Journal homepage
www.ajas.uoanbar.edu.iq
Anbar Journal of Agricultural Sciences
(University of Anbar – College of Agriculture)

ESTIMATION OF THE GENETIC ACTION AND COMBINING ABILITY OF SUNFLOWER USING CYTOPLASMIC MALE STERILITY

Z. A. Abdulhamed [1]*   H. S. Hamad [1]   B. M. Abdulkareem [2]

[1] College of Agriculture, University of Anbar.
[2] Accommodation Department, University of Anbar, Ramadi, Iraq.

***Correspondence to:** Zeyad A. Abdulhamed, Department of Field Crops, College of Agriculture, University of Anbar, Ramadi. Iraq.
Email: ag.zeyad.abdul-hamedr@uoanbar.edu.iq

Article info

Received: 2025-01-26
Accepted: 2025-03-30
Published: 2025-06-30

DOI-Crossref:
10.32649/ajas.2025.187596

Cite as:
Abdulhamed, Z. A., Hamad, H. S., and Abdulkareem, B. M. (2025). Estimation of the genetic action and combining ability of sunflower using cytoplasmic male sterility. Anbar Journal of Agricultural Sciences, 23(1): 627-640.

Abstract

The research was conducted in the fields of a farmer in Ramadi city, Iraq, on the left bank side of the Euphrates River. The study aimed to know sunflowers' ability and genetic action using cytoplasmic male sterility. Five cytoplasmically male-sterile sunflower lines (A6, A10, A12, A13, and A16) were crossed with three testers carrying fertility restoration genes and the multi-head trait (R1, R2, and R3). A (line × tester) system was applied to 15 hybrids. The lines were planted during the spring of 2023 to produce 15 hybrids. In the autumn season of 2023, seeds of the genetic combinations (8 parents + 15 hybrids) were planted using a randomized complete block design (RCBD) with three replications. The experiment aimed to evaluate the lines and hybrids, estimate the general and specific combining abilities of the parents and hybrids, and study other genetic traits. The results of the genetic combining ability showed significant differences in all the studied traits. A10 line exhibited the highest value in disk area, measuring 194.31 cm², with 934.40 seeds per disk and a yield of 67.73 g. A13 line excelled in 1000-seed weight, yielding 74.2 g. Meanwhile, the A6 line showed the highest oil content in seeds, reaching 49.12%. Among the testers, R1 was the best for most traits. The hybrid A10×R3 recorded the highest values in disk area of 249.13 cm², number of seeds per disk of 1356.04 seeds, and yield of 94.71 g. On the other hand, the hybrid A12 × R1 recorded the highest oil content in seeds, with 47.21%. The specific combining ability variance components were more significant than the general combining ability variance components. Moreover, the dominance genetic variance was more significant than the additive genetic variance. The narrow-sense heritability ranged between 3.95% for oil content and 55.09% for plant height. This led to a dominance degree higher than one for most of the studied traits. It can be concluded from this study that confident superior parents can be utilized in crosses to develop individual hybrids with specific combining abilities, leading to high seed yield. This is because most traits were influenced by dominance and over-dominance.

Keywords: Dominance, Male Sterility, Heritability, Hybrids, Fertile Lines.

تقدير الفعل الجيني وقابلية الائتلاف لزهرة الشمس باستعمال العقم الذكري السايتوبلازمي

زياد عبدالجبار عبدالحميد [1]* هديل صبار حمد [1] براء محمود عبدالكريم [2]

[1] كلية الزراعة، جامعة الانبار.

[2] الاقسام الداخلية، جامعة الانبار.

***المراسلة الى:** زياد عبدالجبار عبدالحميد، قسم المحاصيل الحقلية، كلية الزراعة، جامعة الانبار، الرمادي، العراق.

البريد الالكتروني: ag.zeyad.abdul-hamedr@uoanbar.edu.iq

الخلاصة

تم إجراء البحث في حقول أحد المزارعين في مدينة الرمادي، على الضفة اليسرى لنهر الفرات. الهدف كان دراسة قابلية الأئتلاف والفعل الجيني في زهرة الشمس باستخدام العقم الذكري السايتوبلازمي. تم التضريب بين خمس سلالات عقيمة سايتوبلازمياً من زهرة الشمس، وهيA6 ، A10، A12، A13، A16، مع ثلاث فواحص تحمل جينات استعادة الخصوبة وصفة تعدد الرؤوس، وهي R1، R2، R3. تم تطبيق نظام التزاوج السلالة × الفاحص، وأُنتج 15 هجيناً. زرعت السلالات خلال الموسم الربيعي لعام 2023 بهدف إنتاج 15 هجيناً. في الموسم الخريفي لعام 2023، زرعت بذور التراكيب الوراثية (8 آباء + 15 هجين) باستخدام تصميم القطاعات الكاملة المعشاة (RCBD) مع ثلاث مكررات. كان الهدف من هذه التجربة هو تقويم السلالات والهجن، وتقدير قابلية الائتلاف العامة للإباء والخاصة للهجن، فضلا عن دراسة بعض المعالم الوراثية الأخرى. تم تحليل البيانات وتقديم رؤى

حول كيفية تحسين خصائص زهرة الشمس من خلال هذه الأساليب. أظهرت نتائج مقارنة التراكيب الوراثية وجود اختلافات معنوية في جميع الصفات المدروسة. تميزت السلالة A10 بإعطائها أعلى قيمة في مساحة القرص، إذ بلغت 194.31 سم²، وعدد البذور بالقرص 934.40 بذرة، وحاصل البذور بلغ 67.73 غم، تفوقت السلالة A13 في وزن 1000 بذرة، إذ أعطت 74.2 غم. بينما تميزت السلالة A6 بأعلى نسبة زيت في البذور، حيث بلغت 49.12.% وأما بالنسبة للفواحص، فكان الفاحص الأول R1 هو الأفضل في معظم الصفات. في حين اعطى الهجين A10 × R3 أعطى أعلى قيمة في مساحة القرص 249.13 سم²، وعدد البذور بالقرص 1356.04 بذرة، وحاصل بذور القرص 94.71 غم. في حين أن الهجين R1 × A12 سجل أعلى نسبة زيت في البذور 47.21%. كما أظهرت مكونات تباين القدرة الخاصة على الأئتلاف أنها أكبر من مكونات تباين القدرة العامة على الأئتلاف. وكان التباين الوراثي السيادي أكثر أهمية من التباين الوراثي المضيف. تراوحت نسبة التوريث في معناها الضيق بين 3.95% لنسبة الزيت و55.09% في ارتفاع النبات. هذا أدى إلى ارتفاع درجة السيادة عن واحد صحيح لمعظم الصفات المدروسة. يمكن استنتاج من هذه الدراسة أنه يمكن استخدام بعض الآباء المتفوقة في التضريبات لاستنباط هجن فردية ذات قابلية اتحاد خاصة، مما يؤدي إلى إنتاج حاصل بذور عالي. لأن معظم الصفات كانت تحت تأثير السيادة والسيادة الفائقة.

كلمات مفتاحية: السيادة، العقم الذكري، التوريث، الهجن، سلالات خصبة.

Introduction

Sunflower (*Helianthus annuus* L.) is one of the most important oil crops in the world. Its seeds contain a high percentage of oil (55%). The crop ranks third in the world after soybeans and rapeseed in oil production and is a major source of vegetable oil in many countries. In Iraq, sunflower is the first oil crop; in Europe, it ranks second after rapeseed. Sunflower oil is of high quality due to its high content of unsaturated fatty acids. The materials from pressing the seeds are considered good fodder for animals and poultry due to their high protein content of up to 32% and 20-22% carbohydrates. (5). Despite the great importance of this crop, its productivity in Iraq is still low compared to global production. The average yield in Iraq reached 2.11 tons per hectare, while in some countries, it reached 7.5 tons per hectare (10). This large gap in productivity calls for thinking about possible solutions: how can the productivity of this crop be raised? What steps must be taken? Taking action to narrow the gap between local and global production. Developing well-thought-out programs and plans to improve productivity is essential: modern agricultural techniques can be used, and appropriate conditions for crop growth can be provided. Hybrid production requires evaluating crop lines to identify those with high combinability. These lines provide indicators for producing high-yielding hybrids and help understand the nature of genetic action affecting the trait. The selection of the appropriate lineage depends on two main factors: the traits of the lines themselves. For example, crop productivity, the formation of sufficient pollen grains, resistance to diseases and insects, the ability to adapt to environmental factors, and the behavioral compatibility of the lines in the hybrid (which determines the extent to which the lineage interacts with other lines in the hybrid), which is an important factor for hybridization success. Sunflowers are a crop with a high rate of cross-pollination, where yields decrease when internal pollination occurs (self-breeding) and increase when crossing genetically distant parents. For this reason, researchers prefer producing single hybrids to maximize the potential of hybrid vigor. Single hybrids have advantages such as high yield and uniform growth and maturity.

Sunflower hybrids are grown on over 21 million hectares worldwide (26). In some countries, such as the United States, Europe, Argentina, and Australia, 100% of sunflower oil production depends on hybrid cultivation (11, 12 and 23). However, what made this possible? The discovery of cytoplasmic male sterility (CMS) and fertility restoration (RF) genes in the 1970s played a major role in the development of sunflower cultivation. CMS has become an essential tool for efficient hybridization (18, 19 and 24). The crop requires the removal of pollen from the mother plant, and this transformation has revolutionized hybrid breeding and increased productivity. Thanks to these technologies, sunflower hybrid breeding has developed rapidly and efficiently. The application of CMS could solve agricultural problems in certain regions. This study evaluates cytoplasmically sterile and genetically fertile lines to determine hybrid vigor and general and specific combining ability. This is done to select superior lines that can produce high-yielding hybrids. Additionally, the study aims to estimate the heritability and degree of dominance of the studied traits. This information is essential for understanding how genetics influence traits of interest to production, such as seed yield, oil content, and disease resistance. Through this study, lines that exhibit good interaction with each other in hybrids can be identified. This interaction enhances the vigor of the hybrid, thereby increasing its productivity. For example, if lines with high combining ability are identified, significant yield increases can be achieved.

Materials and Methods

To test and evaluate sunflower lines for hybrid production using cytoplasmic male sterility, a field study was conducted on five cytoplasmically sterile lines (A-Lines) and three genetically fertile, multi-headed lines (R-Lines). These lines were obtained from the Iraqi General Commission for Agricultural Research. A hybridization program was applied according to the (line × tester) mating system. The sterile lines (3 lines) were used with the fertile, multi-headed lines (5 lines) to produce diverse hybrids (15 hybrids).

Table 1: Type and symbols of the lines used in the study of Iraq.

Line Number	Code	Notes
1	R1	Genetically fertile line (R-Lines)
2	R2	Genetically fertile line (R-Lines)
3	R3	Genetically fertile line (R-Lines)
4	A6	Cytoplasmically sterile line (A-Lines)
5	A10	Cytoplasmically sterile line (A-Lines)
6	A12	Cytoplasmically sterile line (A-Lines)
7	A13	Cytoplasmically sterile line (A-Lines)
8	A16	Genetically fertile line (R-Lines)

The study was conducted during the spring and autumn seasons of 2023 in a farmer's fields in Ramadi city on the left bank of the Euphrates River. In the spring season, the seeds of the studied lines were sown on March 2, 2023, alternately in rows at a ratio of 3 sterile lines to 1 fertile line. The distance between holes was set at 0.20 m and between rows at 0.70 m. To conduct crosses and produce hybrid seeds, discs of a group of plants of the studied lines were coated at the beginning of the appearance of the petal leaves. The cytoplasmically sterile lines were crossed with the genetically fertile lines using the (line × tester) mating system proposed by (20). Fifteen hybrids were produced from this process. Lines R1, R2, and R3 were used as testers, while lines A16, A13, A12, A10, and A6 were used as mothers. At the end of the season, plants were harvested from all eight parents and fifteen hybrids. The seeds were manually sown in preparation for planting in the control experiment. In the fall season of 2023, hybrid seeds were planted with the parents at the same site on July 10, 2023. A randomized complete block design (RCBD) with three replicates was used. The experimental unit consisted of five 6-meter-long rows, with a distance of 0.75 meters between rows and 0.30 meters between holes. Three seeds were sown in each hole, and the number of plants was reduced to one plant per hole. All agricultural operations were carried out according to established recommendations. Phosphate fertilizer (P_2O_5) was added at 200 kg ha^{-1} before planting. Urea fertilizer (N) was added at 220 kg ha^{-1} in two batches.

All studied traits were measured on an individual plant basis at a rate of ten plants per treatment (from the median lines). Guard lines (lateral lines) were excluded from the analysis. The following traits were studied: stem diameter (mm), disc area (cm^2), number of disc seeds, 1000-seed weight (g), seed yield per plant (g), and oil percentage. The data were statistically analyzed using the Line×Tester analysis method, which was suggested by (19) and explained by (25), where the parents are divided into two groups, the first representing the parents used in the test (Testers, T=3) and the second the parents required to be evaluated (Lines, L=5). According to the analysis method, the number of hybrids will be equal to the product of the lines L× the number of testers T, which represents fifteen individual hybrids, and accordingly, the number of genetic compositions will be (8+15) =23.

The effects of general and specific combining ability were estimated as follows:

The effect of general combining ability (GCA) for the lines to be tested:

$$\widehat{gl} = \frac{xL\,...}{tr} - \frac{x\,...}{Ltr}$$

The effect of the general ability to coalesce (GCA) on the parents using testers:

$$\widehat{gt} = \frac{x.j}{Lt} - \frac{x\,...}{Ltr}$$

Effects of special combining ability (S.C.A) for the hybrids (i,j):

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

The phenotypic variance components (б^{2}p), including host variance (б^{2}A), dominance variance (б^{2}D), and environmental variance (б^{2}E), were estimated from the mean expected variance (EMS) values of the fixed model, and б^{2}E= Mse.
The degree of heritability in the broad sense (H^2.B.S) and narrow sense (h^2.n.S) and the average degree of dominance (ā) were estimated as follows:

$$\%H^2_{B.S} = \frac{\delta^2 G}{\delta^2 P} \times 100$$

$$\%h^2_{n.s} = \frac{\delta^2 A}{\delta^2 P} \times 100$$

$$\bar{a} = \sqrt{\frac{2\,\delta^2\,D}{\delta^2\,A}}$$

Standard errors for the effect of coalition capacity were estimated using the method (23).

$$S.E\,(\widehat{gi} - \widehat{gj})\ Line = \sqrt{\frac{2\,mse}{rt}}$$

$$S.E\,(\widehat{gi} - \widehat{gj})\ Tester = \sqrt{\frac{2\,mse}{rL}}$$

$$S.E\left(\widehat{Sij} - \widehat{Sik}\right) = \sqrt{\frac{2\,mse}{r}}$$

Results and Discussion

Table 2 shows significant differences in the mean squares of the genotypes for all studied traits at the 1% level. There were significant differences in the mean squares of parents, parents versus crosses, and crosses, as well as between lines and testers, in addition to the interaction between lines and testers (Lines × Tester Interaction). These results confirm what has been indicated by many previous studies (1, 2, 4, 6, 13, 16 and 20), all of which found significant differences between the studied genotypes. This means these genotypes can be the basis for studying their genetic behavior more deeply.

Table 2: Analysis of variance by (Tester Analysis × Line) for the studied traits in sunflower.

Sources of Variation	df	Mean Squares					
		Stem diameter ml	Disc area cm^2	Number of seeds per disc	Weight of 1000 seeds (g)	Seed yield per plant (g)	The oil content of seeds
Replicates	2	5.1	9.4	8.82	69.3	5.3	4.28
Genetic Structures	22	** 15332	** 4827	** 77592.1	** 299.3	** 762.3	** 14.93
Parents	7	** 17792	** 7495	** 69582.2	** 386.91	** 994.8	** 23.23
Parents vs. Hybrids	1	** 9227	** 5872.2	** 126983	** 496.13	** 994.9	** 20.33
Hybrids	14	** 302.2	** 198.7	** 8732.8	** 103.29	** 30.85	** 5.91
lines	4	** 298.9	** 421.3	** 8873.4	** 113.17	** 20.22	** 6.78
Testers	2	** 307.2	** 99.97	** 200321	** 182.09	** 30.74	* 1.92
Lines x Testers	8	** 238.1	** 96.83	** 2994.9	** 40.11	** 11.93	** 2.31
Experimental Error	44	28.91	25.88	63.09	8.36	3.65	0.44

Table 3 shows the average values of the parents and individual hybrids for the studied traits. The results showed significant differences between the genotypes and their hybrids, where parent A10 was distinguished by giving the highest values in disc area (188.73 cm^2), number of seeds per disc (924.28 seeds), and seed yield (66.65 g). Parent A13 excelled in 1000-seed weight, giving 73.3 g. Parent A16 excelled in disc diameter, reaching its highest value of 27 mm. Parent A6, on the other hand, gave the highest percentage of seed oil, reaching 48.32%. For hybrids, the hybrid 3R × A16 was superior in disc area (243.91 cm^2), number of seeds per disc (1346.92 seeds), and seed yield per plant (93.14 g). The hybrid 1R × A13 did not differ significantly from the hybrid 3R × A10 in these traits. The hybrid 3R × A16 was superior in stem diameter, which reached 29 mm, while the hybrid 1R × A12 was distinguished by its highest seed oil percentage, 46.11%. These results confirm the findings of many previous studies (3, 4, 7, 8, 9,12, 18, 21 and 25) that there are significant differences between individual hybrids and their parents in many studied traits. These differences between parents and hybrids provide an opportunity to select the most appropriate genetic compositions to improve crop productivity and what traits are believed to be given priority in improving future hybrids.

Table 3: Averages of the studied traits for parents and first-generation hybrids in sunflower plants.

Genetic Structures	Characteristics					
	Stem Diameter ml	Disk Area cm2	Number of Seeds per Disc	Weight of 1000 Seeds g	Seed Yield per Plant g	Seed Oil Percentage%
R1	21	74.77	591.63	35.3	20.78	46.66
R2	22	76.18	486.96	40.5	18.67	40.54
R3	25	81.89	459.65	37.4	19.46	43.13
A6	25	160.87	836.33	64.6	53.77	48.32
A10	26	188.73	924.28	49.2	66.65	41.86
A12	22	153.81	846.34	59.5	53.55	46.50
A13	23	156.22	624.91	73.3	58.12	44.14
A16	27	164.99	846.23	61.6	64.15	46.61
A6 × R1	23	163.37	730.45	48.4	64.13	41.66
A10× R1	24	176.35	949.86	41.7	79.07	42.25
A12 × R1	25	237.82	1094.33	63.8	64.21	46.11
A13× R1	24	250.57	1239.85	58.6	87.11	38.73
A16 × R1	23	178.63	1034.93	83.3	73.07	37.44
A6 × R2	27	155.91	890.99	92.4	65.11	41.87
A10× R2	22	197.09	1001.46	59.2	58.21	43.41
A12 × R2	24	226.65	848.81	95.8	65.07	39.87
A13× R2	26	193.12	977.72	59.3	76.62	45.38
A16× R2	28	194.95	750.77	75.7	74.26	41.98
A6 × R3	27	212.72	1026.13	85.5	68.85	40.87
A10× R3	26	243.91	1346.92	68.3	93.14	41.77
A12 × R3	25	204.71	980.72	63.8	84.85	45.36
A13× R3	25	185.55	1090.36	68.6	74.25	41.82
A16 × R3	29	217.77	1020.82	86.9	71.66	40.92
L.S.D 5%	**1.60**	**7.61**	**20.87**	**2.48**	**2.38**	**1.02**

The parents were evaluated by estimating the effects of general combining ability, Table 4. The results showed that parent R3 exhibited significant combining in the desirable direction for all traits except oil percentage. Parent R1 exhibited undesirable combining for all traits except stem diameter. Parent R2 exhibited desirable combining for 1000-seed weight and oil percentage, while parent A6 exhibited desirable combining for stem diameter and 1000-seed weight only, while undesirable combining for the remaining traits. The results indicate that some parents may be useful for increasing average seed weight in offspring from crosses. Parent A6 can be used to increase seed weight, although its effect on other traits may be undesirable. However, the A13, A10, and tester R1 exhibited significant combining effects toward reducing seed weight, and parent A10 exhibited desirable combining for disc area. Likewise, parent A12 showed a favorable combination for disc area, kernel weight, and oil percentage, while parent A13 showed a favorable combination for all traits except 1000 seed weight and oil percentage, where the combination was unfavorable. Parent A16 showed a favorable combination of disc diameter, disc area, and plant yield about seed yield. Lineages A10, A13, A16, and tester R3 showed a positive and significant effect, indicating that these lines can transfer genes associated with high seed yield to their progeny. Therefore, they can be used as parents in hybridization programs to improve yield efficiency and increase seed production. This is consistent with the findings of (14 and 17), who found that using these parents to improve yield in hybridization programs may contribute to increasing sunflower productivity and how the hybridization method can be improved to select the most effective parents.

Table 4: Effects of general combining ability of each parent on the studied traits in sunflower.

testers	Characteristics					
	Stem diameter	**Disc area**	**Number of seeds per disc**	**Weight of 1000 seeds**	**Seed yield of the plant**	**The oil content of the seeds**
1R	-4.69	-1.40	-4.54	-4.80	-0.12	-0.24
2R	-1.10	-2.63	-33.35	3.12	-2.22	0.19
3R	7.92	4.14	36.12	1.68	2.34	0.08
S.E.(g^i-g^j)	**0.36**	**1.69**	**4.63**	**0.55**	**0.52**	**0.23**
line						
A6	2.18	-7.74	-36.05	2.77	-2.84	-0.03
A10	-9.70	2.83	39.04	-5.57	1.66	0.05
A12	-4.82	8.41	-5.46	1.64	-1.99	0.70
A13	0.88	0.40	40.27	-3.80	2.64	-0.05
A16	11.31	-3.94	-37.79	4.96	0.52	-0.69
S.E.(g^i-g^j)	**0.46**	**2.18**	**5.98**	**0.71**	**0.68**	**0.29**

When estimating the effect of special combining ability on hybrids (Table 5), the results were as follows: The hybrid 3R × A16 showed a special combining effect for all studied traits, except for seed yield, and the hybrid 1R × A6 showed an undesirable special combining effect for all traits. The hybrid 3R × A10 showed a significant and desirable effect for all traits except for oil percentage. The seed yield per plant reached 4.01 g, indicating that the parents of these hybrids can be used for recrossing, as they can transmit the traits to the resulting hybrid. The hybrid 2R × A13 showed a special combining effect for many traits and positively affected disc area and seed yield per plant. The results confirm that some hybrids can positively affect special combining ability. For example, the 3R x A10 hybrid is a good choice for the future due to its positive effect on most traits, contributing to improved yield and noticing that hybrids that positively affect special combining ability (SCA) may be useful for improving yield, which can be beneficial in improving crop quality or quantity. Some hybrids exhibited a positive and significant effect on SCA, while others exhibited a negative and significant effect. These differences demonstrate the wide variation among hybrids in their specific combining effects. When parents have a positive and significant effect on GCA for a trait, this often leads to similar significant effects in their offspring. This indicates the emergence of a dominant gene effect. Dominant genes are the primary factor determining the outcome of a genetic trait. Whereas, if GCA is positive and significant for a particular trait, this enhances gene expression, but no positive effect on SCA has been demonstrated. The reason is the influence of the host genes on this trait. The results confirm that special combining ability is considered more important than general combining ability in some cases, which is consistent with the findings of researchers (11, 13, 15, 20, 25 and 26). If the special combining ability is dominant, the genetic influence is more pronounced and significant, and these results can be used to improve crop performance and increase productivity.

Table 5: Estimates of specific combining ability.

Hybrid	Characteristics					
	Stem diameter	**Disc area**	**Number of seeds per disc**	**Weight of 1000 seeds**	**Plant seed yield**	**Seed oil percentage**
A6 × R1	-12.50	-4.30	-46.14	-4.36	-0.49	-0.39
A10× R1	17.17	-9.39	-45.21	-0.24	0.99	-0.18
A12 × R1	2.23	7.15	44.76	0.05	-1.44	1.15
A13× R1	5.49	10.48	50.31	3.46	0.89	-0.71
A16 × R1	-11.73	-4.94	0.29	5.09	0.98	-0.64
A6 × R2	11.56	-5.67	35.14	4.53	1.11	-0.07
A10× R2	-23.26	-0.12	-2.19	-2.18	-2.92	0.70
A12 × R2	0.40	4.87	-9.65	6.01	-0.08	-1.38
A13× R2	6.65	0.35	-9.40	-4.14	1.34	0.99
A16× R2	6.64	0.88	-10.92	-3.21	1.82	0.29
A6 × R3	1.94	8.97	14.01	2.82	-0.62	-0.22
A10× R3	7.09	9.54	49.41	3.43	4.01	- 0.14
A12 × R3	-5.84	-10.87	-32.12	-4.06	1.58	0.43
A13× R3	-10.15	-10.50	-37.89	0.68	-2.66	-0.29
A16 × R3	4.96	4.11	13.61	1.11	-1.92	0.38
S.E. (s^ij–s^ik)	**0.79**	**3.78**	**10.36**	**1.23**	**1.18**	**0.51**

Table 6 shows the values of the variance components, broad and narrow heritability, and the average degree of dominance for the studied traits. The ratio of the general combining ability (GCA) components to the specific combining ability (SCA) components was less than one for all traits, indicating that the dominant effect of genes is the main factor controlling the inheritance of traits. In other words, dominant genes contribute significantly to the determination of traits. Broad heritability, however, was particularly high for some traits. For example, the heritability of stem diameter was 98.71%, number of seeds per disc was 94.11%, and 1000-seed weight was 93.20%. This suggests that these traits possess high genetic variation while environmental variation is low. This increases the likelihood of these traits being passed on to the next generation. These results can be used to improve plant breeding programs and direct efforts toward improving traits with high heritability. Narrow-sense heritability values were high for most traits, ranging from 18.66% for seed yield to 53.66% for seed number per disc. This is due to the high additive genetic variance for these traits, suggesting they could be improved through quantitative selection. The mean degree of dominance was more significant than one for all traits studied, indicating the predominance of genes controlling the inheritance of these traits. This is consistent with the findings of several researchers (15, 22 and 24), who found that the ratio of the components of the variance of general combining ability to the variance of specific combining ability was less than one. Heritability was relatively high in the broad and moderate in the narrow sense, while the mean degree of dominance was more significant than one.

Table 6: Estimation of genetic parameters of the studied traits in sunflower.

Genetic parameters	Characteristics					
	Stem diameter (ml)	Disc area (cm²)	Number of seeds per disc	Weight of 1000 seeds (g)	Plant seed yield (g)	Seed oil percentage
σ^2gca	8.11	8.48	733.33	5.98	0.56	0.16
σ^2 sca	56.64	24.93	1105.27	19.16	2.79	0.61
σ^2gca / σ^2sca	0.14	0.34	0.66	0.31	0.20	0.26
σ^2A	16.22	16.96	1466.66	11.96	1.12	0.32
σ^2D	56.64	24.93	1105.27	19.16	2.79	0.61
σ^2G	72.86	41.89	2571.93	31.12	3.91	0.93
σ^2E	0.95	21.42	160.94	2.27	2.09	0.39
σ^2P	73.81	63.31	2732.87	33.39	6.00	1.32
%H^2.b.s.	98.71	66.17	94.11	93.20	65.17	70.45
%h^2.n.s.	21.98	26.79	53.66	35.82	18.66	24.24
a^{-}	**2.64**	**1.71**	**1.23**	**1.79**	**2.23**	**1.95**

Conclusions

The variance components in specific combining ability (SCA) are more significant than general combining ability (GCA) for all studied traits except stem diameter. The best parents for seed yield were R3, A10, and A13, the best in combining ability for seed yield. The 3R × A10 hybrid achieved high GCA values, making it superior in seed yield compared to the others. The hybrids showed high narrow-sense heritability for some traits, indicating that these traits are highly heritable and transferable from generation to generation. These traits can be improved using quantitative selection, but improvement is more rapid in the presence of superdominance effects. It was observed that dominance variance was the main component of genetic variance, which was reflected in the super dominance value, which significantly affected the heritability of the traits. This makes obtaining suitable genotypes in the first generations more difficult during selection. Since improving some traits will be difficult through selection alone in early generations, techniques based on hybridization will be more effective. These results support the idea that selection alone may not be sufficient in all cases, especially if there are strong dominance effects. Therefore, hybridization may be the optimal solution for improving genetic traits.

Supplementary Materials:

No Supplementary Materials.

Author Contributions:

Authors 1 and 2 are plant breeding specialists, and the research was carried out in the field and according to the scientific method, and the institution did not fund the research.

Funding:

This research received no external funding.

Institutional Review Board Statement:

The study was conducted following the protocol authorized by the Head of the Ethics Committee, University of Anbar.

Informed Consent Statement:

No Informed Consent Statement.

Data Availability Statement:

No Data Availability Statement.

Conflicts of Interest:

The authors declare no conflict of interest.

Acknowledgments:

The authors are thankful to The College Dean and the Head of the Field Crops. The College of Agriculture, University of Anbar, Iraq. We thank the undergraduate students for their valuable help and technical assistance in conducting this research.

Disclaimer/Journal's Note:

The statements, opinions, and data contained in all publications are solely those of the individual author(s) and contributor(s) and not of AJAS and/or the editor(s). AJAS and/or the editor(s) disclaim responsibility for any injury to people or property resulting from any ideas, methods, instructions, or products referred to in the content.

References

1. Ahmad, S., Khan, M. S., Swati, M. S., Shah, G. S., and Khalil, I. H. (2005). A study on heterosis and inbreeding depression in sunflower (Helianthus annuus L.). Songklanakarin J. Sci. Technol, 27(1): 1-8.
2. Aldelaimi, H. J. H, Salama, M. A., and Alfahdawi, H. D. (2013). Combining ability, Gene action and some parameters in sunflower by using half- diallel crosses. Iraq Alanbar J. Agric. Sci., 11(2): 106- 117.
3. AL-Rawi, A. S. (2012). Selection by Honeycomb for Seed Weight in Sunflower. M.Sc. Thesis, Dept. of Field Crops Sci., Coll. of Agric. Univ. of Baghdad, Iraq. P 52.
4. Al-Rawi, W. M. (2003). Area of capitulum as an indicator for seed yield in sunflower. The Iraqi J. of Agric. Sci., 34(1): 75-78.
5. Aziz, S. R., and A. Rashid, S. (2023). Impact Of Using Sunflower Seed Meal In Broiler Male Diets On Performance Traits And Carcass Characteristics. Anbar Journal of Agricultural Sciences, 21(1): 148-157. doi: 10.32649/ajas.2023.179726.
6. Bddry, D. R. (2011). Combining ability analysis for Yield and its contributing characters in sunflower (*Helianthus annuus* L.). Madras Agric. j., 99(7-12): 295-300.
7. Binodh, A. K., Manivannan, N., and Varman, P. V. (2008). Combining ability analysis for yield and its contributing characters in sunflower (Helianthus annuus L.). Madras Agricultural Journal, 95(7/12): 295-300.
8. Elsahookie, M. M., and Eltaweel, S. K. (2001). Selection, heritability and genetic gain of sunflower seed weight by parent-offspring regression. The Iraqi J. Agric. Sci, 32(1): 99-108.
9. F.A.O. (2023). year Book. Production. V. 76. https://openknowledge.fao.org/server/api/core/bitstreams/6e04f2b4-82fc-4740-8cd5-9b66f5335239/content
10. genetic analysis. Biometrical methods in quantitative genetic analysis, 304.

11. Habibullah Habib, H. H., Mehdi, S. S., Abdul Rashid, A. R., Saeed Iqbal, S. I., and Anjum, M. A. (2006). Heterosis studies in sunflower (Helianthus annuus L.) crosses for agronomic traits and oil yield under Faisalabad conditions Pakistan Journal of Agricultural Sciences, 43(¾): 131-135.
12. Hamad, H. S., Abdulkareem, B. M., Abdulhamed, Z. A., and Abood, N. M. (2024). Genotypic and phenotypic variance, correlation, and path coefficient analysis in maize. Anbar Journal of Agricultural Sciences, 22(2): 1214-1227. https://doi.org/10.32649/ajas.2024.149998.1265.
13. Hashim, J.J., & A. Kakarash, S. (2024). Impact of nano-conventional npk foliar application and row distance on some growth and chemical traits of sunflower (helianthus annuus l.) Anbar Journal of Agricultural Sciences, 22*(2*), 1050-1069. https://doi.org/ 10.32649/ajas.2024.148303. 1196
14. Hassan, W. A. (2016). Estimation of some genetic parameters of growth and yield characters of sunflower under three plant densities. Iraqi Journal of Agricultural Sciences, 47(4): 921-932.
15. Hladni, N., Jocić, S., Miklič, V., Kraljević-Balalić, M., and Škorić, D. (2008). Combining ability for stem diameter and plant height in sunflower (Helianthus annuus L.). Int. Conf.» Conventional and molecular breeding of field and veget. crops «. Novi Sad, 1: 487-490.
16. Ibrahim, M. M., and Abdulhamed, Z. A. (2023). Efficiency of selection in inducing genetic-molecular variations in sunflower. In IOP Conference Series: Earth and Environmental Science, 1158(6): p. 062032. DOI:10.1088/1755-1315/1158/6/062032.
17. Jan, M., Hassan, G., Hussain, I., and Din, R. (2006). Combining ability analysis of Yield and Yield Components in Sunflower. Pakistan Journal of Biological Sciences. 9(12): 2328-2332. https://doi.org/10.3923/pjbs.2006.2328.2332.
18. Kaya, Y., and Atakisi, I. K. (2004). Combining ability analysis of some yield characters of sunflower (Helianthus annuus L.)/análisis de aptitud combinatoria de algunas características de rendimiento de girasol (Helianthus annuus L.)/analyse des aptitudes combinatoires de quelques caractéristiques de rendement du tournesoL (Helianthus annuus L.). Helia, 27(41): 75-84. https://doi.org/10.2298/hel0441075y.
19. Kempthorne, O. (1957). An introduction of genetic statistics, John Willey and Sons Inc. New York, USA, 468-473.
20. Khan, H., Ahmad, H., Ali, H., and Alam, M. (2008). Magnitude of combining ability of sunflower genotypes in different environments. Pakistan Journal of Botany, 40(1): 151.
21. Khattab. (2020). Estimation of Some Genetic Indicators of Sunflower *Helianthus annus* L. Varieties growth and production characteristics under different plant densities. Syrian Journal of Agricultural Research 7(1): 246-261.
22. Kinman, M. L. (1970). i970. New developments in the USDA and state experiment station sunflower breeding programs. In Proc. 4th Int. Sunflower Conf., Memphis, TN. Int. Sunflower Assoc., Toowoomba, Australia, 181-184.

23. Ruiz, R. A., and Maddonni, G. A. (2006). Sunflower seed weight and oil concentration under different post-flowering source-sink ratios. Crop Science, 46(2): 671-680. https://doi.org/10.2135/cropsci2005.06-0139.
24. Škorić, D., Jocić, S., Hladni, N., and Vannozzi, G. P. (2007). An analysis of heterotic potential for agronomically important traits in sunflower (*Helianthus annuus* L.). Helia, 30(46): 55-74. https://doi.org/10.2298/hel0746055s.
25. Sneha, M. A., Desai, B. K., Umesh, M. R., Koppalkar, B. G., and Kuchanur, P. H. (2022). Effect of planting density and fertilizer rate on performance of newly developed sunflower hybrids (Helianthus annuus L.). The Pharma Innovation, 11(8): 167-178.
26. Volotovich, A. A., Silkova, T. A., Fomchenko, N. S., Prokhorenko, O. V., and Davydenko, O. G. (2008). Combining ability and heterosis effects in Sunflower of Byelorussian orining. Helia, 32(48): 111-118. https://doi.org/10.2298/hel0848111v.