.857               | -29.625                  | 15.189            | -5.897             | 0              | 8.83             |
|                    | 3x4     | 3.591                | 70.74                    | 21.472            | -2.453             | -7.403         | 89.52            |
|                    | 3x5     | 9.635                | 20.251                   | 18.023            | -1.287             | 4.222          | 18.98            |
|                    | 3x6     | -5.453               | 30.37                    | 31.901            | -2.162             | -7.926         | 50.386           |
|                    | 4x5     | 4.321                | 13.343                   | 6.395             | 19.988             | -40.052        | 35.998           |
|                    | 4x6     | 0.755                | 44.186                   | 10                | 5.635              | 2.761          | 18.703           |
|                    | 5x6     | 5.99                 | 18.023                   | 1.479             | -4.417             | 8.53           | 57.299           |
|                    | S.E     | 1.296                | 4.321                    | 0.417             | 4.041              | 4.504          | 1.679            |

Table (4) shows the estimation of the effects of general combining ability to each parent of the studied traits. The best parent 5 in the yield per plant (8.83), the weight of 1000 seeds (5.87), the diameter of the disc (0.47) and the Plant height (6.98), all its effects were positive and significant. This parent can be used to possess the desired genes and contribute great degree to the transfer of the character into a hybrid. This finding is consistent with the [2, 4]. This indicates that the general combining ability of to have significant and positive effects in some parents in the transfer of traits studied.

While followed by the parent (6), where all its effects were positive, except for the two trait of leave area and the weight of 1000 seeds, Where the effects were negative and gave the highest positive and significant effect in the number of seeds with the disc (55.18). This refers to the possibility of benefiting from this parent (6) in the transfer of desirable traits to his crosses and his contribution to a large extent in the transfer of traits to the hybrids resulting from his crosses. Agree this result with [18, 19, 20, 21].

Table 4. Estimates of GCA effects of each parent for all studied traits

| Genotypes | Plant height (cm) | Leaf area (cm) | Diameter disc (cm) | No. of seeds/disc | Weight of 1000 seed (gm) | yield per plant (gm) |
|-----------|------------------|----------------|-------------------|-------------------|--------------------------|----------------------|
| P1        | -7.629           | 11.654         | 0.037             | 1.582             | -9.750                   | -10.269              |
| P2        | -3.428           | 1.479          | -1.112            | -44.217           | 4.462                    | 1.606                |
Table (5) shows the estimation of the specific combining ability effects for each hybrid in its studied characteristics. (1 × 5) was the best in plant height (11.32), and (5 × 6) was the best in the leaves area (40.68). (3 × 6) is the best in the disc diameter (2.94). While (4 × 5) the best number of seeds in the disc (126.88). (3 × 4), the best in the weight of 1000 seeds (28.84). And the yield per plant (28.46) in the crossing (3 x 4). This shows that some of the crosses showed a significant positive effect, while others showed a negative effect on the SCA to the studied traits.

There was a variation between some crosses of the effects on the specific combining ability. Where parents have a positive and significant impact of the general combining ability to a degree of traits, give the same effects in the same direction in the effects of their impact on the specific combining ability of the Union. This means showing the dominance influence of genes. While the effects of the general combining ability are positive and significant to the character from traits, there was no positive impact on the specific combining ability, this is caused by the effect of the additive gene action in the studied traits [22, 23, 24].

| Characters | Plant height (cm) | Leaf area (cm) | Diameter disc (cm) | No. of seeds/disc | Weight of 1000 seed (gm) | yield per plant (gm) |
|------------|------------------|----------------|-------------------|------------------|--------------------------|---------------------|
| 1x2        | 5.438            | 3.6            | 0.946             | 93.186           | -5.341                   | -0.077              |
| 1x3        | -7.335           | -9.9           | -1.066            | 35.181           | -3.091                   | -1.023              |
| 1x4        | 7.575            | 26.8375        | 1.059             | -31.876          | 0.108                    | -1.814              |
| 1x5        | 11.327           | 14.4375        | 2.258             | -56.951          | -10.353                  | -14.292             |
| 1x6        | 3.114            | -8.225         | 2.208             | 15.286           | 2.133                    | 2.439               |
| 2x3        | 8.463            | -1.625         | -0.316            | -34.018          | -28.003                  | -28.167             |
| 2x4        | -7.415           | 26.9125        | -1.491            | -2.476           | -7.003                   | -7.352              |
| 2x5        | 4.925            | 27.4125        | -0.091            | -45.551          | 13.533                   | 10.238              |
| 2x6        | -6.086           | -12.65         | 1.358             | -52.113          | -3.278                   | -6.397              |
Table (6) shows the genetic parameters of studied traits. It shows the values of the components of variance, inheritance ratios and the degree of dominance. When estimating the components of genetic variation, by analyzing correlation coefficient and path analysis between yield and its components. The values of the dominance variance were higher than the Non-dominance variance in the characteristics of leaf area, disc diameter, 1000 grain weight and yield plant. Indicate that the genes of dominance variation are more important than genes for additive variation in inheritance control of these traits. These results are agreed with the findings of both [7].

The lowest percentage of plant leaf area is 24.142

The ratio of inheritance in the broad sense was high for all studied traits, ranging from (97.74) for the individual plant yield and (99.81) for the number of seeds in the disc, this is due to the high value of genetic variation and low environmental variation. While the percentage of inheritance in the narrow sense ranged between the lowest percentage of plant leaf area is (24.142) and (78.31) for plant height. The degree of dominance was greater than one for all traits except the plant height and this indicates the existence of the effects of over-dominance of genes that control the inheritance of traits. The expected genetic improvement was high for the number of seeds with the disc (249.15) and ranged from (0.92) for the individual plant yield and (27.42) for the diameter disc. These results agreed [10,18,25].

| Genetic parameters | Plant height (cm) | Leaf area (cm) | Diameter disc (cm) | No. of seeds/disc | Weight of 1000 seed (gm) | yield per plant (gm) |
|--------------------|-------------------|----------------|-------------------|-------------------|-------------------------|---------------------|
| \(\delta^2 A\)     | 189.263           | 2056.47        | 11.403            | 11394.792        | 93.990                  | 82.798              |
| \(\delta^2 D\)     | 48.220            | 6421.02        | 11.763            | 10541.367        | 211.420                 | 223.090             |
| \(\delta^2 G\)     | 237.483           | 8419.327       | 23.167            | 21936.158        | 305.410                 | 305.888             |
| \(\delta^2 E\)     | 4.200             | 50.737         | 0.437             | 40.833           | 4.200                  | 7.050               |
| \(\delta^2 P\)     | 241.683           | 8470.063       | 23.603            | 21976.992        | 309.610                 | 312.938             |
| \(H^2_{b.s}\)      | 98.262            | 99.401         | 98.150            | 99.814           | 98.643                  | 97.747              |
| \(H^2_{n.s}\)      | 78.310            | 24.142         | 48.312            | 51.849           | 30.358                  | 26.458              |
4. Conclusion

Due to variances among (Cytoplasm Meals Striated) CMS lines which used as lines, conclude from the above that the parent (6) is the best parents for its superiority in the traits of plant height and the number of seeds per disc. (3 × 4) was the best in the hybridization of the plant yield where it gave a value of (89.52%). And cross (5 × 6) is the best in the number of seeds per disk gave a hybridization value of (24.73%). While the parent (6) is the best in the effects of the General combining ability of the number of seeds in the disc, where gave a value of (55.18). The effects of the specific combining ability cross (5 × 6) was the best in the leaves area where it gave a value of (40.68) therefore for improving these traits, GCA effects of parents can be considered as suitable criteria for SCA prediction of the crosses.

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