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Original Article

Performance and genetic parameters of yield and its components of half-sib families in Sunflower (*Helianthus annuus* L.)

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ABSTRACT

Forty-six testcrosses sunflower produced in 2010 season from two testers, (A_3 and A_{21}). Cytoplasmic Male Sterility (CMS) and 23 S_1 lines at Shandaweel Agri. Res. Station. In 2011 season, the experiment included 46 top-crosses, two testers (B_3 and B_{21}) and $Giza_{102}$. The Randomized Complete Block Design (RCBD) with three replications was used. Data were recorded on days to 50% flowering, days to maturity, plant height, stalk diameter, head diameter, 100-achene weight, achene yield/plant, achene yield/plot and oil content. The results show highly significant differences among half-sibs for all the studied traits. These results indicate the presence of diversity among half-sib families. Heterosis of the best 10 H.S families in oil content relative to the grand mean ranged from 4.53 to 13.65% but the heterosis ranged from 2.37 to 11.04% relative to the base pop. were Nos. 3, 8, 17, 24, 28, 30, 34, 36, 38 and 46. The results indicated that the respective S1 lines would have good g.c.a for oil content and were selected as parents to produce the first cycle of recurrent selection for the H.S pop. Broad sense heritability (H) for half-sib families were high for all studied traits except for days to 50% flowering, it was moderate.
Phenotypic coefficients of variability for various traits were relatively higher than genotypic coefficient of variability for H.S families because the phenotypic variance included the effect of environment. Oil content was negative and insignificant correlated with days to 50% flowering, days to maturity, head diameter and 100-achene weight, but was positive, poor and insignificant with achene yield. Achene yield/plot was positively and highly significant correlated with achene yield/plant, 100-achene weight and head diameter.

KEYWORDS

Sunflower,

***Helianthus annuus*,**

Genetic variability,

Half-Sib family,

Inbred lines,

Heterosis.

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INTRODUCTION

Increasing of oil yield is one of the most important goals in sunflower breeding programs. The Egyptian sunflower improvement program aims to combine high oil content, earliness and short stems from foreign germplasm with high yield potential and adaptability of local varieties.

The superior open-pollinated cultivars so derived must have high self-fertility and oil content, midem plant height, certain level of uniformity for morphological characters, disease and insect resistance and high seed yield.

Recurrent half-sib selection is one of the methods of intra- population improvement (**Sprague & Eberhart 1977**). It brings about improvement in a trait by increasing the frequency of gene (s) determining that trait. The change in gene and genotypic frequency can be studied through the use of mean, variance, skewness and kurtosis of the population undergoing selection (**Mather & Jinks 1971**; **Roy 2000**).

Recurrent half-sib selection has been widely employed for improving populations in maize. It has been applied to the present sunflower population. **Yenice & Arslan** (**1997**) they reported that, hybrid vigour under irrigated conditions was 92.62% for oil yield, 77.90% for seed yield, 48.24% for diameter of the seedless center of the head, 8.87% for 1000-seed weight, 7.57% for husk percentage, 5.51% for oil percentage and 4.90% for stalk yield. There was no heterosis for plant height and head diameter. **Nehru *et al*.** (**2000**) found that the majority of the crosses showed heterosis for the mid-parental values indicating non-additive action. **Seneviratne *et al*.** (**2004**) found that heritability values were high for seed yield, 100-seed weight, days to 50% flowering, days to maturity, plant height, head diameter and oil yield. High heritability coupled with high genetic advance was observed for head diameter and oil yield. **Syeda *et al*.** (**2011**) found that, low to high level of genetic variability existed among the hybrids for head diameter, seed yield/plant and yield/hectare. **Muhammad *et al*.** (**2013**) found that the weight of hundred seed had positive but non-significant association with the head diameter and the seed yield. Seed yield had negative correlation with oil contents and suggested to break it either through conventional or novel breeding techniques to breed high yielding hybrids with maximum oil contents.

The objectives of this study:

1. Estimate the heterosis as the best criterion for producing crosses.
2. Identify the desirable S_1 lines *per se* and availability to use these lines in synthetic variety production after testing of their combining abilities.

MATERIALS AND METHODS

$Giza_{102}$ an open-pollinated variety of sunflower were sown on June 20^{th}, 2010 at Shandaweel Agri. Res. Station. Approximately 100 plants were selected and selfed and tested for general combining ability by top-crossing them to the two testers, (A_3 and A_{21}). After harvest, 23 S_1 *per se* lines and 46 testcrosses, which produced enough seed, were chosen for evaluation in the next season.

In 2011 season, the experiment included 46 top-crosses, two testers (B_3 and B_{21}) and $Giza_{102}$ were evaluated. The Randomized Complete Block Design (RCBD) with three replications was used; the plot size was 1 row, 4 meter long and 60 cm apart. Planting was done in hills spaced 25cm apart. Seedlings were thinned to one plant per hill before the first irrigation (two weeks after planting). The cultural practices followed the recommendation for oil seed sunflower production. At harvest, the oil percentage was determined in all genotypes.

A) Earliness traits

1. Days to 50% flowering: number of days from sowing date to appearance of heads 50% of plants.
2. Days to maturity: was measured as number of days from sowing date until the head became yellow on plot basis.

B) Growth traits

The following traits were taken from random sample of five guarded plants. These plants were chosen from each plot and assigned to be fixed for the following measurements.

1. Plant height (cm): average length in cm from soil level to the tip of the head.
2. Stalk diameter (cm): measured at 30cm above the soil surface with vernier-calipers, at nearest 0.1 cm.

3. Head diameter (cm): estimated as an average of maximum width of the head.

C) Yield and yield components

1. 100-achene weight (g): One hundred seed were counted and weighed from the bulk of the guarded plants in grams.
2. Achene yield/plant (g): estimated as average of seed weight/head.
3. Achene yield/plot (g): measured from the adjusted seed yield/plot.
4. Oil content: random sample of seeds were taken from the seed yield of the five guarded plants. The oil content was determined by soxalet apparatus using petroleum ether (Bp40-60 c°) as solvent according to the official method (**A. O. A. C. 1980**).

Statistical analysis

Analysis of variance for testcrosses was carried out according to **Steel & Torrie** (**1980**), and the forms of the analysis of variance are shown in Table 1. The expected mean square for (half sib) according to **Hallauer & Miranda** (**1981**) were used to estimate the following genetic parameters., phenotypic, genotypic variance., heritability and phenotypic and genotypic coefficient of variation. Means wear compared using revised L.S.D at 1 and 5% level.

Table (1) Form of the analysis of variance for H.S.

S.O.V	D.F	M.S	E.M.S
Rep.	r-1		
Genotypes	f-1	M_2	$\sigma^2_{e} + r\sigma^2_{g}$
Error	(r-1) (f-1)	M_1	σ^2_{e}

Where: σ^2_g is the genotypic variance of half sib; σ^2_e is the error variances of half sib.

Simple correlation coefficients were calculated among all the studied traits using the following equation:

$$r_{x.y} = \frac{Cov_{x.y}}{\sqrt{\sigma^2_x \times \sigma^2_y}}$$

RESULTS AND DISCUSSION

I- Evaluation of half-sibs from the two tester inbred lines and 23 S_1 lines obtained from population $Giza_{102}$ of sunflower:

Analysis of variance of half-sib pop. for agronomic traits, yield and yield component are listed in Table (2). The results show highly significant differences among half-sibs for all the studied traits. These results indicate the presence of diversity among half-sib.

I.1. Mean performance of H.S families

I.1.1. Days to 50% flowering

Average performance of H.S families for days to 50% flowering are presented in Table (3). Days to 50% flowering of H.S varied from 48.33 to 54.67 with an average of 51.54 days. While the days to 50% flowering of the tester 1, tester 2 and base pop. $Giza_{102}$ were 54.00, 52.67 and 49.33 days, respectively. Twenty six out of forty-six H.S families were earlier than the grand mean, but one H.S family No.1 flowered significantly earlier than the grand mean. Heterosis of this half-sib relative to the grand mean was - 6.23%. While there were four half-sibs (Nos. 14, 15, 20 and 41) flowered significantly later than the grand mean.

On the other hand, almost half-sibs families were flowered significantly and highly significantly later than the base pop. $Giza_{102}$. The earliest half-sib family No.1 was not decreased significantly the base population. These results indicated that the respective S1 line of this half-sib would has good general combining ability for early flowering.

I.1.2. Days to maturity

For days to maturity of half-sibs families (Table 4) ranged from 78.00 to 86.00 with an average of 81.57 days. While it was 81.67, 85.67 and 82.33 days for the tester 1, 2 and the base pop. $Giza_{102}$, respectively. Ten H.S families Nos. 1, 3, 6, 19, 24, 26, 28, 29, 31 and 36 significantly and highly significantly earlier matured than the grand mean. Heterosis of these half-sibs relative to the grand mean were -3.97, -3.97, -3.15, -3.56, -3.56, -4.78, -4.38, -3.97, -3.15 and -3.15%, respectively. While there were nine half-sibs families Nos. 2. 4, 8, 14, 20, 37, 38, 43 and 45 significantly and highly significantly later matured than the grand mean.

On the other side, sixteen half-sibs families were significantly and highly significantly earlier matured than the base pop. $Giza_{102}$, Nos. 1, 3, 6, 7, 19, 21, 24, 26, 28, 29, 31, 33, 35, 36, 42 and 44. Heterosis of these were -4.86, -4.86, -4.04, -2.83, -4.45, -3.23, -4.45, -5.66, -5.26, -4.86, -4.04, -3.64, -3.23, -4.04, -2.83 and -3.23%, respectively. These results indicated that the respective S_1 lines of these half-sibs families would have good general combining ability of early maturing and would considers best combiners for earliness.

Table (2) Mean squares (MS) of all studied traits for H.S families, two testers and base population.

S.O.V	D.F	MS								
		Days to 50% flowering	Days to maturity	Plant height (cm)	Stalk diameter (cm)	Head diameter (cm)	100-achene weight (g)	Achene yield/plant (g)	Achene yield/plot (g)	Oil content (%)
Rep.	2	1.86	1.11	161.84	0.016	0.71	0.26	1.14	1377.28	1.22
H.S families	48	6.28**	16.15**	520.14**	0.252**	9.99**	3.11**	834.72**	63374.28**	11.72**
Error	96	1.88	1.66	16.96	0.006	0.58	0.16	15.46	1227.34	0.27

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

I.1.3. Plant height (cm)

Plant height of half-sibs families (Table 5) varied from 161.67 to 218.33 with an average of 182.41 cm. While it was 161.33, 162.67 and 153.67 for the tester 1, 2 and the base pop. $Giza_{102}$. Seventeen half-sib families Nos. 1, 5, 12, 21, 24, 26, 28, 29, 30, 32, 33, 34, 35, 36, 38, 40 and 44 out of fourteen H.S families were highly significant shorter comparing the grand mean. Heterosis for those H.S families were -8.27, -4.43, -7.72, -7.17, -11.37, -9.36, -9.73%, -5.16, -6.44, -4.61, -7.17, -5.53, -6.62, -6.26, -4.43, -4.79 and -11.01%, respectively. The S1 lines per se of those H.S would be considered as a good combiner for shortness.

On the other side, there were 17 H.S families Nos. 2, 4, 8, 10, 11, 14, 15, 16, 18, 20, 22, 23, 31, 41, 42, 43 and 45 were tall significantly or highly significant compared to the grand mean. Those H.S gave heterosis values of 7.63, 3.43, 19.69, 5.99, 7.63, 9.64, 3.61, 3.43, 8.55, 8.91, 5.44, 4.16, 7.08, 4.71, 3.43, 8.91 and 5.99%, respectively. The results in Table (5), showed that all half-sib families were highly significant than the base pop. $Giza_{102}$.

I.1.4. Stalk diameter (cm)

Stalk diameter of forty-six half-sibs (Table 6) presented the mean performance which ranged from 1.95 to 3.07 with an average of 2.50 cm, while the mean of the tester 1, 2 and the base pop.

Giza102 were 1.73, 2.75 and 2.40 cm, respectively. Results of stalk diameter showed that, sixteen out of forty-six H.S families were highly significantly exhibited the grand mean. Sixteen H.S families Nos. 2, 5, 8, 10, 12, 14, 15, 23, 25, 27, 36, 39, 41, 43, 45 and 46 gave the high values of stalk diameter, which their heterosis from the grand mean were 19.6, 6.80, 16.80, 8.00, 9.20, 12.80, 8.80, 22.80, 18.80, 10.40, 8.00, 12.00, 15.60, 14.80 and 5.60%, respectively.

Table (3) Mean performance and heterosis (h %) of grand mean and base population for days to 50% flowering in half sib (H.S) families.

No. of S_1 lines	Days to 50% flowering					
	Mean of Half-sib		H of G. Mean		H of Base Pop.	
	Tester		Tester		Tester	
	A_3	A_{21}	A_3	A_{21}	A_3	A_{21}
1	48.33	49.67	-6.23*	-3.63	-2.03	0.69
2	51.00	51.00	-1.05	-1.05	3.39	3.39
3	50.00	50.00	-2.99	-2.99	1.36	1.36
4	49.67	50.67	-3.63	-1.69	0.69	2.72
5	51.67	51.33	0.25	-0.41	4.74	4.05
6	50.67	49.67	-1.69	-3.63	2.72	0.69
7	52.67	53.67	2.19	4.13	6.77**	8.80**
8	51.67	52.33	0.25	1.53	4.74	6.08*
9	52.67	52.33	2.19	1.53	6.77**	6.08*
10	50.33	50.00	-2.35	-2.99	2.03	1.36
11	50.33	51.00	-2.35	-1.05	2.03	3.39
12	51.33	50.00	-0.41	-2.99	4.05	1.36
13	52.00	51.00	0.89	-1.05	5.41*	3.39
14	54.67	51.33	6.07*	-0.41	10.83**	4.05
15	54.00	52.33	4.77*	1.53	9.47**	6.08*
16	52.67	50.33	2.19	-2.35	6.77**	2.03
17	51.33	51.33	-0.41	-0.41	4.05	4.05
18	52.67	54.33	2.19	5.41*	6.77**	10.14**
19	52.67	50.00	2.19	-2.99	6.77**	1.36
20	54.00	52.67	4.77*	2.19	9.47**	6.77**
21	51.67	51.33	0.25	-0.41	4.74	4.05
22	53.00	53.00	2.83	2.83	7.44**	7.44**
23	51.33	51.33	-0.41	-0.41	4.05	4.05
G. Mean		51.54	Base Pop.		49.33	
Tester 1	54.00					
Tester 2	52.67					
LSD'0.05	2.44		4.73		4.95	
LSD'0.01	3.26		6.33		6.61	

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

On the other hand, twenty half-sib families exhibited significantly and higher heterosis than the base pop. Giza102. For stalk diameter relative to the base pop. The best ten half-sib families can be ranked as follow: Nos. 2, 8, 12, 14, 23, 25, 27, 41, 43 and 45). Heterosis of those half-sib families were 24.58, 21.67, 13.75, 17.50, 27.92, 23.75, 15.00, 16.67, 20.42 and 19.58%, respectively. These results assumed that the respective S1 lines would have good g.c.a for stalk diameter.

I.1.5. Head diameter (cm)

Head diameter of forty-six half-sib families (Table 7), revealed that the mean performance varied from 17.47 to 24.93 with mean of 21.70 cm, while the mean of tester 1, 2 and base pop. Giza102 were 16.87, 18.87 and 18.13 cm, respectively.

Results of head diameter showed that eight out of forty-six H.S families possessed high values comparing grand mean. Three H.S families nos. 2, 5 and 45 exhibited significantly and highly significantly than the grand mean. Heterosis of those H.S families were 6.59, 14.88 and 9.68%, respectively.

Table (4) Mean performance and heterosis (h %) of grand mean and base population for days to maturity in half sib (H.S) families.

No. of S_1 lines	Days to maturity					
	Mean of Half-sib		H of G. Mean		H of Base Pop.	
	Tester		Tester		Tester	
	A_3	A_{21}	A_3	A_{21}	A_3	A_{21}
1	78.33	78.67	-3.97**	-3.56**	-4.86**	-4.45**
2	84.33	83.67	3.38**	2.57*	2.43	1.63
3	78.33	77.67	-3.97**	-4.78**	-4.86**	-5.66**
4	85.00	83.67	4.20**	2.57*	3.24**	1.63
5	80.33	78.00	-1.52	-4.38**	-2.43	-5.26**
6	79.00	78.33	-3.15*	-3.97**	-4.04**	-4.86**
7	80.00	81.00	-1.92	-0.70	-2.83*	-1.62
8	85.00	79.00	4.20**	-3.15*	3.24**	-4.04**
9	81.00	82.67	-0.70	1.35	-1.62	0.41
10	83.33	79.33	2.16	-2.75	1.21	-3.64**
11	83.00	82.00	1.75	0.53	0.81	-0.40
12	82.67	79.67	1.35	-2.33	0.41	-3.23**
13	83.00	79.00	1.75	-3.15*	0.81	-4.04**
14	84.00	83.67	2.98*	2.57*	2.03	1.63
15	80.67	86.00	-1.10	5.43**	-2.02	4.46**
16	80.33	83.33	-1.52	2.16	-2.43	1.21
17	80.67	83.33	-1.10	2.16	-2.02	1.21
18	81.00	83.33	-0.70	2.16	-1.62	1.21
19	78.67	80.00	-3.56**	-1.92	-4.45**	-2.83*
20	84.33	84.00	3.38**	2.98*	2.43	2.03
21	79.67	79.67	-2.33	-2.33	-3.23**	-3.23**
22	83.67	84.67	2.57*	3.80**	1.63	2.84*
23	82.67	82.67	1.35	1.35	0.41	0.41
G. Mean		81.57	Base Pop.		82.33	
Tester 1	81.67					
Tester 2	85.67					
LSD'0.05	2.03		2.49		2.47	
LSD'0.01	2.66		3.26		3.23	

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

On the other side, there were twenty-seven H.S families exhibited significantly or highly significantly high values of heterosis compared to the base pop. The 10 best H.S have highly significantly heterosis for head diameter Nos. 1, 2, 5, 11, 13, 14, 37, 41, 43 and 45 with heterosis of 23.94, 27.58, 37.51, 22.45, 19.86, 25.04, 19.53, 23.94, 19.53 and 31.27%. These results assumed that the respective S1 lines would have good g.c.a for head diameter.

I.1.6.100-achene weight (g)

Average performance for H.S families for 100-achene weight Table (8) ranged from 5.61 to 9.60 with an average of 8.04, g as compared to 6.19, 6.49 and 8.27, g for the tester 1, 2 and the base pop. $Giza_{102}$. Eleven H.S families Nos. 1, 7, 8, 11, 14, 32, 33, 37, 41, 43 and 45 exhibited significantly or highly significantly high heterosis compared to the grand mean and recorded 10.95, 13.31, 18.28, 19.90, 19.40, 9.08, 10.57, 9.58, 10.95, 14.93 and 10.95%, respectively.

Table (5) Mean performance and heterosis (h %) of grand mean and base population for plant height in half sib (H.S) families.

No. of S_1 lines	Plant height, cm					
	Mean of Half-sib		H of G. Mean		H of Base Pop.	
	Tester		Tester		Tester	
	A_3	A_{21}	A_3	A_{21}	A_3	A_{21}
1	167.33	161.67	-8.27**	-11.37**	8.89**	5.21**
2	196.33	185.33	7.63**	1.60	27.76**	20.60**
3	182.00	165.33	-0.22	-9.36**	18.44**	7.59**
4	188.67	186.33	3.43*	2.15	22.78**	21.25**
5	174.33	164.67	-4.43**	-9.73**	13.44**	7.16**
6	179.67	173.00	-1.50	-5.16**	16.92**	12.58**
7	179.00	170.67	-1.87	-6.44**	16.48**	11.06**
8	218.33	195.33	19.69**	7.08**	42.08**	27.11**
9	186.67	174.00	2.34	-4.61**	21.47**	13.23**
10	193.33	169.33	5.99**	-7.17**	25.81**	10.19**
11	196.33	172.33	7.63**	-5.53**	27.76**	12.14**
12	168.33	170.33	-7.72**	-6.62**	9.54**	10.84**
13	184.00	171.00	0.87	-6.26**	19.74**	11.28**
14	200.00	180.00	9.64**	-1.32	30.15**	17.13**
15	189.00	174.33	3.61*	-4.43**	22.99**	13.44**
16	188.67	186.67	3.43*	2.34	22.78**	21.47**
17	184.33	173.67	1.05	-4.79**	19.95**	13.01**
18	198.00	191.00	8.55**	4.71**	28.85**	24.29**
19	180.00	188.67	-1.32	3.43*	17.13**	22.78**
20	198.67	198.67	8.91**	8.91**	29.28**	29.28**
21	169.33	162.33	-7.17**	-11.01**	10.19**	5.64**
22	192.33	193.33	5.44**	5.99**	25.16**	25.81**
23	190.00	178.00	4.16*	-2.42	23.64**	15.83**
G. Mean		182.41	Base Pop.		153.67	
Tester 1	161.33					
Tester 2	162.67					
LSD'0.05	5.89		3.23		3.83	
LSD'0.01	7.71		4.23		5.02	

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

On the other hand, most values of heterosis were negative. Moreover, thirteen H.S families were higher than the base pop. The nine best H.S families Nos. 1, 7, 8, 11, 14, 33, 41, 43 and 45 have significantly or highly significantly higher heterosis for head diameter. Heterosis of those half-sibs were 7.86, 10.16, 14.99, 16.57, 16.08, 7.50, 7.86, 11.73 and 7.86%, respectively. The obtained results indicated that the respective S_1 lines would have good combiners for this trait.

I.1.7. Achene yield/plant (g)

The average of achene yield/plant for half-sibs are presented in Table (9). The achene yield/plant varied from 44.00 to 107.58 with an average of 76.78, g/plant. While it was 57.01, 64.04 and 72.51 g/plant for the tester 1, 2 and the base pop. $Giza_{102}$, respectively. Seventeen out of forty-six H.S families exhibited significantly or highly significantly high heterosis comparing the grand mean. The best ten H.S families were Nos. 1, 8, 11, 16, 22, 23, 33, 37, 43 and 45, and their heterosis amounted 28.87, 31.67, 30.72 21.32, 37.11, 32.05, 40.11, 27.75 and 35.39%, respectively.

For heterosis relative to the base pop. $Giza_{102}$, most of H.S families (29 out of 46) were more than the base pop. The best ten H.S families have highly significantly heterosis relative to the base pop. for achene yield/plant Nos. 45, 43, 37, 33, 23, 22, 16, 11, 8 and 1. Their heterosis were 43.36, 35.28, 48.37, 39.83, 45.18, 28.47, 29.98, 38.42, 39.43 and 36.46%, respectively. These results indicated that the respective S1 lines would have good g.c.a for achene yield/plant.

Table (6) Mean performance and heterosis (h %) of grand mean and base population for stalk diameter in half sib (H.S) families.

No. of S_1 lines	Stalk diameter, cm					
	Mean of Half-sib		H of G. Mean		H of Base Pop.	
	Tester		Tester		Tester	
	A_3	A_{21}	A_3	A_{21}	A_3	A_{21}
1	2.09	2.27	-16.40**	-9.20**	-12.92**	-5.42*
2	2.99	2.97	19.60**	18.80**	24.58**	23.75**
3	2.37	2.20	-5.20*	-12.00**	-1.25	-8.33**
4	2.50	2.76	0.00	10.40**	4.17	15.00**
5	2.67	2.07	6.80**	-17.20**	11.25**	-13.75**
6	1.95	2.25	-22.00**	-10.0**	-18.75**	-6.25**
7	2.58	2.46	3.20	-1.60	7.50**	2.50
8	2.92	2.49	16.80**	-0.40	21.67**	3.75
9	2.21	2.27	-11.60**	-9.20**	-7.92**	-5.42*
10	2.70	2.14	8.00**	-14.40**	12.50**	-10.83**
11	2.48	2.53	-0.80	1.20	3.33	5.42*
12	2.73	2.43	9.20**	-2.80	13.75**	1.25
13	2.26	2.70	-9.60**	8.00**	-5.83**	12.50**
14	2.82	2.53	12.80**	1.20	17.50**	5.42*
15	2.72	2.48	8.80**	-0.80	13.33**	3.33
16	2.50	2.64	0.00	5.60**	4.17	10.00**
17	2.48	2.11	-0.80	-15.60**	3.33	-12.08**
18	2.29	2.80	-8.40**	12.00**	-4.58*	16.67**
19	2.27	2.50	-9.20**	0.00	-5.42*	4.17
20	2.39	2.89	-4.40*	15.60**	-0.42	20.42**
21	2.52	2.16	0.80	-13.60**	5.00*	-10.00**
22	2.46	2.87	-1.60	14.80**	2.50	19.58**
23	3.07	2.64	22.80**	5.60**	27.92**	10.00**
G. Mean		2.50	Base Pop.		2.40	
Tester 1	1.73					
Tester 2	2.75					
LSD’0.05	0.11		4.40		4.58	
LSD’0.01	0.14		5.60		5.83	

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

I.1.8. Achene yield/plot (g)

Average of forty-six half-sibs for achene yield/plot ranged from 396.00 to 959.80 with an average of 691.28, g/plot. While the mean of the tester 1, 2 and the base pop. was 510.73, 582.36 and 680.28, g/plot, respectively (Table 10).

Seventeen out of forty-six H.S families were significant or highly significant compared to the grand mean and the base pop. Giza102. The ten best H.S families were Nos. 1, 8, 11, 22, 23, 32, 33, 37, 43 and 45.

Heterosis of those H.S families relative to the grand mean were 30.90, 33.75, 32.30, 21.91, 35.11, 21.94, 33.25, 41.09, 30.05 and 34.59%, respectively, as compared to 28.82, 31.63, 30.19, 19.97, 32.96, 20.00, 31.13, 38.84, 27.98 and 32.45%, relative to the base pop. Giza102. These results indicated that the S1 lines have high g.c.a for achene yield/plot.

Table (7) Mean performance and heterosis (h %) of grand mean and base population for head diameter in half sib (H.S) families.

No. of S_1 lines	Head diameter, cm					
	Mean of Half-sib		H of G. Mean		H of Base Pop.	
	Tester		Tester		Tester	
	A_3	A_{21}	A_3	A_{21}	A_3	A_{21}
1	22.47	20.07	3.55	-7.51**	23.94**	10.70**
2	23.13	19.20	6.59*	-11.52**	27.58**	5.90
3	18.60	19.33	-14.29**	-10.92**	2.59	6.62*
4	17.47	20.00	-19.49**	-7.83**	-3.64	10.31**
5	24.93	18.47	14.88**	-14.88**	37.51**	1.88
6	21.47	20.80	-1.06	-4.15	18.42**	14.73**
7	19.20	20.40	-11.52**	-5.99*	5.90	12.52**
8	19.47	20.93	-10.28**	-3.55	7.39*	15.44**
9	17.80	18.80	-17.97**	-13.36**	-1.82	3.70
10	18.27	21.00	-15.81**	-3.23	0.77	15.83**
11	22.20	19.20	2.30	-11.52**	22.45**	5.90
12	18.27	18.13	-15.81**	-16.45**	0.77	0.00
13	21.73	17.80	0.14	-17.97**	19.86**	-1.82
14	22.67	21.67	4.47	-0.14	25.04**	19.53**
15	18.33	20.53	-15.53**	-5.39*	1.10	13.24**
16	19.27	19.67	-11.20**	-9.35**	6.29	8.49**
17	17.60	19.67	-18.89**	-9.35**	-2.92	8.49**
18	18.07	22.47	-16.73**	3.55	-0.33	23.94**
19	18.53	19.87	-14.61**	-8.43**	2.21	9.60**
20	18.33	21.67	-15.53**	-0.14	1.10	19.53**
21	19.80	20.87	-8.76**	-3.82	9.21**	15.11**
22	18.27	23.80	-15.81**	9.68**	0.77	31.27**
23	21.27	21.33	-1.98	-1.71	17.32**	17.65**
G. Mean		21.70	Base Pop.		18.13	
Tester 1	16.87					
Tester 2	18.87					
LSD'0.05	1.15		5.30		6.34	
LSD'0.01	1.51		6.96		8.33	

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

I.1.9. Oil content (%)

Regarding to oil content (Table 11) the mean performance of forty-six half-sibs families varied from 36.64 to 44.95 with an average of 39.55%, while the oil content to the tester 1, 2 and the base pop. were 41.57, 38.89 and 40.48%, respectively. Eighteen H.S families were more than the grand mean. The best 10 H.S families gave highly significantly heterosis and can be ranked as following: No. 3, 8, 17, 24, 28, 30, 34, 36, 38 and 46. Heterosis of those H.S families relative to the grand mean were 6.83, 5.76, 6.32, 5.21, 9.53, 4.53, 4.78, 6.55, 13.65 and 11.48%, respectively.

On the other hand, the best 10 H.S families were Nos. 3, 8, 17, 24, 28, 30, 34, 36, 38 and 46, surpassed significantly and highly significantly compared to the base pop. and possessed heterosis of 4.37, 3.33, 3.88, 2.79, 7.02, 2.37, 4.10, 11.04 and 8.92%, respectively. The results indicated that the respective S1 lines would have good g.c.a for oil content and were selected as parents to produce the first cycle of recurrent selection for the H.S pop. Five S1 lines Nos.1, 7, 11, 15 and 17 involved as parents for cycle-1 on the base of per se and H.S families. Results are in agreement to various earlier studies of **Yenice & Arslan** (**1997**) they found heterosis of 67.95% for oil yield, 54.03% for seed yield, 11.89% for plant height, 11.49% for head diameter, 7.79% for oil percentage, 6.16% for diameter of the seedless center of the head, 4.92% for stalk yield and 4.80% for husk percentage. **Nehru *et al*. (2000)**, **Goksoy *et al*. (2002)** found that the rates of heterosis observed in plant height, head diameter, seed number/head, 1000-seed weight, seed weight/plant (head) and seed yield/ha were 11.2, 14.7, 35.8, 15.7, 59.4 and 65.7%, respectively.

Table (8) Mean performance and heterosis (h %) of grand mean and base population for 100-achene weight in half sib (H.S) families.

No. of S_1 lines	100-achene weight					
	Mean of Half-sib		H of G. Mean		H of Base Pop.	
	Tester		Tester		Tester	
	A_3	A_{21}	A_3	A_{21}	A_3	A_{21}
1	8.92	8.34	10.95**	3.73	7.86*	0.85
2	8.42	7.51	4.73	-6.59	1.81	-9.19*
3	7.64	7.03	-4.98	-12.56**	-7.62*	-14.99**
4	5.61	8.06	-30.22**	0.25	-32.16**	-2.54
5	7.70	7.21	-4.23	-10.32**	-6.89	-12.82**
6	6.71	6.03	-16.54**	-25.00**	-18.86**	-27.09**
7	9.11	8.09	13.31**	0.62	10.16**	-2.18
8	9.51	6.96	18.28**	-13.43**	14.99**	-15.84**
9	6.57	8.77	-18.28**	9.08*	-20.56**	6.05
10	7.42	8.89	-7.71*	10.57**	-10.28**	7.50*
11	9.64	6.87	19.90**	-14.55**	16.57**	-16.93**
12	7.95	8.03	-1.12	-0.12	-3.87	-2.90
13	7.21	7.32	-10.32**	-8.96*	-12.82**	-11.49**
14	9.60	8.81	19.40**	9.58*	16.08**	6.53
15	6.19	7.25	-23.01**	-9.83**	-25.15**	-12.33**
16	8.05	7.58	0.12	-5.72	-2.66	-8.34*
17	7.62	6.21	-5.22	-22.76**	-7.86*	-24.91**
18	6.71	8.92	-16.54**	10.95**	-18.86**	7.86*
19	6.40	6.91	-20.40**	-14.05**	-22.61**	-16.44**
20	8.10	9.24	0.75	14.93**	-2.06	11.73**
21	7.70	7.30	-4.23	-9.20*	-6.89	-11.73**
22	8.10	8.92	0.75	10.95**	-2.06	7.86*
23	8.18	7.19	1.74	-10.57**	-1.09	-13.06**
G. Mean		8.04	Base Pop.		8.27	
$Tester_1$	6.19					
$Tester_2$	6.49					
LSD'0.05	0.60		7.46		7.28	
LSD'0.01	0.79		9.83		9.55	

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

Ahmad *et al.* (2005) showed highly significant heterosis in F1 hybrids for yield and leaf area and ranging from 102 to 3.9% and 46.3 to 163.9%, respectively. **Khan *et al*. (2008)** showed heterosis estimates of F1 hybrids and ranged from 5.60 to 185.02% and -9.06 to 181.73% for yield hectare -1, 23.33 to 171.66% and -43.91 to 127.36% for harvest index and -4.78 to 52.85% and -18.39 to 42.50% for oil content, respectively.

Syeda *et al*. (2011) found that, low to high level of genetic variability existed among the hybrids for all characters (head diameter, seed yield/plant and yield/hectare) as revealed by analysis of variance. **Bahy *et al*. (2010)** showed highly significant positive heterotic effects were observed in eight crosses out of 24 crosses in the combined data over the two years for achene oil percentages, heterotic values ranged from -5.11 (L3 x Rf1) to 6.79 (L19 x Rf4).

It is worth to mention that the H.S family (No. 8) was good g.c.a for some traits such as 100-achene weight, achene yield/plant, achene yield/plot and oil content.

Table (9) Mean performance and heterosis (h %) of grand mean and base population for achene yield/plant in half sib (H.S) families.

No. of S_1 lines	Achene yield/plant, g					
	Mean of Half-sib		H of G. Mean		H of Base Pop.	
	Tester		Tester		Tester	
	A_3	A_{21}	A_3	A_{21}	A_3	A_{21}
1	98.95	84.05	28.87**	9.47*	36.46**	15.92**
2	89.67	80.34	16.79**	4.64	23.67**	10.80**
3	70.93	44.00	-7.62*	-42.69**	-2.18	-39.32**
4	54.59	72.95	-28.90**	-4.99	-24.71**	0.61
5	74.01	68.38	-3.61	-10.94**	2.07	-5.70
6	52.67	53.11	-31.40**	-30.83**	-27.36**	-26.75**
7	77.85	91.34	1.39	18.96**	7.36	25.97**
8	101.10	49.39	31.67**	-35.67**	39.43**	-31.89**
9	64.15	92.33	-16.45**	20.25**	-11.53**	27.33**
10	68.82	101.39	-10.37**	32.05**	-5.09	39.83**
11	100.37	77.45	30.72**	0.87	38.42**	6.81
12	75.55	69.22	-1.60	-9.85**	4.19	-4.54
13	69.81	74.91	-9.08*	-2.44	-3.72	3.31
14	83.69	107.58	9.00*	40.11**	15.42**	48.37**
15	53.79	72.42	-29.94**	-5.68	-25.82**	-0.12
16	94.25	77.91	22.75**	1.47	29.98**	7.45
17	79.89	52.81	4.05	-31.22**	10.18**	-27.17**
18	53.04	92.72	-30.92**	20.76**	-26.85**	27.87**
19	63.17	81.25	-17.73**	5.82	-12.88**	12.05**
20	87.54	98.09	14.01**	27.75**	20.73**	35.28**
21	68.88	73.19	-10.29**	-4.68	-5.01	0.94
22	93.15	103.95	21.32**	35.39**	28.47**	43.36**
23	105.27	73.34	37.11**	-4.48	45.18**	1.14
G. Mean		76.78	Base Pop.		72.51	
Tester 1	57.01					
Tester 2	64.04					
LSD'0.05	5.62		7.32		7.75	
LSD'0.01	7.35		9.57		10.14	

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

I.2. Variance components and heritability

Genotypic and phenotypic variance and broad sense heritability (H) are presented in Table (12). Results revealed that genotypic variance for all studied traits were less than the phenotypic variance, this due to that the genotypic variance depend upon the effect of additive and dominance but the phenotypic variance due to the effect of genotypic variance and environment. The genotypic variance for all studied traits were low except for achene yield/plant and achene yield/plot, indicating that the more variability in the base population for achene yield.

Broad sense heritability (H) for half-sib families were high for all studied traits except for days to50% flowering, it was moderate. These results due to the genetic variability among the studied genotypes (H.S families). Our results are in agreement with those obtained by **Seneviratne *et al.*** (**2003**) found that high broad-sense heritability coupled with high genetic advance was observed for head diameter and oil yield, indicating the presence of additive gene action controlling these traits. But, plant height, 100-seed weight and oil content, characterized by high heritability estimates with moderate genetic advance, were controlled by both additive and non-additive gene action. **Seneviratne *et al*. (2004)** showed that heritability values were high for seed yield, 100-seed weight, days to 50% flowering, days to maturity, plant height, head diameter and oil yield. High heritability coupled with high genetic advance was observed for head diameter and oil yield. **Mijic *et al*. (2009)** found that phenotypic and genotypic coefficients of variation were highest for grain yield, followed by oil yield and 1000-grain weight.

Table (10) Mean performance and heterosis (h %) of grand mean and base population for achene yield/plot in half sib (H.S) families.

No. of S_1 lines	Achene yield/plot, g					
	Mean of Half-sib		H of G. Mean		H of Base Pop.	
	Tester		Tester		Tester	
	A_3	A_{21}	A_3	A_{21}	A_3	A_{21}
1	890.52	779.48	28.82**	12.76**	30.90**	14.58**
2	804.73	716.36	16.41**	3.63	18.29**	5.30
3	631.56	396.00	-8.64*	-42.71**	-7.16	-41.79**
4	498.57	653.46	-27.88**	-5.47	-26.71**	-3.94
5	655.79	612.10	-5.13	-11.45**	-3.60	-10.02**
6	465.67	480.29	-32.64**	-30.52	-31.55**	-29.40**
7	694.86	804.41	0.52	16.37**	2.14	18.25**
8	909.90	469.94	31.63**	-32.02**	33.75**	-30.92**
9	577.38	829.53	-16.48**	20.00	-15.13**	21.94**
10	622.71	906.50	-9.92**	31.13**	-8.46*	33.25**
11	900.00	687.38	30.19**	-0.56	32.30**	1.04
12	684.65	615.67	-0.96	-10.94**	0.64	-9.50*
13	620.00	693.00	-10.31**	0.25	-8.86*	1.87
14	750.33	959.80	8.54*	38.84**	10.30**	41.09**
15	491.10	656.48	-28.96**	-5.03	-27.81**	-3.50
16	828.69	710.17	19.88**	2.73	21.82**	4.39
17	716.31	497.59	3.62	-28.02**	5.30	-26.86**
18	469.24	819.39	-32.12**	18.53**	-31.02**	20.45**
19	581.83	729.60	-15.83**	5.54	-14.47**	7.25
20	787.86	884.70	13.97**	27.98**	15.81**	30.05**
21	610.28	681.07	-11.72**	-1.48	-10.29**	0.12
22	829.32	915.58	19.97**	32.45**	21.91**	34.59**
23	919.13	660.73	32.96**	-4.42	35.11**	-2.87
G. Mean		691.28	Base Pop.		680.28	
Tester 1	510.73					
Tester 2	582.36					
LSD’0.05	50.06		7.24		7.36	
LSD’0.01	65.51		9.48		6.63	

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

High values of heritability were estimated for oil content and plant height, medium for 1000-grain weight and test weight, and low values for grain and oil yield.

Generally, heritability values alone cannot provide any indication of the amount of progress that would results selection because heritability in broad sense includes both additive and non-additive gene action **Seneviratne *et al*. (2004)**.

High heritability estimates were observed for plant height, stalk diameter, achene yield/plot, head diameter, achene yield/plant, oil content, days to maturity, days to 50% flowering and 100-achene weight, and their values were 98.84, 98.39, 97.86, 96.90, 96.81, 96.20, 95.04, 93.46 and 92.55%, respectively (**Attia *et al*. 2014**). Estimates of phenotypic (pcv) and genotypic (gcv) coefficient of variability of all studied traits for H.S families are presented in Table (12).

Table (11) Mean performance and heterosis (h %) of grand mean and base population for oil content in half sib (H.S) families.

No. of S_1 lines	Oil content, %					
	Mean of Half-sib		H of G. Mean		H of Base Pop.	
	Tester		Tester		Tester	
	A_3	A_{21}	A_3	A_{21}	A_3	A_{21}
1	37.64	41.61	-4.83**	5.21**	-7.02**	2.79**
2	38.45	40.12	-2.78**	1.44	-5.01**	-0.89
3	42.25	40.50	6.83**	2.40*	4.37**	0.05
4	39.49	38.78	-0.15	-1.95*	-2.45**	-4.20**
5	39.04	43.32	-1.29	9.53**	-3.56**	7.02**
6	37.90	39.36	-4.17**	-0.48	-6.37**	-2.77**
7	39.45	41.34	-0.25	4.53**	-2.54**	2.12*
8	41.83	38.30	5.76**	-3.16**	3.33**	-5.39**
9	37.46	38.76	-5.28**	-2.00*	-7.46*	-4.25**
10	36.85	38.63	-6.83**	-2.33*	-8.97**	-4.57**
11	41.08	41.44	3.87**	4.78**	1.48	2.37*
12	38.14	39.97	-3.57**	1.06	-5.78**	-1.26
13	41.25	42.14	4.30**	6.55**	1.90*	4.10**
14	37.36	40.80	-5.54**	3.16**	-7.71**	0.79
15	39.91	44.95	0.91	13.65**	-1.41	11.04**
16	37.92	38.31	-4.12**	-3.14**	-6.32**	-5.36**
17	42.05	38.50	6.32**	-2.65**	3.88**	-4.89**
18	36.64	39.68	-7.36**	0.33	-9.49**	-1.98*
19	36.19	37.10	-8.50**	-6.19**	-10.60**	-8.35**
20	39.24	37.97	-0.78	-3.99**	-3.06**	-6.20**
21	38.62	39.38	-2.35*	-0.43	-4.59**	-2.72**
22	38.42	38.12	-2.86**	-3.62**	-5.09**	-5.83**
23	37.18	44.09	-5.99**	11.48**	-8.15**	8.92**
G. Mean		39.55	Base Pop.		40.48	
Tester $_1$	41.57					
Tester $_2$	38.89					
LSD'0.05	0.74		1.87		1.83	
LSD'0.01	0.97		2.45		2.40	

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

Phenotypic coefficients of variability for various traits were relatively higher than genotypic coefficient of variability for H.S families, because the phenotypic variance included the effect of environment. The phenotypic coefficient of variability values for achene yield/plant, achene yield/plot, 100-achene weight and stalk diameter for H.S families were 21.70, 21.03, 13.24 and 11.59%, respectively. These values of phenotypic coefficient were high comparing with those of H.S families for other traits such as days to 50% flowering, days to maturity, oil content, plant height and head diameter. These values were amounted 2.81, 2.84,5.00, 7.28 and 9.16%, respectively. These results indicated that the large environmental variance associated with later traits. While genotypic coefficient of variability values for achene yield/plant, achene yield/plot, 100-achene weight and stalk diameter for H.S families were 21.50, 20.82, 12.86 and 11.45%, respectively. These values of genotypic coefficient were high comparing with those of H.S families for another traits, such as days to 50% flowering, days to maturity, oil content, plant height and head diameter. These values were 2.35, 2.69, 4.94, 7.16 and 8.89%, respectively. These results indicated the base population had more variability and genetic variance. These results were in harmony with the results of **Ashok *et al*.** (**2000**), **Khan** (**2001**), **Seneviratne *et al*.** (**2004**) and **Attia *et al*.** (**2014**).

Table (12) Variance components (genotypic variance ($\sigma^2 g$), phenotypic variance ($\sigma^2 ph$), genotypic coefficient of variance (GCV), phenotypic coefficient of variance (PCV) and broad sense heritability (H %) of all studied traits for H.S families, two testers and base population.

S.O.V	MS								
	Days to 50% flowering	Days to maturity	Plant height (cm)	Stalk diameter (cm)	Head diameter (cm)	100-achene weight (g)	Achene yield/plant (g)	Achene yield/plot (g)	Oil content (%)
σ^2 g	1.47	4.83	167.73	0.082	3.14	0.98	273.10	20715.65	3.82
σ^2 Ph	2.10	5.38	173.38	0.084	3.33	1.04	278.25	21124.76	3.91
G.C.V%	2.35	2.69	7.16	11.45	8.89	12.86	21.50	20.82	4.94
P.C.V%	2.81	2.84	7.28	11.59	9.16	13.24	21.70	21.03	5.00
H%	70.00	89.78	96.74	97.62	94.29	94.23	98.15	98.06	97.70

I. 3. Correlation coefficients (r)

The correlation of characters may be due to genetic linkage or pleiotropy. Knowledge of correlation studies paves the way to know the associations prevailing between highly heritable characters with economic characters (Falconer 1989). Correlation coefficients between yield, its component and days to maturity for H.S families of sunflower.

Oil content was negative and insignificant correlated with days to 50% flowering, days to maturity, head diameter and 100-achene weight, but was positive, poor and insignificant with achene yield (Table 13).

Achene yield/plot was positively and highly significant correlated with achene yield/plant, 100-achene weight and head diameter.

Table 13. Correlation coefficients among studied traits for H.S families

Traits	Days to 50% flowering	Days to maturity	Head diameter (cm)	100-achene weight (g)	Achene yield/plant (g)	Achene yield/plot (g)	Oil Content (%)
Days to 50% flowering							
Days to maturity	0.250**						
Head diameter, cm	-0.031	0.090					
100-achene weight, g	0.038	0.189	0.406**				
Achene yield/plant, g	0.009	0.296**	0.387**	0.727**			
Achene yield/plot, g	0.037	0.282**	0.372**	0.783**	0.954**		
Oil content, %	-0.052	-0.040	-0.111	-0.034	0.008	0.004	

The correlated coefficients among yield component was positive and highly significant between achene yield/plant with head diameter and 100-achene weight, and between 100-achene weight and head diameter.

Days to maturity was positive and highly significantly correlated with days to 50% flowering and with yield and its component except, 100-achene weight and head diameter were positive and not significant. **Chaudhary & Anand** (**1993**) showed positive relation between yield and oil content. **Jayarame** (**1994**), **Satisha** (**1995**), **Manjula** (**1997**) and **Vega** ***et al*.** (**2001**). **Habibullah** ***et al*.** (**2007**) found that significant positive correlation between days to maturity, plant height and oil content on one side and oil yield on the other side. **Muhammad** ***et al*.** (**2013**) found that the weight of hundred seed had positive but non-significant association with the head diameter and the seed yield. Seed yield had negative correlation with oil contents and suggested to break it either through conventional or novel breeding techniques to breed high yielding hybrids with maximum oil contents. **Attia** ***et al*.** (**2014**) reveled that correlation coefficients between each pair of yield components were positive and highly significant for achene yield/plant with head diameter and 100-achene weight, with head diameter.

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