Journal of Plant Production

Journal homepage: www.jpp.mans.edu.eg
Available online at: www.jpp.journals.ekb.eg

Genetic Analysis for some Economic Traits in Sunflower (*Helianthus annuus* L.).

Ahmed, M. A.*; T. H. A. Hassan and M. R. F. Abou Mowafy

Oil Crops Research Department, Field Crops Research Institute, A. R. C. Egypt

ABSTRACT

Seven sunflower cytoplasmic male sterile (CMS lines) and three Rf-restorer (tester lines) were used to obtain 21 F_1 hybrids according to line x tester mating design. All the 21 F_1 hybrids, 7 lines, and three testers were evaluated at Sakha Agricultural Research Station, Kafer El-Sheikh Governorate during 2017 season. The results showed highly significant differences among the genotypes for all the studied traits. The major role of dominant genes was found because the degree of dominance was greater than unity. These results indicated the preponderance of dominant gene action and the feasibility of hybrid sunflower development. A_5 and A_9 of CMS lines and RF_1 of restorer lines proved to the best general combiners for head diameter, seed yield plant^{-1} and seed oil content. The cross combinations of A_5 x Rf_1 and A_7 x Rf_8 were identified as the best for seed yield per plant with highly significant SCA effects and heterosis. Combining ability analysis indicated that both genetic components, additive and non-additive, were important in expression of investigated traits. The components of genetic variance indicated that the non-additive component played the main role in the inheritance of all studied traits. Heritability in broad sense (h^2_b) was larger than that in narrow sense (h^2n) for all studied traits.

Keywords: Sunflower, line x tester, combining ability, heterosis, gene action, heritability.

INTRODUCTION

Sunflower (*Heliathus annuus* L.) is one of the main three crop species along with soybean and canola which account for approximately of the world vegetable edible oil. Sunflower is grown on 26.64 million hectares in the world, producing 53.48 million metric tons of seed yield (USDA 2019). Egypt's production of edible vegetable oils has been suffering from several problems due to meet the needs of the lower domestic production of oil crops that resulted in failing to meet the needs of domestic consumption. Estimate of combining ability is essential to select suitable parents for hybridization and identification of promising hybrids in breeding programs. The general combining ability and specific combining ability variances provide estimation for additive and non additive gene action, respectively.

Recently, the importance of sunflower hybrids cultivation increased because of their higher seed yield compared to cross-pollinated varieties in many countries in the world. Hybrids of sunflower are more stable, highly self-fertile, with high yield performance, and more uniform at maturity (Kaya and Atakisi, 2004).

Knowledge about combining abilities of the genotypes involved in breeding program as well as fundamental understanding of the genetic determinants accelerates the breeding process and enhance probability to achieve the desired goal. Combining abilities are divided into general (GCA) and specific (SCA) combining abilities. the average performance of a line in a set of hybrid combinations refers to GCA, while SCA refers to deviate of a certain cross from the expectation on the basis of average performance of the lines involved. Combining abilities provide information about nature of gene effects involved in expression of certain trait as higher GCA indicate greater role of additive effects, while SCA is referred to non-additive gene effects. Combining abilities are widely used in breeding programs in order to identify superior genotypes that can enhance progress of sunflower breeding (Kaya and Atakisi 2004; Masood *et al.* 2005; Karasu *et al.* 2010 and Kang *et al.* 2013).

The present study aimed to evaluate the combining ability, to determine the nature and magnitude of gene action, heterosis for yield and related traits and to detect the appropriate hybrids for breeding program in a line x tester crossing design for sunflower.

MATERIALS AND METHODS

In this study seven cytoplasmic male sterile (CMS), A-lines, three restorers- Rf (tester lines) and their (7 x 3) which produced $21F_1$ hybrids were used (Table1). The A-lines were A_1, A_3, A_5,A_7, A_9, A_{12},and A_{15}. The testers (Rf-lines) were Rf_1, Rf_8, and Rf_{11}**.** They are male restorer lines with good combining abilities. Hybrid combinations were created by crossing A-sterile lines with Rf-restorer testers during year 2016 at Giza Agricultural Research Station, Field Crops Research Institute, A.R.C. Egypt. Crossing was undertaken into line x tester fashion and seeds were separately harvested to study the heterosis and combining ability.

Table 1. A- lines and restorers (*cms* and *Rf*) used

CMS/Rf	Habitus	Origin	Type
A_1	Non-branched, Single headed	Argentine	Oilseed
A_3	Non-branched, Single headed	Romania	Oilseed
A_5	Non-branched, Single headed	U.S.A	Oilseed
A_7	Non-branched, Single headed	Romania	Oilseed
A_9	Non-branched, Single headed	Russia	Oilseed
A_{12}	Non-branched, Single headed	Russia	Oilseed
A_{15}	Non-branched, Single headed	Russia	Oilseed
Rf_1	Branched, multi headed	Egypt	Oilseed
RF_8	Branched, multi headed	Egypt	Oilseed
RF_{11}	Branched, multi headed	Egypt	Oilseed

During the summer of 2017, seven cytoplasmic male sterile, and three restorer lines and their 21 F_1 hybrid

* **Corresponding author.**
E-mail address: mohamedsunflwer@gmail.com
DOI: 10.21608/jpp.2021.157370

combinations were evaluated in Randomized Complete Block Design (RCBD) with three replications at Sakha Agricultural Research Station, Field Crops Research Institute, A.R.C. Egypt. Each plot consisted of four ridges 4 m long and 60 cm between ridges and 20 cm between plants within row. Three seeds were planted per hill and thinned to one plant per hill. All Agricultural practices were done as recommended for oil seed sunflower cultivation. Data were recorded for days to 50% flowering, plant height (cm), head diameter (cm), total seeds number per plant, seed yield/plant (g), 100 seed weight (g) and oil content % was which determined according to A.O.A.C (1990) using soxhlet apparatus and diethyl ether as solvent.

Statistical analysis:

Means of the recorded data were analyzed according to analysis of variance of randomized complete block design with three replicates, as described by Gomez and Gomez (1984). Least significant difference (LSD) was used to compare the means at 5% and 1% levels of probability.

Better parent heterosis effect (heterobeltiosis) was calculated by comparing mean values of F_1 generation with respect to the average value of better parent and significance was determined using t-test.

$$h = \frac{\overline{F1} - \overline{BP}}{\overline{BP}} \times 100 \ (\%)$$

Where,

h = heterosis effect $\overline{BP}$ = average value of better parent for analyzed trait

$\overline{F1}$ = average value of F1 hybrid for analyzed trait

Heterosis was calculated as a percentage increase or decrease in the F_1 mean from its better parents. The combining ability analysis were done in accordance with the procedure developed by Kempthorne (1969) and Singh and Choudry (1976).

RESULTS AND DISCUSSION

The mean squares of line x tester analysis for lines, testers, and their interactions for all studied traits are presented in Table (2). Results revealed that genotypes and parents exhibited highly significant differences for all studied traits indicating that variability is existed among all inbred lines. Data revealed that crosses were highly and significantly differed in all studied traits. Mean squares due to parents vs. crosses were significant for all studied traits. Significant differences in parents vs. crosses indicated the presence of heterosis in the crosses that may be manifested for the development of high yielding sunflower hybrids. Meanwhile, the lines revealed significant differences in their traits except head diameter and seed yield per plant. Tester and line x tester interaction exhibited significant differences for all traits. These results are in agreement with those obtained by Azab *et al.* (2014), Imran *et al.* (2015) and Supriya *et al.*(2017).

Mean performance

The mean values of A-lines showed wide differences with a range from (A_3) 55.67 to (A_7) 62.67 days for days to 50% flowering, (A_5)122.72 to (A_1)153.86 cm for plant height, (A_3)1.75 to (A_5)1.89 cm for stem diameter, (A_7) 16.23 (A_5) to18.77 cm for head diameter, (A_3) 779.7 to (A_5) 983.8 for total seed number per plant, (A_9) 5.66 to (A_3) 6.54 g for 100-seed weight, (A_3) 43.96 to (A_5) 56.61 g for seed yield per plant, and (A_1) 36.93 to (A_5) 38.25% for seed oil content %, respectively.

Table 2. Analysis of variance and mean square of the line x tester analysis for all studied traits.

S.O.V	d.f	Days to 50 % flowering	Plant height (cm)	Stem diameter (cm)	Head diameter (cm)	No. of Seeds per plant	100-seed weight (g)	Seed yield / plant(g)	Oil content %
Rep	2	9.034	41.82	0.003	2.039	933.968	0.349	22.273	1.020
Genotypes	30	35.398**	507.336**	0.260**	14.878**	44218.594**	2.221**	479.263**	12.203**
Parents	9	29.659**	537.594**	0.296**	9.420**	21564.078**	3.997**	534.238**	1.386
Crosses	20	31.675**	336.511**	0.193**	17.719**	35974.792**	1.111**	159.838**	14.843**
P.vs.C	1	161.515**	3651.526**	1.276**	7.194**	412985.284**	8.443**	6373.006**	56.758**
Lines	6	48.570**	923.348**	0.199**	16.708**	32025.821**	1.472**	121.233**	6.614**
Testers	2	26.503**	102.964**	0.764**	74.313**	92146.833**	0.062	745.36**	40.032**
L x T	12	24.090**	82.016**	0.094**	8.792**	28587.27**	1.105**	81.553**	14.759**
Error	60	3.350	15.5967	0.02	0.904	5843.434	0.255	9.011	1.466

Among Rf-testers they ranged from 52.67 (Rf_{11}) to (Rf8) 55.67 for days for days to 50% flowering, (Rf_8) 113.79 to (Rf_{11}) 126.20 cm for plant height, (Rf_8) 1.09 to (Rf_1) 1.26cm for stem diameter, (Rf_8) 13.73 to (Rf_1) 15.87 cm for head diameter, (Rf_8) 735 to (Rf_{11}) 846.3 for total seed number per plant, (Rf_{11}) 3.09 to (Rf_1) 4.87 g for 100-seed weight, (Rf_8) 21.7 to (Rf_1) 30.30 g for seed yield per plant, and (Rf_{11}) 38.41 to (Rf_1) 38.91% for seed oil content%, respectively.

Mean performance of sunflower hybrids ranged from 50.33 days for (A_7xRf_{11}) to 63.91 days for (A_1xRf_1) for days to 50% flowering, 128.19 cm for (A_5xRf_8) to 167.53 cm for (A_3xRf_{11}) for plant height; 1.47 cm for (A_7xRf_{11}) and for ($A_{12}xRf_{11}$) to 2.50 cm for (A_5xRf_1) for stem diameter; 13.67 cm for (A_7xRf_{11}) to 22.60 cm for (A_5xRf_1) for head diameter; 48.65 g for (A_7xRf_{11}) to75.20 g for (A_5xRf_1) for seed yield per plant; 864.7 for (A_9 xRf_{11}) to 1294.6 for (A_5xRf_1) for total seed number per plant; 5.27 g for ($A_{15}xRf_1$) to 7.75 g for (A_9xRf_{11}) for 100-seed weight and from 32.66% for ($A_{15}xRf_{11}$) to 40.18 % for ($A_{15}xRf_8$) for oil content.

General combining ability (GCA) and specific combining ability (SCA) effects

Line x tester analysis can evaluate more number of genotypes as compared to diallel and partial diallel mating design. This technique can be used even when the inbred lines have self-incompatibility and male sterility where diallel crosses entirely fail to such abnormal conditions. The success of any breeding programme largely depends on selection of suitable parental lines. Information regarding different types of gene action, relative magnitude of genetic variance and combining ability estimates are important genetic parameters for the improvement of sunflower Sher *et al.*, (2009). The presence of non-additive genetic variances and effects, presumably dominant genes are the primary justification for initiating the hybrid development programme in sunflower. Higher GCA effects are more desirable for self-pollinated crops and varieties released as pure lines while, SCA is more important for the production of hybrids in cross pollinated crops (Hallauer and Miranda, 1986). The magnitude of SCA variance was greater than GCA variance for most of the traits except seed oil content indicating predominance of non-additive variance controlling the expression of these traits. Similar results were reported by Karasu *et al.* (2010), Dudhe *et al.* (2011), Hladni *et al.* (2011) and Patil *et al.* (2017).

General combining ability effects

General combining ability effects are presented in Table 4. For days to 50% flowering, results indicated that inbred lines A_7 and A_{12} exhibited negative and highly significant GCA effects.

These inbred lines are considered the best inbred lines for earliness. The inbred line A_5 was the best general combiner for plant height, stem diameter, head diameter, total number of seeds per plant, seed yield per plant and seed oil content % and manifested positive and highly significant GCA effects. While, line A_9 was the best general combiner for head diameter, 100-seed weight, seed yield per plant and seed oil content % and possessed positive and significant or highly significant GCA effects.

Table 3. Mean performance of F_1 sunflower hybrids and their parents for all the studied traits.

Genotypes	Days to 50 % flowering	Plant height (cm)	Stem diameter (cm)	Head diameter (cm)	Seeds per plant	100-seed weight (g)	Seed yield / plant(g)	Seed Oil content%
A_1 x Rf_1	63.91	157.91	1.97	18.47	1001.6	6.58	66.58	38.14
A_1x Rf_8	53.86	152.77	1.77	16.40	996.8	5.86	57.86	36.32
A_1 x Rf_{11}	53.75	167.29	1.70	16.00	990.1	5.85	55.08	33.04
A_3 x Rf_1	60.00	157.13	1.87	17.53	983.7	6.66	66.24	38.04
A_3x Rf_8	53.33	150.08	1.84	16.87	1042.1	5.66	65.18	36.38
A_3 x Rf_{11}	60.00	167.53	1.75	16.27	1005.5	5.74	58.63	33.85
A_5 x Rf_1	52.00	139.67	2.50	22.60	1294.6	5.78	75.20	39.68
A_5x Rf_8	53.33	128.19	1.87	17.20	951.6	6.97	59.51	37.98
A_5 x Rf_{11}	54.33	132.81	1.87	17.87	1115.6	6.09	58.30	34.25
A_7 x Rf_1	51.67	137.39	2.15	21.00	1054.7	6.08	70.64	37.00
A_7x Rf_8	53.67	134.78	2.13	20.27	1126.6	5.35	68.39	35.96
A_7 x Rf_{11}	50.33	135.65	1.47	13.67	902.2	5.71	48.65	32.54
A_9 x Rf_1	56.33	143.90	2.27	22.60	1122.1	6.66	71.55	35.91
A_9 x Rf_8	54.00	144.05	1.77	16.53	971.1	6.24	60.46	37.32
A_9 x Rf_{11}	52.67	141.50	1.85	17.00	864.7	7.75	66.13	38.78
A_{12} x Rf_1	51.33	142.19	1.73	16.07	1042.6	5.76	59.12	34.10
A_{12}x Rf_8	52.67	148.13	1.63	15.40	885.0	6.40	57.01	35.16
A_{12}x Rf_{11}	52.33	141.05	1.47	14.33	839.8	5.81	48.75	36.89
A_{15} x Rf_1	54.00	136.73	2.00	18.73	1129.6	5.27	67.83	35.28
A_{15}x Rf_8	53.67	141.38	1.57	15.27	886.7	6.50	52.03	40.18
A_{15} xRf_{11}	53.67	144.54	1.80	16.60	1077.5	5.31	60.30	32.66
A_1	56.45	152.27	1.77	17.63	963.0	5.79	55.88	36.93
A_3	55.67	153.86	1.75	17.33	779.7	6.52	43.96	37.72
A_5	58.33	122.72	1.89	18.77	971.0	6.13	56.61	38.25
A_7	62.67	124.10	1.75	16.23	810.8	5.79	44.49	37.55
A_9	57.33	126.49	1.83	18.33	983.8	5.66	56.00	37.52
A_{12}	59.33	136.56	1.76	17.60	874.3	6.24	48.28	37.13
A_{15}	60.33	138.65	1.82	18.79	907.3	6.54	55.56	37.28
Rf_1	53.00	121.26	1.26	15.87	838.0	4.87	30.30	38.65
Rf_8	55.67	113.79	1.09	13.73	735.0	3.89	21.70	38.91
Rf_{11}	52.67	126.20	1.12	14.37	846.3	3.09	26.07	38.41
Mean	54.83	140.66	1.77	17.27	967.5	5.88	56.56	36.62

For testers, the results suggested that genotype Rf_1 was the best general combiner for stem diameter, head diameter, seed yield per plant, total number of seeds and seed oil content %. While, Rf_8 was the best general combiner for plant height and seed oil content %. These results were in accordance with the findings of Azab *et al.*(2014); Imran *et al.*(2015); Memon *et al.*(2015); Vikas *et al.*(2017); Cvejic *et al.*(2017); Biradar *et al.*(2018), Bhoite *et al.*(2018), Singh *et al.* (2018), Telangre *et al.*(2019), Haddadan *et al.* (2020) and Rizwan *et al.,* (2020) .

Table 4. General combining ability effects of sunflower lines and testers for yield and its contributing traits.

genotypes	Days to 50% flowering	Plant height (cm)	Stem diameter (cm)	Head diameter (cm)	Seeds per plant	100-seed weight (g)	Seed yield/ Plant (g)	Seed oil content %
				Lines				
A_1	2.846**	14.339**	-0.044	-0.505	-17.386	-0.001	-1.754	-0.332
A_3	3.452**	13.264**	-0.035	-0.571	-3.097	-0.079	1.760	-0.075
A_5	-1.104	-11.428**	0.224**	1.762**	107.07**	0.184	2.744*	1.140*
A_7	-2.437**	-9.044**	0.06	0.851*	14.325	-0.383	0.964	-0.996
A_9	0.007	-1.835	0.107	1.251**	-27.575	0.788**	4.455**	1.172*
A_{12}	-2.215**	-1.194	-0.245**	-2.194**	-91.075**	-0.106	-6.631**	-0.784
A_{15}	-0.548	-4.102*	-0.066	-0.594	17.737	-0.403*	-1.538	-0.125
LSD 5%	1.442	3.111	0.111	0.749	60.215	0.398	2.365	0.954
LSD 1%	2.062	4.449	0.159	1.071	86.124	0.569	3.382	1.365
				Testers				
Rf_1	1.280*	0.004	0.213**	2.111**	76.303**	0.015	6.573**	0.713*
Rf_8	-0.822	-2.216*	-0.059	-0.613*	-33.535	0.045	-1.529	0.878*
Rf_{11}	-0.458	2.213*	-0.154**	-1.498**	-42.768*	-0.060	-5.044**	-1.591**
LSD 5%	0.944	2.037	0.072	0.490	39.420	0.260	1.548	0.624
LSD 1%	1.350	2.913	0.104	0.701	56.382	0.372	2.214	0.893

Specific combining ability effects

Specific combining ability effects of 21 hybrids for all the studied traits are presented in Table 5. Results showed that, three hybrids (A_1 x Rf_{11}), (A_3 x Rf_8), and (A_5 x Rf_1) for days to 50 % flowering , tow hybrids (A_5 x Rf_1), and (A_7 x Rf_8**)** for stem diameter. three hybrids (A_5 x Rf_1), (A_7 x Rf_8**)** and (A_9xRf_1)for head diameter, one hybrid (A_7 x Rf_8**)** for total number of seeds per plant. tow hybrids (A_9 x Rf_{11}) and (A_7xRf_8) for 100-seed weight and four hybrids (A_5 x Rf_1), (A_9 x Rf_{11}), (A_{12} x Rf_{11}**)** and (A_{15} x Rf_8**)** for seed oil content % had positive and significant or highly significant SCA effects.

For seed yield per plant, four hybrids A_5 x Rf_1, A_7 x Rf_8, A_9 x Rf_{11} and A_{15} x Rf_{11} had positive and significant or highly significant SCA effects with 4.294,7.359,5.126 and 5.466, respectively, having high x high, low x low and high x low GCA parental combination, showing a genetic interaction of the additive and none additive types of gene action.

Table 5. Estimation of specific combining ability effects of 21 sunflower hybrids for yield and related traits.

hybrid	Days to 50 % flowering	Plant height (cm)	Stem diameter (cm)	Head diameter (cm)	No. of seeds plant^{-1}	100-seed weight (g)	Seed yield plant^{-1}(g)	Seed oil content %
A_1 x Rf_1	5.458**	-1.421	-0.058	-0.600	-70.881	0.467	0.165	1.591
A_1x Rf_8	-2.490	-4.335	0.015	0.057	34.191	-0.279	-0.450	-0.390
A_1 x Rf_{11}	-2.968*	5.756*	0.043	0.543	36.691	-0.188	0.285	-1.201
A_3 x Rf_1	0.942	-1.119	-0.167	-1.467*	-103.07	0.625	-3.685	1.238
A_3x Rf_8	-3.622**	-5.953*	0.082	0.591	65.235	-0.405	3.360	-0.578
A_3 x Rf_{11}	2.680	7.072*	0.084	0.876	37.835	-0.220	0.325	-0.651
A_5 x Rf_1	-2.502*	6.107*	0.208*	1.267	97.697	0.515	4.294*	1.663*
A_5x Rf_8	0.934	-3.151	-0.153	-1.410*	-135.465*	0.648	-3.298	-0.205
A_5 x Rf_{11}	1.569	-2.956	-0.055	0.143	37.768	-0.133	-0.996	-1.459
A_7 x Rf_1	-1.502	1.445	0.018	0.578	-49.425	0.349	1.507	1.116
A_7x Rf_8	2.600*	1.055	0.277**	2.568**	132.313*	-0.411	7.359**	-0.083
A_7 x Rf_{11}	-1.098	-2.500	-0.295**	-3.146**	-82.887	0.061	-8.866**	-1.033
A_9 x Rf_1	0.720	0.747	0.091	1.778*	-59.808	-0.239	-1.071	-2.139*
A_9 x Rf_8	0.489	3.113	-0.137	-1.565*	18.679	-0.688	-4.055	-0.894
A_9 x Rf_{11}	-1.209	-3.859	0.045	-0.213	-74.487	0.927*	5.126*	3.033**
A_{12} x Rf_1	-2.058	-1.601	-0.090	-1.311*	43.807	-0.245	-2.414	-1.997*
A_{12}x Rf_8	1.378	6.558*	0.079	0.746	-3.887	0.368	3.581	-1.101
A_{12}x Rf_{11}	0.680	-4.957	0.011	0.565	-39.921	-0.123	-1.167	3.098**
A_{15} x Rf_1	-1.058	-4.157	-0.002	-0.244	22.064	-0.441	1.206	.-1.472
A_{15}x Rf_8	0.711	2.713	-0.163	-0.987	-111.065*	0.766*	-6.499**	3.260**
A_{15} xRf_{11}	0.347	1.444	0.165	1.232	89.002	-0.325	5.466*	-1.788*
LSD 5%	2.497	5.388	0.192	1.297	104.295	0.689	4.095	1.652
LSD 1%	3.572	7.707	0.276	1.855	149.172	0.985	5.858	2.363

Heterosis Effects

Heterosis was calculated as parent increase of F1 over its better parent (BP) for studied traits. Exploitation of heterosis to maximize yield of agricultural crops has become one of the most important methods of plant breeding. Major objectives of the present study were to identify promising hybrids which may give high degree of useful heterosis. Estimates of heterosis for the 21 F_1 crosses as a percentage of the better parent for the studied traits are presented in Table 6.

Heterosis values for days to 50% flowering ranged from -13.21% for hybrid (A_3 x Rf_1) to 20.72 % for hybrid (A_1 x Rf_1). Twelve hybrids recorded significant or highly significant negative heterosis. These hybrids were earlier than earliest parents.

Plant height ranged from 8.22 % (A_5 x Rf_{11}) to 34.26 % (A_1 x Rf_8) and are in agreement with the values reported by significant heterotic effect on plant height in relation to the better parent (6.1%-51.6%) with hybrid combinations was determined by Hladni *et al.* (2006). All the hybrids, showed significant or highly significant positive heterosis for plant height, further supporting this conclusion was the fact that the $\delta^2 D/ \delta^2 A$ ratio for plant height found in the F_1 generation were over the value of one (1.63) under experiment condition.

Table 6. Heterosis percent relative to better parent (Heterobeltiosis) for the studied traits.

hybrid	Days to 50 % flowering	Plant height (cm)	Stem diameter (cm)	Head diameter (cm)	No. of seeds plant^{-1}	100-seed weight (g)	Seed yield plant^{-1}(g)	Seed oil content%
A_1 x Rf_1	20.72**	30.22**	10.90**	-0.600	4.01	13.65**	19.14**	-1.33
A_1x Rf_8	-3.35**	34.26**	-0.38	0.057	3.51	1.27	3.54	-6.66**
A_1 x Rf_{11}	2.05*	32.56**	-4.14	0.543*	2.81	1.04	-1.43	-13.98**
A_3 x Rf_1	-13.21**	29.58**	6.46**	-1.467	17.39**	2.04	50.69**	-1.58
A_3x Rf_8	-4.19**	31.90**	5.13*	0.591	33.65**	-13.29**	48.29**	-6.51**
A_3 x Rf_{11}	13.92**	32.75**	-0.19	0.876	18.81**	-12.06**	33.39**	-11.89**
A_5 x Rf_1	-1.89*	15.18**	32.51**	1.267	33.33**	-5.66**	32.84**	2.66**
A_5x Rf_8	-4.20**	12.66**	-1.06	-1.410	-1.99	13.82**	5.12**	-2.41**
A_5 x Rf_{11}	3.16**	8.22*	-0.88	0.143	14.90**	-0.65	2.94	-10.83**
A_7 x Rf_1	-2.52**	13.30**	22.43**	0.58	25.87**	5.01*	58.77**	-4.28**
A_7x Rf_8	-3.59**	18.45**	21.67**	2.568**	38.95**	-7.60**	53.71**	-7.58**
A_7 x Rf_{11}	-4.43**	9.39**	-16.35**	-3.146**	6.61**	-1.27	9.34**	-15.28**
A_9 x Rf_1	6.29**	18.67**	24.09**	1.778*	14.05**	17.74**	27.77**	-7.09**
A_9 x Rf_8	-2.99**	26.59**	-3.28	-1.565*	-1.29	10.31**	7.97**	-4.09**
A_9 x Rf_{11}	0.00	12.13**	1.46	-0.213	-12.11**	37.01**	18.09**	0.95
A_{12} x Rf_1	-3.14**	17.26**	-1.33	-1.311	19.24**	-7.64**	22.45**	-11.78**
A_{12}x Rf_8	-5.39**	30.19**	-7.21**	0.746	1.22	2.67	18.09**	-9.65**
A_{12}x Rf_{11}	-0.65	11.76**	-16.51**	0.565	-3.95	-6.89**	0.97	-3.97**
A_{15} x Rf_1	1.89*	12.75**	9.69**	-0.244	24.43**	-19.43**	22.10**	-8.72**
A_{15}x Rf_8	-3.59*	24.25**	-14.08**	-0.987	-2.33	-0.51	-6.35**	3.25**
A_{15} xRf_{11}	1.90*	14.53**	-1.28	1.232	18.69**	-18.82**	8.54**	-14.98**
LSD 5%	2.989	6.359	0.229	1.552	124.83	0.824	4.095	1.98
LSD 1%	4.275	9.095	0.328	2.220	178.542	1.179	5.857	2.832

Stem diameter, ranged from -16.51% for hybrid (A_{12} x Rf_{11}) to 32.51% for hybrid (A_5 x Rf_1) Habib *et al.* (2006) found highest positive heterotic effects for stem diameter .

Head diameter, ranged from -3.15% for hybrid (A_7 x Rf_{11}) to 2.57% for hybrid (A_7 x Rf_8). Three hybrids showed positive and significant or highly significant heterosis for this trait, was also, found by (Haq *et al.* 2006).

Total number of seeds per plant ranged from -12.11% for hybrid (A_9 x Rf_{11}) to 38.95% for hybrid (A_7 x Rf_8) and twelve hybrids showed positive significant or highly significant heterotic effects. accordingly. Habib *et al.* (2006) also reported positive heterosis for number of seeds per head.

100-achene weight ranged from -19.43% for hybrid (A_{15} x Rf_1) to 37.01% for hybrid (A_9 x Rf_{11}) and six hybrids showed positive and significant or highly significant heterotic effects. This indicates that these hybrids had high 100-seed weight than the best parent. The results are also similar to those obtained by Habib *et al.* (2006).

Seed yield per plant in the data revealed that varied from -6.35% (A_{15}xRf_8) to 58.77% (A_7xRf_1) for hybrids. sixteen hybrids showed highly significant positive heterosis, which indicates that these hybrids had higher seed yield per plant than the better parent. These results are in agreement with those of Haldni *et al.*2006.

Seed oil content, ranged from -13.98 (A_1 x Rf_{11}) to 3.25 (A_{15} x Rf_8). However, highly significant positive heterotic effects were observed in tow hybrids out of 21 hybrids. The hybrid (A_{15} x Rf_8) exhibited maximum positive heterotic effect (3.25%), along with 40.18 mean seed oil percentage. Similar results were obtained by Tan (2010), Hladni *et al.* (2011), Azab *et al.* (2014), Encheva *et al.* (2015), Ingle *et al.* (2015), Cvejic *et al.*(2017), Vikas *et al.* (2017), Bhoite *et al.* (2018) Abd ElHadi *et al.*(2019), Khan *et al.* (2019), and Haddadan *et al.* (2020) .They indicated that heterosis was manifested in yield crosses for many studied traits.

Gene action and heritability

The partitioning of genetic variance for all studied traits are presented in Table 7. Results indicated that the non-additive genetic variance including dominance (δ^2 D) were larger than their corresponding additive genetic variance (δ^2 A) for all studied traits. It is indicated that non-additive genetic variances played the major role in the inheritance of these traits. This showed that hybridization program could be effective in the improvement of those traits. The important of non-additive variances were verified by the dominance degree ratio, which was more than unity for all studied traits (Table 7). The preponderance of non-additive gene action for these traits was supported in the results of Karasu *et al.* (2010), Dudhe *et al.* (2011), Hladni *et al.* (2011) and Patil *et al.* (2017).

Heritability values in broad and narrow senses were calculated and results are shown in Table 7. Results revealed that broad heritability ($h^2_{b.s}$) estimates were larger than their corresponding values of narrow sense heritability ($h^2_{n.s}$) for all studied traits. Values of heritability in broad sense ranged between 76.95 % for 100-seed weight to 91.13 % for head diameter, while the heritability in narrow sense ranged from 1.16 % for 100-seed weight to 32.65 % for plant height. These results are in agreement with those obtained by many other authors like Hladni *et al.* (2003); Khan *et al.* (2007), Abou-Mowafy (2010), Attia *et al.* (2012) and Memon *et al.* (2014).

Table 7. The partitioning of the genetic variances for genotypes for all studied traits.

Genetic and heritability	Days to 50 % flowering	Plant height (cm)	Stem diameter (cm)	Head diameter (cm)	No. of Seeds plant^{-1}	100- seed weight (g)	Seed yield plant^{-1}	Oil content %
GCA	0.198	6.627	0.003	0.232	192.383	0.000	2.039	0.002
SCA	6.913	21.609	0.025	2.629	7581.279	0.283	24.181	4.431
δ^2A	0.395	13.255	0.005	0.465	384.767	0.000	4.077	0.004
δ^2D	6.913	21.609	0.025	2.629	7581.279	0.239	24.181	4.431
$(\delta^2 D/ \delta^2 A)^{1/2}$	4.18	1.28	1.44	2.38	4.44	4.66	2.44	33.28
δ^2G	7.308	34.864	0.030	3.094	7966.046	0.239	28.258	4.435
δ^2e	1.117	17.190	0.020	0.904	5843.434	0.255	9.011	0.489
δ^2ph	8.425	52.054	0.050	3.994	13809.48	0.494	37.269	4.924
h^2b	86.75	85.88	82.05	91.13	80.35	76.95	90.39	90.08
h^2n	4.69	32.65	14.00	13.69	3.88	1.16	13.04	1.22

Contribution of lines, testers and line x tester interactions to total variance

Lines, testers and their interaction revealed different contribution in expression of the studied traits (Table 8). Contribution of lines in the expression of days to 50% flowering, plant height, 100 seed weight and number of seeds per plant were the greatest. Contribution of testers in expression of stem diameter, head diameter, seed yield per plant (g) and seed oil content were the greatest. Interaction between lines and testers expressed high contributions in many traits, being the number of seeds plant^{-1},100-seed weight and seed oil content.

Table 7. Average contribution of A-lines, Rf-tester and their interaction to expression of studied traits.

Trait	Days to 50% flowering	Plant height (cm)	Stem diameter (cm)	Head diameter (cm)	No.of Seeds plant^{-1}	100-seed weight (g)	Seed yield plant^{-1} (g)	Seed oil content %
Lines	46.00	82.32	30.99	28.29	26.71	39.76	22.75	13.37
Testers	8.37	3.06	39.63	41.94	25.61	0.56	46.63	26.97
LxT	45.63	14.62	29.39	29.77	47.68	59.68	30.61	59.66

REFERENCES

Abd El-Hadi A.H. , K.A. Zaied, Clara R. Azzam and Marwa M. Nasr El-Din (2019). Genetical studies on sunflower using half diallel analysis. Egypt. J. Plant Breed. 23(7):1585- 1509.

Abou-Mowafy, M. R. F. (2010). Studies on heterosis and combining ability of some important characters in sunflower. M.Sc. Thesis, Fac. Agric., Kafrelsheikh Univ. Egypt.

A.O.A.C (1990). Official methods of analysis of the association of official analysis agriculture chemists, 15th Washington, D.C., USA.

Attia, S. A. M., E .H. EL-Seidy, A. A. El-Gammaal and R. M. M. Awad (2012). Heritability, genetic advance and associations among Characters of sunflower hybrids. J. Agric. Res., 38: 254-264.

Azab, A.M., H.E. Yassien, G.H. Abed El-Hai, S.M. Attia and M.A. Ahmed (2014). Combining abilities and heterosis for yield and yield components in sunflower. Al-Azhar. J.Agric. Res., (21):120-133.

Bhoite, K.D., R.B. Dubey, Mukesh Vyas, S.L Mundra and K.D Ameta (2018).Evaluation of combining ability and heterosis for seed yield in breeding lines of sunflower (*Helianthus annuus* L.) using line x tester analysis. J. of Pharmacognosy and Phytochemistry 7(5): 1457-1464.

Biradar S., A. Vijaykumar and G. Naidu (2018). Combining ability analysis for seed yield and its component traits with diverse CMS sources in sunflower (*Helianthus annuus* L.). Int. J. Curr. Microbiol. App. Sci. 7:954-960.

Cvejic S., S. Jocic ,E.Mladenovic , M. Jockovic , D. Miladinovic ,I. Imerovski and A. Dimitrijevic (2017).Evaluation of combining ability in ornamental sunflower for floral and morphological traits Czech J. Genet. Plant Breed., 53 (2): 83–88.

Dudhe, M.Y., M.K. Moon, and S.S. Lande, (2011). Study of gene action for restorer lines in sunflower. HELIA, 34 (54) 159-164.

Encheva, J., G. Georgiev and E. Penchev (2015). Heterosis effects for agronomically important traits in sunflower (*Helianthus annuus* L.). Bulgarian J. Agric. Sci., 21 (2):336–341.

Gomez, K. A., and A. A. Gomez. (1984). Statistical Procedure for Agriculture Research. John Wiley and Sons Inc., 2nd (Ed): New York, U.S.A. Pp-25-31.

Habib, H., S. S. Mehdi, A. Rashid, S. Iqbal and M. A. Anjum (2006). Heterosis studies in sunflower crosses for agronomic traits and oil yield under Faisalabad conditions. Pak. J. Agri. Sci. 43(3-4): 131-135.

Haddadan, A. Z., M. Ghaffari, E. M. Hervan and B. Alizadeh (2020) Impact of parent inbred lines on heterosis expression for agronomic characteristics in sunflower. Czech Journal of Genetics and Plant Breeding, 56 (3): 123–132.

Hallauer A. R. and J. B. Miranda (1986). Quantitative genetics in maize breeding. Iowa State University Press, Ames, IA, USA. pp. 267-294.

Haq A., A. Rashid, M.A. Butt, M.A. Akhter, M. Aslam and A. Saeed. (2006). Evaluation of sunflower (*Helianthus annuus* L.) hybrids for yield and yield components in central Punjab. J. Agric. Res, 44(4): 277-284.

Hladni N., D. Skoric and M. K. Balalic (2003). Genetic variance of sunflower yield components (*Helianthus annuus* L.). Genetica, 35:1-9.

Hladni, N., D. Skoric, M. Kraljevic-Balalic, Z. Satiac and D. E. Jovanovic (2006). Combining ability for oil content and its correlations with other yield components in sunflower (*Helianthus annuus* L.). Helia 29(44): 101-110.

Hladni N. D., M.K., Skoric, S., Balalic, V., Jocic, A.Miklic, and N. Dusanic (2011) Lines × tester analysis for yield components in sunflower and their correlations with seed yield (*Helianthus annuus* L.). Genetica, 43:297-306.

Imran M., A. qasrani. M.A. Nawaz, M.K.Shabaz, M.Asif and Q.Ali (2015). Combining ability analysis for yield related traits in sunflower (*Helianthus annuus* L.). Am-Euras. J. Agric. & Environ. Sci., 15 (3): 424-436.

Ingle A.U., S.S. Nichal, E.R.Vaidya, R.D. Ratnaparkhi and M.N. Kathale (2015). Heterosis for seed yield, its components and oil content in sunflower (*Helianthus annuus* L.). Trends in Biosciences 8 (16), 4352 -4364.

Kang S.A., F.A. Khan M.Z. Ahsan W.S. Chatha and F. Saeed (2013). Estimation of combining ability for the development of hybrid genotypes in sunflower (*Helianthus annuus* L.). J Biol. Agric. Healthc. 3:68-74.

Karasu A., O.Z. Mehmet M. Sincik A.T. Goksoy and Z.M. Turn (2010). Combining ability and heterosis for yield and yield components in sunflower. Not Bot Hort Agrobot Cluj. 38:259-264.

Kaya, Y., and L.K. Atakisi (2004). Combining ability analysis of some yield characters on sunflower (*Helianthus annuus* L.). Hilia, 24(41):75-84.

Kempthorne, O. (1969). An Introduction to Genetic Statistics. John Wiley and Sons Inc., Landon, New York.

Khan, H., S. Muhammad, R. Shah and N. Iqbal (2007). Genetic analysis of yield and some yield components in sunflower. Sarhad. J. Agric., 23: 985-990.

Khan U., M. Arshad, M. A. Khan, M. Ashraf, A. Saleem, S. Awan, S. Azam and U. Shamim (2019). Heterosis expression analysis and its impact on different agro-morphological characters in sunflower (*H. annuus* L.) hybrids. Ihsan Sibtain Shah Pakistan J. of Agri. Res. 32(2): 325-333

Masood, J., Farhatullah and G. Hassan (2005). Heterosis estimates for yield and yield components in sunflower. Pak. J. Biol. Sci. 8(4): 553-557.

Memon, S., M. J. Baloch, G. M. Baloch and M. I. Keerio. (2015). Heterotic effects in F1s and inbreeding depression in F2 hybrids of sunflower. Pak. J. Sci. Ind. Res., 58: 1-10.

Memon S. , M. J. Baloch, G. M. Baloch and M. I. Keerio (2014). Heritability and correlation studied for phonological, seed yield and oil traits in sunflower (*Helianthus annuus* L.) Pak. J. Agri., Agril. Engg., Vet. Sci., 30 (2): 159-171.

Patil T. R. , V. K., Vikas M. Kenganal, I. Shankergoud and J. R. Diwan (2017). Combining ability studies in restorer lines of sunflower (*Helianthus annuus* L.). J. Appl. & Nat. Sci. 9 (1): 603 - 608.

Rizwan M., H. A. Sadaqat, M. A. Iqbal and F.S. Awan (2020). Genetic assessment and combining ability analysis of achene yield and oil quality traits in (*Helianthus annuus* L.) hybrids. Pak.J. Agri. Sci. 57(1):101-108.

Sher A.K., A. Habib, K.Ayub, S.Muhammad, M.K. Shah and A.Bashir (2009). Using line × tester analysis for earliness and plant height traits in sunflower (*Helianthus annuus* L.). Recent Res. Sci. Technol.1:202-206.

Singh, R.K. and Chouduary, B. D., (1976). Biometrical Techniques in Genetics and Breeding. Int. Bioscience Publishers. Hisar. India.

Singh U.K., D. Kumar and R. Kumar (2018). Determining combining ability in sunflower (*Helianthus annus* L.). Int.J.Curr.Microbiol.App. Sci.7(5): 2290-2305

Supriya, S.M., Vikas V. Kulkarni, C.N. Ranganatha and P.G. Suresha (2017). Quantitative analysis of oil yield and its components in newly developed hybrids of sunflower (*Helianthus annuus* L.) Int.J.Curr.Microbiol.App.Sci 6(8): 3088-3098.

Tan, A.S. (2010) Study on the determination of combining abilities of inbred lines for hybrid breeding using line x tester analysis in sunflower (*Helianthus annuus* L.). HELIA, 33, Nr. 53, p.p. 131-148.

Telangre S. S., K. R. Kamble, S. P. Pole and M. M. Solanki (2019). Studies on combining ability of new restorer lines in sunflower (*Helianthus annuus* L.). Electronic Journal of Plant Breeding, 10 (3):1339 – 1344.

Vikas V. Kulkarni and S.M. Supriya (2017). Heterosis and combing ability studies for yield and yield component traits in sunflower (*Helianthus annuus* L.). Int.J.Curr. Microbiol.App.Sci. *6*(9): 3346- 3357.

USDA (2019). United States Department of Agriculture, Foreign Agricultural Service. Oilseeds: World Market and Trade.

التحليل الوراثى لبعض الصفات الاقتصادية فى محصول زهره الشمس

محمد عبد الرحيم أحمد*، تامر حسن على حسن و محمد رمضان فتح الله أبو موافي

قسم بحوث المحاصيل الزيتية- معهد بحوث المحاصيل الحقلية-مركز البحوث الزراعية

استخدم في تلك الدراسة سبعة سلالات من محصول زهره الشمس عقيمة الذكر سيتوبلازميا كأمهات وثلاثة كشافات معيده للخصوبة كآباء للحصول على بذرة21هجين طبقا لنظام التزاوج السلالة في الكشاف .تم تقييم جميع الـ تراكـ يب الوراثية (21 هجين و7 أمهات و3 كشافات) في محطة البحوث الزراعية بسخا خلال الموسم الصيفي 2017 . وقد أظهرت النتائج وجود تأثيرات عالية المعنوية لكل التراكيب الوراثية المستخدمة على جميع الصفات تحت الدراسة. أشارت النتائج أن تأثير القدرة العامة على الائتلاف كان مرتفعا للسلالتين A_9 , A_5بالنسبة لمعظم الصفات تحت الدراسة. إلى جانب أن الكشاف Rf_1 أظهر أعلى قدرة عامه على الائتلاف لمعظم الصفات تحت الدراسة. وكان أفضل الهجن لمحصول النبات (A_5 x Rf_1 و (A_7 x RF_8) مع تماثل عالي المعنوية في القدرة الخاصة على الائتلاف و قوة الهجين. كما أشارت النتائج أيضا إلى أن تأثير الفعل الجيني غير المضيف كان أعلى من الفعل الجيني المضيف إلى جانب أنه يلعب الدور الأكبر في توريث جميع الصفات تحت الدراسة. أما بالنسبة لمعامل التوريث في المدى الواسع فكان أعلى من معامل التوريث في المدى الضيق لكل الصفات تحت الدراسة.وعلى ذلك يمكن أن تدخل هذه الهجن في برامج إنتاج الهجن التجارية لمحصول زهره الشمس.