

## Line × Tester analysis for Yield and its Attributes in Sesame (*Sesamum indicum* L.)

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**T**HIS RESEARCH work was conducted at Shandaweel Research Station, Sohag, Egypt, to study the combining ability and heterosis for yield and its attributes via Line × Tester analysis in sesame. Line × Tester mating design was applied in 2012 season using seven lines and four testers. In the two summers season 2013 and 2014, twenty-eight F<sub>1</sub> hybrids, their parents and one commercial variety (Shandaweel 3) as a check were evaluated. Mean squares due to genotypes and years via combined analysis for the two years were highly significant for all studied traits, except each of 1000-seed weight and oil percentage across years. Also, mean squares due to the interaction between genotypes × years were highly significant for all the studied traits, except days to 50% flowering, branches plant<sup>-1</sup> and 1000-seed weight. The analysis revealed that high significant differences were found among crosses and lines for all the studied traits over the two years. Likewise, it appeared high significant differences among the four testers for all traits, except for 1000-seed weight. High significant variances were detected for line × tester interaction over years for all studied traits. In this context, results showed that significant and highly significant differences were found for all the studied traits for the interactions; crosses × year (except for length of fruiting zone, branches plant<sup>-1</sup> and 1000-seed weight), tester × year (except for height of the first capsule, number of branches plant<sup>-1</sup> and 1000-seed weight) and parents × crosses × year (except for days to 50% flowering, number of branches plant<sup>-1</sup>, capsule length, 1000-seed weight and oil percentage). In general, the four crosses Giza32 × N.A.372, Shandaweel 2000 × Local 176, Shandaweel 2000 × H. 68 Family 21 and Shandaweel 2000 × N.A.652 were found to be the heaviest in most of the studied traits compared to their better parents. The parents N. A. 372, H.68 family 21 and Giza 32 were good combiners for improvement most studied traits. Also, desirable SCA effects were obtained for most studied traits. The crosses; Shandaweel 3 × local 176 and Shandaweel 2000 × N. A. 96 had the maximum SCA desirable effects for earliness. However, for seed yield plant<sup>-1</sup> the crosses; Shandaweel 3 × N. A. 96, Shandaweel 2000 × Local 176, Giza 32 × N. A. 372, Sohag 1 × Local 166 and Sohag 1 × H. 68 Family 21 had most desirable SCA effects for seed yield plant<sup>-1</sup>.

**Keywords:** Sesame (*Sesamum indicum* L.), Line × Tester analysis, Combining ability, Heterosis.

In Egypt there is a big gap between production and consumption of vegetable oils. Sesame is one of the most important oilseed crops, which grown in many parts in the world. The total cultivated area of sesame in Egypt was about 82000 feddan in 2013 season, which produced 41328 ton, with an average seed yield of 0.504 ton/feddan (FAO, 2013).

One of the problems of sesame production in Egypt is unstable the productivity of the cultivated varieties. So, the main objectives of many sesame-breeding programs are improvement of seed yield productivity and stability. Therefore, the best-adapted varieties are desirable as parents in crossing programs aiming to improve seed yield potentiality and other economic traits. Also, it is seemed importance of studying the genetic architecture of the important agronomic traits and estimating each of general (GCA) and specific combining ability (SCA). Combining ability analysis aimed to understand the nature and extent of types of gene action in the inheritance of yield and its components for obtaining better recombination. Sumathi & Kalaimani (2000), Manivannan & Ganesan (2001), Kumar *et al.* (2004), Attia *et al.* (2004), Vidhyavathi *et al.* (2005), Kumar *et al.* (2006), Gwade *et al.* (2007), El-Shkness & Khalifa (2007), El-Shkness *et al.* (2009), Abdelaziz *et al.* (2010) and Sedeck & Shafie (2013), found that the non-additive type of gene action was predominant for days to 50 % flowering, number of branches plant<sup>-1</sup>, number of capsules plant<sup>-1</sup> and seed yield plant<sup>-1</sup>. On the other hand, many researchers (Hassaballa *et al.*, 1996; Ramesh *et al.*, 2000; Devasena *et al.*, 2001; Manivannan & Ganesan, 2001; Nijagum *et al.*, 2002; Sarvanan & Nadarajan, 2003; Donghwi *et al.*, 2006; Banerjee & Kole, 2009; El-Shkness *et al.*, 2009; Abdelaziz *et al.*, 2010 and Sedeck & Shafie, 2013) indicated that the importance of additive and non-additive gene action for all the studied traits. But, the additive gene effects were greater than non-additive gene effects for days to 50 % flowering, plant height, number of branches plant<sup>-1</sup>, number of capsules plant<sup>-1</sup> and seed yield plant<sup>-1</sup>. Heterosis is considered as one of the most important tools that provide important information for improving seed yield and its components traits in sesame. The purposes of this research work were to study the combining ability and effects of heterosis for yield and its attributes via Line × Tester analysis.

### Material and Methods

The current research work was done at Research Farm of Shandaweel Agricultural Research Station, Sohag, Egypt, during 2012, 2013 and 2014 summer seasons to study heterosis and combining ability of seed yield and its components in sesame. The materials used in this work were seven lines viz., (L<sub>1</sub>) line N. A. 372, (L<sub>2</sub>) local 166, (L<sub>3</sub>) local 176, (L<sub>4</sub>) N. A. 96, (L<sub>5</sub>) H. 68 Family 21, (L<sub>6</sub>) H.88 Family 17 and (L<sub>7</sub>) N. A. 652 and four testers viz., (T<sub>1</sub>) Giza 32, (T<sub>2</sub>) line Sohag 1, (T<sub>3</sub>) Shandaweel 3 and (T<sub>4</sub>) line Shandaweel 2000, that vary in agronomic and morphological traits were selected for this study. The pedigree and origin of these genotypes is shown in Table 1.

**TABLE 1. The Pedigree and origin of the used genotypes.**

No.	Line and Tester	Origin	Pedigree
Line 1	N. A. 372	U.S.A	Unknown
Line 2	local 166	Egypt 1981	Unknown
Line 3	local 176	Egypt	Unknown
Line 4	N. A. 96	FAO	Unknown
Line 5	H. 68 Family 21	Egypt	A line selected from line B 21 x line 574
Line 6	H.88 Family 17	Egypt	A line selected from line B 21 x line 574
Line 7	N. A. 652	U.S.A	Unknown
Tester 1	Giza 32	Egypt 1986	Local variety A line selected from Giza white x type 9
Tester 2	Sohag 1	Egypt	A line selected from Bengalian x Giza 32
Tester 3	Shandaweel 3	Egypt 1987	A line selected from Giza 32 x N. A. 130
Tester 4	Shandaweel 2000	Egypt	A line selected from N.A.413 x AN.A.777

A Line × Tester fashion was done using the seven lines and the four testers in 2012 summer season. The resulting 28 top crosses and their 11 parents were evaluated during the two summer growing seasons 2013 and 2014 in randomized complete block design with three replications. Each entry was sown in single row; 4 meters long, 50 cm width and the hills within row were spaced 20 cm apart with one plant left per hill after thinning. The cultural practices were applied according to the recommendations. Surface irrigation system was used in the experimental site. Some soil properties of the experimental site are shown in Table 2.

**TABLE 2. Some soil properties of the experimental site (average the three growing seasons).**

Sand (%)	Silt (%)	(%) Clay	Soil texture	PH (1:1)	Organic matter	EC (ds m <sup>-1</sup> )
55.21	11.64	33.15	Sandy clay	7.50	1.89	0.37

At harvest time, ten guarded plants from each entry were taken to record the following data on the traits;

- 1- Height of first capsule in cm.
- 2- Plant height in cm.
- 3- Length of fruiting zone in cm.
- 4- Number of branches plant<sup>-1</sup>.
- 5- Number of capsules plant<sup>-1</sup>.
- 6- Capsule length in cm.
- 7- 1000-seed weight in grams.
- 8- Seed yield plant<sup>-1</sup> in grams.
- 9- Seed oil content as percentage. Oil was extracted by using petroleum ether (60-80°C) and Soxhelt apparatus according to AOAC (1980).

Furthermore number of days from planting to flowering 50 % of plants for each entry was recorded. Line × tester analysis was performed according to Steel & Torrie (1980). Combining ability effects were computed by the Line × tester method according to Singh & Chaudhary (1985). In this analysis, the parents mean squares are considered estimates of general combining ability (GCA),

while the mean squares of male  $\times$  female interactions provides an estimate of specific combining ability (SCA). Heterosis expressed as percentage was calculated as the deviation of  $F_1$  means from the better parent (BP), as described by Bhatt (1971) as follow:

$$H (\%) = \frac{F_1 - BP}{BP} \times 100$$

The significant of heterosis effect was tested by LSD test.

## Results and Discussion

### *Analysis of variance*

The combined analyses of variance for studied traits over two years are listed in Table 3. Analysis of variance revealed high significant mean squares due to genotypes and years for all studied traits except 1000-seed weight and oil percentage for years. The interaction of genotypes  $\times$  years recorded highly significant differences for all the studied traits, except for days to flowering, number of branches plant<sup>-1</sup> and 1000-seed weight which were insignificant. This indicates that different of environmental conditions during both years. Furthermore, results of line  $\times$  tester analysis showed high significant variances among crosses and lines for all of the studied traits over years (Table 3). The testers showed significant variances for all traits, except for 1000-seed weight. The results indicated that, mean sum of squares due to Line  $\times$  tester interaction were highly significant for all studied traits over two years. Significant and Highly significant variances were observed for crosses  $\times$  year and tester  $\times$  year interactions for most studied traits. Meanwhile, variances due to line  $\times$  year (L  $\times$  Y) and line  $\times$  tester  $\times$  year (L  $\times$  T  $\times$  Y) interactions were highly significant for days to 50% flowering, plant height, oil percentage and seed yield plant<sup>-1</sup> for (L  $\times$  Y) and for days to 50% flowering, height of the first capsule and seed oil content % only for (L  $\times$  T  $\times$  Y). These results indicated that the studied crosses had different ranking from year to another. In addition, it indicated that importance of evaluation the crosses at many environments, especially for seed yield. These results showed also great diversity for both lines and testers in seed yield, which contributed to the performance of their respective crosses. These results are in the line with those obtained by Manivannan & Ganesan (2001), Kar *et al.* (2002), Sanker & Kumar (2003), Kumar *et al.* (2004), Vidhyavathi *et al.* (2005), Taher & El-Samanody (2006), El-Shakhess *et al.* (2007), Banerjee & Kole (2009), El-Shakhess *et al.* (2009), Abdelaziz *et al.* (2010) and Sedeck & Shafei (2013).

### *Mean performance*

The combined data over the two years for the studied traits are presented in Table 4. Number of days to 50% flowering ranged from 44.83 (N.A.372) to 56.33 (Local166) with an average of 75.50 days among the parental lines. While, among the crosses, it varied from 42.00 (Giza32  $\times$  Local 166) to 52.17 (Shandaweel 3  $\times$  N.A.96) with an average of 47.08 days. In general out of the crosses, six were earlier than their earlier parents and sixteen were significantly

TABLE 3. Line × tester analysis of thirty nine entries for the studied traits evaluated over the two years 2013 and 2014.

Source of variation	Degrees of freedom	Mean squares												
		Days to 50 % flowering	Height of first capsule (cm)	Plant height (cm)	Length of fruiting zone (cm)	Number of branches plant <sup>-1</sup>	Number of capsules plant <sup>-1</sup>	Capsule length (cm)	1000-seed weight (g)	Seed oil content %	Seed yield plant <sup>-1</sup> (g)			
Years (Y)	1	517.34***	36512.5***	29063.8***	1901.24***	50.59***	230991.***	0.03	4.65	227.84***	29063.8***			
Reps / Yea.	4	1.667	100.62	182.1*	36.8	0.72	807.45*	0.21	1.36***	4.97	182.1*			
Genotype(G)	38	222.8***	2450.86***	1132.6***	3809.77***	12.01***	4272.15***	1.6***	1.83***	222.76***	1132.58***			
Parents (P)	10	260.47***	2604.35***	352.5***	1286.51***	7.84***	3969.44***	0.83***	0.43***	260.47***	352.46***			
Crosses (C)	27	214.30***	2482.13***	936.03***	4777.69***	12.64***	1698.77***	1.63***	1.9***	214.3***	936.03***			
Lines (L)	6	99.54***	5765.31***	2027.02***	1241.57***	11.04***	2650.14***	0.61***	4.15***	99.54***	2027.02***			
Tester (T)	3	925.29***	3587.62***	312.57***	27282.87***	47.41***	1763.29***	10.59***	0.27	925.29***	312.57***			
P vs. C	1	74.24**	71.62	14240.7***	2908.38***	36.71***	76780.49***	8.67***	14.12***	74.24**	14240.7***			
L x T	18	134.06***	1203.49***	676.27***	2205.54***	7.38***	1370.9***	0.48***	1.42***	134.06***	676.27***			
G x Y	38	37.11**	500.76***	289.8***	758.34***	0.41	692.66***	0.48***	0.05	37.11**	289.83***			
P x Y	10	34.07**	1020.71***	224.37***	2049.99***	0.35	1140.18***	0.39***	0.02	34.07**	224.37***			
P vs. C x Y	1	1.96	782.55*	5546.32***	2341.99***	1.52	1782.69*	0.2	0.32	1.96	5546.32***			
C x Y	27	39.54**	297.75***	119.39***	221.3	0.39	486.54*	0.53***	0.05	39.54**	119.39***			
L x Y	6	46.76**	251.59	246.03***	73.31	0.23	244.51	0.08	0.06	46.76**	246.03***			
T x Y	3	86.28**	179.71	150.8*	1201.29***	0.91	2484.01***	3.71***	0.01	86.28**	150.8*			
L x T x Y	18	29.35***	332.81***	71.95	107.29	0.36	234.3	0.15	0.05	29.35***	71.95			
Error	152	2.10	125.70	55.42	142.27	0.70	305.96	0.16	0.13	2.10	55.42			

\*, \*\*\*, Significant at 0.05 and 0.01 probability levels, respectively.

TABLE 4. Mean performance of all genotypes for the studied traits in 2013 and 2014 growing seasons and their combined data.

Genotypes	Days to 50% flowering		Height of first capsule (cm)		Plant height (m)		Length of fruiting zone (cm)					
	2013	2014	2013	2014	2013	2014	2013	2014				
Giza 32 x N.A. 372	52.63	48.67	50.65	61.33	66.50	236.0	211.7	223.85	193.3	201.7	197.50	
Giza 32 x Local 166	43.00	41.00	42.00	73.67	64.34	235.3	211.7	223.50	191.3	203.3	197.30	
Giza 32 x Local 176	48.00	41.67	44.84	82.33	68.67	250.7	233.3	242.00	215.0	220.0	217.50	
Giza 32 x N.A. 96	47.00	42.33	44.67	95.67	85.84	256.0	225.0	240.50	186.7	196.7	191.70	
Giza 32 x H.68 Family 21	51.33	48.00	49.67	110.33	94.67	280.0	245.0	262.50	199.3	210.0	204.65	
Giza 32 x H.88 Family 17	48.00	44.67	46.34	83.00	69.34	269.3	231.7	250.50	221.7	220.0	220.85	
Giza 32 x N.A. 652	48.00	44.67	46.34	76.33	66.17	252.0	236.7	244.35	222.0	220.0	221.00	
Sohag 1 x N.A. 372	46.67	43.33	45.00	73.00	69.00	258.7	230.0	244.35	180.0	161.7	170.85	
Sohag 1 x Local 166	46.00	44.00	45.00	73.00	66.50	233.3	218.3	225.80	172.0	150.0	161.00	
Sohag 1 x Local 176	45.00	43.33	44.17	98.33	79.00	88.67	250.0	226.7	238.35	151.7	148.35	
Sohag 1 x N.A. 96	46.67	44.67	45.67	90.00	86.67	88.34	234.3	231.7	233.00	141.7	139.20	
Sohag 1 x H.68 Family 21	53.33	50.33	51.83	101.33	77.33	89.33	275.3	253.3	264.30	171.3	166.7	169.00
Sohag 1 x H.88 Family 17	47.00	44.33	45.67	84.33	68.00	76.17	236.7	211.7	224.20	160.0	140.0	150.00
Sohag 1 x N.A. 652	46.33	43.67	45.00	74.33	36.00	55.17	235.3	215.0	225.15	182.3	155.0	168.65
Shandaweel 3 x N.A. 372	51.33	48.00	49.67	71.67	68.67	253.7	250.0	251.85	189.7	171.7	180.70	
Shandaweel 3 x Local 166	45.67	43.00	44.34	80.00	62.33	71.17	225.7	210.0	217.85	145.7	135.0	140.35
Shandaweel 3 x Local 176	43.67	41.33	42.50	109.33	86.67	231.3	201.7	216.50	131.3	126.7	129.00	
Shandaweel 3 x N.A. 96	53.33	51.00	52.17	84.00	69.00	270.7	255.0	262.85	200.0	186.7	193.35	
Shandaweel 3 x H.68 Family 21	53.00	50.33	51.67	124.67	88.33	106.50	309.7	268.3	289.00	185.0	171.7	178.35
Shandaweel 3 x H.88 Family 17	46.00	44.33	45.17	133.33	81.67	107.50	283.3	230.0	256.65	150.0	141.7	145.85
Shandaweel 3 x N.A. 652	51.00	43.67	47.34	74.33	69.00	71.67	230.7	226.7	228.70	157.7	140.0	148.85
Shandaweel 2000 x N.A. 372	51.33	49.33	50.33	84.00	68.33	76.17	248.0	235.0	241.50	165.0	145.0	155.00
Shandaweel 2000 x Local 166	44.67	43.00	43.84	109.67	94.67	94.67	265.3	241.7	253.50	155.0	146.7	150.85
Shandaweel 2000 x Local 176	52.33	51.00	51.67	114.67	95.00	104.84	265.7	250.0	257.85	149.3	136.7	143.00
Shandaweel 2000 x N.A. 96	45.67	44.33	45.00	120.00	63.33	91.67	300.0	236.7	268.35	180.0	161.7	170.85
Shandaweel 2000 x H.68 Family 21	52.67	50.33	51.50	166.67	145.00	155.84	264.3	248.3	256.30	135.0	94.3	114.65
Shandaweel 2000 x H.88 Family 17	49.67	47.33	48.50	74.00	76.00	75.00	234.7	238.3	236.50	160.7	148.3	154.50
Shandaweel 2000 x N.A. 652	49.00	46.33	47.67	74.00	50.00	62.00	262.7	238.3	250.50	182.3	171.7	177.00

TABLE 4. Cont.

Genotypes	Days to 50% flowering			Height of first capsule (cm)			Plant height (m)			Length of fruiting zone (cm)		
	2013	2014	Comb.	2013	2014	Comb.	2013	2014	Comb.	2013	2014	Comb.
Mean	48.51	45.64	47.08	93.13	70.44	81.79	255.31	232.56	243.94	174.11	164.45	169.28
N.A. 372	46.33	43.33	44.83	149.33	81.67	115.50	286.00	221.67	253.84	141.33	133.33	137.33
Local 166	54.67	51.00	52.84	90.00	48.33	69.17	230.00	258.67	244.34	145.00	195.00	170.00
Local 176	58.00	54.67	56.34	90.33	56.67	73.50	223.33	288.33	255.83	135.00	225.00	180.00
N.A. 96	53.33	50.33	51.83	84.00	41.67	62.84	271.67	253.33	262.50	180.00	196.67	188.34
H.68 Family 21	55.00	51.67	53.34	89.67	68.33	79.00	253.33	236.67	245.00	165.67	155.00	160.34
H.88 Family 17	53.00	50.33	51.67	71.00	63.67	67.34	230.00	236.67	233.34	166.33	151.67	159.00
N.A. 652	50.00	46.67	48.34	61.67	71.67	66.67	220.00	238.33	229.17	161.67	153.33	157.50
Giza 32	51.00	47.67	49.34	145.00	76.67	110.84	250.00	250.00	250.00	156.67	156.67	156.67
Shahag1	53.33	49.67	51.50	113.33	66.67	90.00	241.67	245.00	243.34	170.00	165.00	167.50
Shandaweel 3	48.67	45.00	46.84	63.33	66.67	65.00	226.67	233.33	230.00	161.67	148.33	155.00
Shandaweel 2000	51.33	48.67	50.00	125.00	101.67	113.34	228.33	230.00	229.17	168.33	120.00	144.17
Mean	52.24	49.00	50.62	98.42	67.61	83.02	241.91	244.73	243.32	159.24	163.64	161.44
Shandaweel 3 (check)	48.67	45.00	46.84	63.33	66.67	65.00	226.67	233.33	230.00	161.67	148.33	155.00
LSD at 0.05			2.97			16.37			25.27			17.55

TABLE 4. Cont.

Genotypes	Number of branches plant <sup>-1</sup>			Number of capsules plant <sup>-1</sup>			Capsule length (cm)			1000-seed weight (g)		
	2013	2014	Comb.	2013	2014	Comb.	2013	2014	Comb.	2013	2014	Comb.
	Giza 32 x N.A. 372	5.47	6.40	5.94	250.0	207.0	228.50	5.47	6.40	5.94	5.30	4.83
Giza 32 x Local 166	4.47	4.9	4.69	196.7	168.3	182.50	4.47	4.90	4.69	3.70	3.43	3.57
Giza 32 x Local 176	4.50	5.43	4.97	236.7	178.3	207.50	4.50	5.43	4.97	3.90	3.60	3.75
Giza 32 x N.A. 96	4.83	5.17	5.00	228.3	173.3	200.80	4.83	5.17	5.00	4.40	4.07	4.24
Giza 32 x H.68 Family 21	4.00	5.33	4.67	245.0	193.3	219.15	4.00	5.33	4.67	4.60	4.20	4.40
Giza 32 x H.88 Family 17	4.40	5.67	5.04	214.0	183.3	198.65	4.40	5.67	5.04	4.03	3.67	3.85
Giza 32 x N.A. 652	4.60	5.67	5.14	223.0	186.7	204.85	4.60	5.67	5.14	4.67	4.33	4.50
Sohag 1 x N.A. 372	2.20	2.00	2.10	216.7	150.0	183.35	4.77	4.10	4.44	4.30	4.00	4.15
Sohag 1 x Local 166	4.27	4.10	4.19	241.0	155.0	198.00	4.27	4.10	4.19	3.90	3.57	3.74
Sohag 1 x Local 176	3.20	2.30	2.75	228.0	143.3	185.65	4.20	4.30	4.25	3.33	3.27	3.30
Sohag 1 x N.A. 96	4.00	3.03	3.52	206.7	140.3	173.50	4.00	4.03	4.02	3.80	3.67	3.74
Sohag 1 x H.68 Family 21	4.50	4.33	4.42	261.7	180.0	220.85	4.50	4.33	4.42	5.17	4.73	4.95
Sohag 1 x H.88 Family 17	4.33	3.93	4.13	238.7	166.7	202.70	4.33	3.93	4.13	4.30	4.00	4.15
Sohag 1 x N.A. 652	3.47	2.17	2.82	256.3	181.7	219.00	4.47	4.17	4.32	4.50	4.13	4.32
Shandaweel 3 x N.A. 372	1.00	1.00	1.00	253.3	186.7	220.00	4.50	4.00	4.25	5.03	4.67	4.85
Shandaweel 3 x Local 166	4.40	3.30	3.85	226.0	141.7	183.85	4.40	4.30	4.35	3.17	3.10	3.14
Shandaweel 3 x Local 176	4.00	3.13	3.57	213.3	135.0	174.15	4.00	4.13	4.07	4.43	3.90	4.17
Shandaweel 3 x N.A. 96	4.50	3.67	4.09	231.7	170.0	200.85	4.50	3.67	4.09	3.20	3.10	3.15
Shandaweel 3 x H.68 Family 21	4.23	3.70	3.97	240.0	178.3	209.15	4.23	3.70	3.97	5.37	4.87	5.12
Shandaweel 3 x H.88 Family 17	2.83	2.57	2.70	213.3	150.0	181.65	3.83	3.57	3.70	5.17	4.57	4.87
Shandaweel 3 x N.A. 652	4.17	3.73	3.95	218.3	158.3	188.30	4.17	3.73	3.95	4.40	4.13	4.27
Shandaweel 2000 x N.A.372	3.83	3.77	3.80	276.7	203.3	240.00	3.83	3.77	3.80	4.60	4.27	4.44
Shandaweel 2000 x Local 166	3.83	3.77	3.80	233.3	148.3	190.80	3.83	3.77	3.80	3.80	3.73	3.77
Shandaweel 2000 x Local 176	4.17	3.83	4.00	246.7	188.3	217.50	4.17	3.83	4.00	5.03	4.57	4.80
Shandaweel 2000 x N.A. 96	3.73	3.57	3.65	220.0	158.3	189.15	3.73	3.57	3.65	3.87	3.63	3.75
Shandaweel 2000 x H.68 Family 21	3.60	2.00	2.80	250.0	138.3	194.15	4.60	4.00	4.30	3.93	3.80	3.87

TABLE 4. Cont.

Genotypes	Number of branches plant <sup>-1</sup>			Number of capsules plant <sup>-1</sup>			Capsule length (cm)			1000-seed weight (g)		
	2013	2014	Comb.	2013	2014	Comb.	2013	2014	Comb.	2013	2014	Comb.
	Shandaweel 2000 x H.88Family17	1.00	1.00	1.00	245.0	176.7	210.85	3.83	3.57	3.70	3.80	3.57
Shandaweel 2000 x N.A. 652	5.60	4.27	4.94	251.7	170.0	210.85	4.60	4.27	4.44	4.90	4.00	4.45
<b>Mean</b>	<b>3.90</b>	<b>3.71</b>	<b>3.81</b>	<b>234.36</b>	<b>168.23</b>	<b>201.30</b>	<b>4.32</b>	<b>4.34</b>	<b>4.33</b>	<b>4.31</b>	<b>3.98</b>	<b>4.15</b>
N.A. 372	3.57	3.50	3.54	155.67	113.33	134.50	3.57	3.50	3.54	3.63	3.47	3.55
Local 166	4.27	4.10	4.19	227.00	143.33	185.17	4.27	4.10	4.19	3.70	3.50	3.60
Local 176	4.17	3.73	3.95	143.67	116.00	129.84	4.17	3.73	3.95	3.60	3.53	3.57
N.A. 96	4.50	3.83	4.17	194.00	157.33	175.67	4.50	3.83	4.17	3.90	3.80	3.85
H 68 Family 21	4.40	4.13	4.27	212.00	145.00	178.50	4.40	4.13	4.27	4.00	3.73	3.87
H 88 Family 17	3.70	3.57	3.64	131.67	106.67	119.17	3.70	3.57	3.64	3.50	3.37	3.44
N.A. 652	3.60	3.57	3.59	168.33	130.00	149.17	3.60	3.53	3.57	3.20	3.17	3.19
Chiza 32	3.47	4.80	4.14	164.00	143.33	153.67	3.47	4.80	4.14	3.50	3.37	3.44
Sohag1	4.53	4.27	4.40	248.67	150.00	199.34	4.53	4.27	4.40	4.30	3.90	4.10
Shandaweel 3	4.00	3.73	3.87	224.33	138.33	181.33	4.00	3.73	3.87	3.80	3.40	3.60
Shandaweel 2000	3.37	3.07	3.22	198.33	130.00	164.17	3.37	3.07	3.22	3.33	3.27	3.30
<b>Mean</b>	<b>3.96</b>	<b>3.85</b>	<b>3.91</b>	<b>187.97</b>	<b>133.94</b>	<b>160.96</b>	<b>3.96</b>	<b>3.84</b>	<b>3.90</b>	<b>3.68</b>	<b>3.50</b>	<b>3.59</b>
Shandaweel 3 (check)	4.00	3.73	3.87	224.33	138.33	181.33	4.00	3.73	3.87	3.80	3.40	5.07
<b>LSD at 0.05</b>			1.30			30.04			0.65			0.53

TABLE 4. Cont.

Genotypes	Seed oil content %			Seed yield plant <sup>-1</sup> (g)		
	2013	2014	Comb.	2013	2014	Comb.
	Giza 32 x N.A. 372	52.07	48.93	50.50	88.94	70.67
Giza 32 x Local 166	28.53	45.13	36.83	31.47	29.57	30.52
Giza 32 x Local 176	34.00	41.53	37.77	61.83	55.63	58.73
Giza 32 x N.A. 96	49.07	45.70	47.39	61.16	51.60	56.38
Giza 32 x H.68 Family 21	47.63	44.17	45.90	73.98	65.77	69.88
Giza 32 x H.88 Family 17	50.37	47.10	48.74	52.27	42.73	47.50
Giza 32 x N.A. 652	54.07	50.97	52.52	62.90	55.17	59.04
Sohag 1 x N.A. 372	55.37	52.30	53.84	56.40	46.93	51.67
Sohag 1 x Local 166	53.77	50.20	51.99	52.92	46.14	49.53
Sohag 1 x Local 176	46.83	43.63	45.23	40.18	37.55	38.87
Sohag 1 x N.A. 96	47.27	43.93	45.60	51.28	46.25	48.77
Sohag 1 x H.68 Family 21	51.77	48.57	50.17	89.00	80.67	84.84
Sohag 1 x H.88 Family 17	41.77	38.70	40.24	59.40	50.53	54.97
Sohag 1 x N.A. 652	50.43	47.20	48.82	50.49	57.93	54.21
Shandaweel 3 x N.A. 372	52.20	49.07	50.64	74.68	70.70	72.69
Shandaweel 3 x Local 166	52.13	48.93	50.53	40.48	38.27	39.38
Shandaweel 3 x Local 176	51.77	48.23	50.00	36.98	33.53	35.26
Shandaweel 3 x N.A. 96	47.83	44.70	46.27	86.48	80.33	83.41
Shandaweel 3 x H.68 Family 21	36.83	33.77	35.30	78.14	71.44	74.79
Shandaweel 3 x H.88 Family 17	50.40	47.30	48.85	43.34	40.63	41.99
Shandaweel 3 x N.A. 652	51.83	48.60	50.22	61.97	58.67	60.32
Shandaweel 2000 x N.A. 372	37.67	45.73	41.70	64.50	60.10	62.30
Shandaweel 2000 x Local 166	29.50	36.37	32.94	39.90	35.28	37.59
Shandaweel 2000 x Local 176	37.63	45.83	41.73	68.81	63.88	66.35

TABLE 4 Cont.

Genotypes	Seed oil content %			Seed yield plant <sup>-1</sup> (g)		
	2013	2014	Comb.	2013	2014	Comb.
Shandaweel 2000 x N.A. 96	44.00	50.67	47.34	49.40	44.20	46.8
Shandaweel 2000 x H.68 Family21	37.37	41.30	39.34	70.49	67.33	68.91
Shandaweel 2000 x H.88Family17	37.10	39.10	38.10	64.55	60.33	62.44
Shandaweel 2000 x N.A. 652	36.83	34.50	35.67	67.82	65.20	66.51
<b>Mean</b>	45.10	45.09	45.10	<b>59.99</b>	<b>54.54</b>	<b>57.27</b>
N.A. 372	38.30	35.57	36.94	32.00	17.80	24.90
Local 166	48.57	45.47	47.02	34.00	17.50	25.75
Local 176	43.23	40.23	41.73	32.20	14.53	23.37
N.A. 96	59.73	54.33	57.03	38.27	45.67	41.97
H.68 Family 21	46.93	43.93	45.43	37.53	20.87	29.20
H.88 Family 17	27.77	34.80	31.29	28.40	15.00	21.70
N.A. 652	50.70	47.70	49.20	24.17	20.40	22.29
Giza 32	45.97	42.87	44.42	26.37	42.33	34.35
Sohag1	32.77	36.07	34.42	36.83	46.67	41.75
Shandaweel 3	42.43	40.10	41.27	33.93	20.07	27.00
Shandaweel 2000	44.97	41.90	43.44	25.73	15.07	20.40
<b>Mean</b>	<b>43.76</b>	<b>42.09</b>	<b>42.93</b>	<b>31.77</b>	<b>25.08</b>	<b>28.43</b>
Shandaweel 3 (check)	42.43	40.10	41.27	33.93	20.07	27.00
<b>LSD at 0.05</b>			5.95			10.70

earlier compare to the check variety. Concerning height of the first capsule, the measurements of parental lines ranged from 62.83cm (N.A.96) to 115.50 (N.A.372) with an average of 83.01 cm. Moreover, among the crosses the values varied from 62.00 (Shandaweel 2000 × N.A.652) to 155.83 (Shandaweel 2000 × H.68 Family 21) with an average of 81.79 cm. The results also indicate that the values of plant height ranged among the lines from 227.50 (Shandaweel 3) to 264.17 (Giza 32 and Sohag1) with an average of 264.71 cm, while varied from 216.50 (Shandaweel 3 × Local 176) to 289.00 (Shandaweel 3 × H.68 Family 21) with an average of 243.94 cm among the crosses. In addition, most of the crosses show superiority in plant height compared to their parents and the check variety. Regarding length of fruiting zone, the combined performance of parental lines ranged from 144.17 (Shandaweel 2000) to 188.33 (N.A.96) with an average of 161.44 cm. While, it varied from 114.67 (Shandaweel 2000 × H.88 Family 17) to 221.00 (Giza 32 × N.A.652) with an average of 170.75 cm among the crosses. Performance of the parental lines and the crosses for number of branches plant<sup>-1</sup> indicate that, the measurements ranged from 1.00 (N.A. 652) to 4.25 (H.88 Family 17) with an average of 3.11, and from 1.00 (Shandaweel 3 × N.A.372 and Shandaweel 2000 × H8 Family 1.87) to 5.94 (Giza32 × N.A.652) with an average of 3.80, respectively. The cross Shandaweel 2000 × N.A. 372 gave the highest number of capsules plant<sup>-1</sup> (240.0) compared to the parents and the check. Results of capsule length indicate that the cross Giza 32 × N.A.372 was the longest one (5.93) compared their parental lines and check (4.27 and 3.87), respectively. The combined data for 1000-seed weight revealed that, the values of parental lines ranged from 3.18 (N.A.652) to 4.10 (Sohag1) with an average of 3.60. Likewise, the crosses had values ranged from 3.13 (Shandaweel 3 × Local 166) to 5.12 (Shandaweel 3 × H 68 Family 21) with an average of 4.14.

Results of seed oil content percentage over two years indicated that, the values of parental lines ranged from 31.28 (H.88 Family 17) to 53.70 (N.A.96) with an average of 42.92. Moreover, the performance of crosses varied from 32.67 (Shandaweel 2000 × Local 166) to 51.18 (Sohag1 × N.A. 372) with an average of 45.58. Results also revealed that, the parental line N. A. 96 had the highest seed oil content (53.70 %) compared to all genotypes. However, the maximum value among crosses was obtained by the cross Sohag × N. A. 372 (51.18 %). Results of seed yield plant<sup>-1</sup> over two years indicate that, the performance of parental lines ranged from 20.40 (Shandaweel 2000) to 41.97 (N.A.96) with an average of 28.43 g, while from 30.52 (Giza 32 × Local 166) to 84.84 (Sohag 1 × H. 68 Family 21) with an average of 57.33 g among the crosses. There were these crosses that had significant heaviest seed yield compared to their parents over two years, reflecting the presence of hybrid vigor. Generally, the best crosses (Giza 32 × N.A. 372), (Sohag1 × H. 68 Family 21) and (Shandaweel 3 × N.A. 96) were the best, whereas, they gave the maximum yield over the two years. Furthermore, these crosses are also significantly outyielded the check variety. So, it could be put these best crosses into evaluation trails in wide scale and could be considered as promising crosses. Also, out of the testers, Sohag 1 was the best and can be used in crossing with more female lines. These results are agreement with those obtained by Shabana *Egypt. J. Agron.* **37**, No.2 (2015)

*et al.* (1996), EL-Ahmar *et al.* (1996), Manivannan & Ganesan (2001), Kar *et al.* (2002), Sanker & Kumar (2003), Kumar *et al.* (2004), Vidhyavathi *et al.* (2005), Taher & El-Samanody (2006), El-Shakhess (2007), Banerjee & Kole (2009), El-Shakhess *et al.* (2009), Abdelaziz *et al.* (2010) and Sedeck & Shafie (2013).

#### *Heterosis effects*

Estimates of heterosis over better parent are listed in Table 5. Heterosis of days to 50 % flowering over the two years ranged from 0.40 to -14.90%. Fifteen crosses exhibited a highly significant negative deviation from better parent. The crosses Giza 32 × Local 166, Sohag1 × Local 166 and Sohag1 × Local 176 showed maximum desirable heterotic effects for earliness. Range of heterosis for height of the first capsule was 3.00 to -40.00 %. Crosses Shandaweel 3 × H. 68 Family 21 and Shandaweel 3 × H. 88 Family 17 showed positive and highly significant heterosis for plant height and recorded the maximum values over the better parent. It is worthy to mention that in sesame, crossing two inbred line could be accompanied by positive heterosis in resulting crosses. Thus, in this case crosses would be always taller than their parent inbred lines.

Nine crosses showed a significant negative heterosis relative to the better parent for fruiting zone. The crosses Giza 32 × N.A. 372, Giza 32 × Local 176, Giza 32 × H.88 Family17, Giza 32 × Local 176 and Giza 32 × N.A.652 recorded the maximum heterosis values compared their better parent. These results indicate that Giza 32 contained the favorable genes for this trait. Thus, it could be involved in any breeding program for improvement this trait. Thirteen crosses revealed highly significant positive heterosis compared to the better parent for number of branches plant<sup>-1</sup>. The crosses Giza 32 × N.A.652, Giza 32 × H.68 Family 21 and Shandaweel 3 × N.A. 652 gave the highest desirable heterotic effect.

Results revealed that sixteen crosses showed positive and significant heterosis relative to better parent for number of capsules plant<sup>-1</sup>. Crosses Giza 32 × N.A. 372, Giza 32 × Local 176, Giza 32 × N.A.652, Shandaweel 2000 × N.A.372 and Shandaweel 2000 x Local 176 had the maximum desirable heterotic effects. Positive and significant heterosis over the better parent were shown in seven crosses for capsule length. Crosses Giza 32 × N.A. 372 and Shandaweel 2000 × N.A. 652 showed the highest heterotic effect for capsule length. The range of heterosis for 1000-seed weight was -19.51 to 0.00%. Positive and significant heterosis was obtained by eighteen crosses for this trait. The three crosses Giza 32 × N.A.372, Shandaweel 2000 x Local 176 and Shandaweel 2000 × N.A.652 gave the maximum desirable heterotic effect for this trait. With respect to seed oil content percentage, values of heterosis ranged from 0.92 to -30.59. Six crosses showed positive and significant heterosis. Crosses Sohag 1 × N.A.372 and Shandaweel 3 × N.A. 372 had the highest heterotic effect for seed oil content percentage. The range of heterosis over better parent for seed yield plant<sup>-1</sup> varied from 18.52 to 237.80%. All crosses except

TABLE 5. Heterosis % over better parent of twenty-eight crosses for the studied traits in 2013 and 2014 growing seasons and their combined data.

Crosses	Days to 50% flowering		Height of the first capsule (cm)		Plant height (cm)		Length of fruiting zone (cm)		
	2013	2014	2013	2014	2013	2014	2013	2014	
Giza 32 x N.A. 372	3.27**	2.10	13.0**	-20.0**	-40.0**	-17.5**	-15.3**	23.4**	28.7**
Giza32 x Local 166	-21.34**	-19.61**	-14.9**	13.8**	-7.0	-5.9**	-18.1**	22.1**	4.3*
Giza32 x Local 176	-17.24**	-23.78**	-9.1**	-8.9*	-6.6	0.3	-19.1**	37.2**	-2.2
Giza 32 x N.A. 96	-11.87**	-15.89**	-9.5**	13.9*	36.6**	-5.8**	-11.2**	3.7**	0.0
Giza32 x H.68 Family21	-6.67**	-7.10**	0.7	23.1**	15.6**	19.8*	10.5**	20.3**	34.0**
Giza32 x H.88 Family17	-9.43**	-11.26**	-6.1**	16.9**	-12.6**	3.0	7.7**	33.3**	40.4**
Giza32 x N.A.652	-5.88**	-6.29**	-4.1**	23.8**	-0.8	0.8	-5.3**	37.3**	40.4**
Sohagi x N.A. 372	-12.50**	-12.75**	0.4	-35.6**	-2.5	-23.3**	-9.6**	-6.1**	-7.5**
Sohagi x Local 166	-15.85**	-13.73**	-12.6**	-18.9**	-3.9	-3.5	-15.5**	-14.5**	-2.0
Sohagi x Local 176	-22.41**	-20.73**	-14.2**	8.9*	39.4**	20.6**	3.5	-21.4**	-9.8**
Sohagi x N.A.96	-12.50**	-11.26**	-11.3**	7.14	108.0**	40.6**	-13.7**	-8.6**	-11.8**
Sohagi x H.68 Family21	-3.03**	-2.58*	0.7	13.01*	16.0**	13.1	8.7**	3.4	0.1
Sohagi x H.88 Family17	-11.87**	-11.92**	-11.3**	18.8**	6.8	13.1	-2.1	-13.6**	-15.1**
Sohagi x N.A. 652	-13.12**	-12.08**	-6.9**	20.5**	-46.0**	-17.3	-2.6	-12.2**	-14.8**
Shandawee13 x N.A.372	5.48**	6.67**	10.8**	13.2*	-1.5	5.6	-11.3**	11.9**	0.8
Shandawee13 x Local166	-16.48**	-15.69**	-5.3**	26.3**	29.0**	9.5	-1.9	-18.7**	-10.8**
Shandawee13 x Local176	-24.71**	-24.39**	-9.3**	72.6**	12.9**	33.3**	2.1	-30.0**	-15.4**
Shandawee13 x N.A.96	0.00	1.32	11.4**	32.6**	29.6**	9.8	-0.4	-0.7	0.1
Shandawee13 x H.68 Family 21	-3.64**	-2.58*	10.3**	96.8**	32.5**	63.9**	22.2**	13.4**	18.0**
Shandawee13 x H. 88 Family17	-13.21**	-11.92**	-3.6**	110.5**	28.3**	65.4**	23.2**	-2.8	10.0**
Shandawee13 x N.A.652	2.00**	-6.43**	1.1	20.5**	3.5	10.3	1.8	-4.9*	-0.2
Shandawee2000 x N.A.372	0.00	1.37	12.3**	-32.8**	-16.3**	-32.8**	-13.3**	2.2	-4.9
Shandawee2000 x Local 166	-18.29**	-15.69**	-12.3**	21.9**	64.8**	36.9**	15.4**	-6.5**	3.8
Shandawee2000 x Local 176	-9.77**	-6.71**	3.3**	26.9**	67.7**	42.6**	16.4**	-13.3**	0.8
Shandawee2000 x N.A. 96	-14.37**	-9.21**	-10.0**	42.8**	52.0**	45.9**	10.4**	-6.6**	2.2
Shandawee2000 x H.68 Family 21	-4.24**	-2.58*	3.0**	85.9**	112.2**	97.3**	4.3*	9.4*	4.6
Shandawee2000 x H.88 Family17	-6.29**	-5.96**	3.0**	4.2	19.4**	11.4	2.0	0.7	1.0
Shandawee2000 x N.A. 652	-4.55**	-4.79**	-1.4	20.0**	-30.2**	-7.0	15.0**	0.0	7.0

\*, \*\* Significant at 0.05 and 0.01 probability levels, respectively.

TABLE 5. Cont.

Crosses	Number of branches plant <sup>1</sup>			Number of capsules plant <sup>1</sup>			Capsule length (cm)			1000 seed weight (g)		
	2013	2014	Comb.	2013	2014	Comb.	2013	2014	Comb.	2013	2014	Comb.
	Giza 32 x N.A. 372	53.3 <sup>***</sup>	33.3 <sup>***</sup>	49.75 <sup>***</sup>	52.4 <sup>***</sup>	40.9 <sup>***</sup>	47.1 <sup>***</sup>	53.3 <sup>***</sup>	33.3 <sup>***</sup>	43.55 <sup>***</sup>	45.87 <sup>***</sup>	39.42 <sup>***</sup>
Giza 32 x Local 166	4.7 <sup>*</sup>	2.1	47.47 <sup>***</sup>	-13.4 <sup>***</sup>	17.4 <sup>***</sup>	-1.4	4.7 <sup>*</sup>	2.1	11.95 <sup>*</sup>	0.00	-1.90	-0.93
Giza 32 x Local 176	8.0 <sup>***</sup>	13.2 <sup>***</sup>	43.64 <sup>***</sup>	44.3 <sup>***</sup>	24.4 <sup>***</sup>	35.0 <sup>***</sup>	8.0 <sup>***</sup>	13.2 <sup>***</sup>	20.16 <sup>***</sup>	8.33 <sup>***</sup>	1.89	5.14 <sup>***</sup>
Giza 32 x N.A. 96	7.4 <sup>***</sup>	7.6 <sup>***</sup>	58.97 <sup>***</sup>	17.7 <sup>***</sup>	10.2 <sup>***</sup>	14.3 <sup>***</sup>	7.4 <sup>***</sup>	7.6 <sup>***</sup>	20.00 <sup>***</sup>	12.82 <sup>***</sup>	7.02 <sup>*</sup>	9.86 <sup>***</sup>
Giza 32 x H.68 Family 21	-9.1 <sup>***</sup>	11.1 <sup>***</sup>	78.76 <sup>***</sup>	15.6 <sup>***</sup>	33.3 <sup>***</sup>	22.8 <sup>***</sup>	-9.1 <sup>***</sup>	11.1 <sup>***</sup>	9.37	15.00 <sup>***</sup>	12.50 <sup>***</sup>	13.79 <sup>***</sup>
Giza32 x H.88 Family 17	18.9 <sup>***</sup>	18.1 <sup>***</sup>	35.29 <sup>***</sup>	30.5 <sup>***</sup>	27.9 <sup>***</sup>	29.3 <sup>***</sup>	18.9 <sup>***</sup>	18.1 <sup>***</sup>	21.77 <sup>***</sup>	15.24 <sup>***</sup>	8.91 <sup>*</sup>	12.14 <sup>***</sup>
Giza 32 x N.A. 652	27.8 <sup>***</sup>	18.1 <sup>***</sup>	112.4 <sup>***</sup>	32.5 <sup>***</sup>	30.2 <sup>***</sup>	33.3 <sup>***</sup>	27.8 <sup>***</sup>	18.0 <sup>***</sup>	24.19 <sup>***</sup>	33.33 <sup>***</sup>	28.71 <sup>***</sup>	31.07 <sup>***</sup>
Sohag1 x N.A. 372	5.2 <sup>*</sup>	-3.9	-51.72 <sup>***</sup>	-12.9 <sup>***</sup>	0.0	-8.0 <sup>*</sup>	5.2 <sup>*</sup>	-3.9	0.76	0.00	2.56	1.22
Sohag1 x Local 166	-5.9 <sup>***</sup>	-3.9	0.38	-3.1	3.3	-0.7	-5.9 <sup>***</sup>	-3.9	-4.92	-9.30 <sup>***</sup>	-8.55 <sup>***</sup>	-8.94 <sup>***</sup>
Sohag1 x Local 176	-7.4 <sup>***</sup>	0.8	-42.15 <sup>***</sup>	-8.3 <sup>***</sup>	-4.4	-6.9	-7.4 <sup>***</sup>	0.8	-3.41	-22.48 <sup>***</sup>	-16.24 <sup>***</sup>	-19.51 <sup>***</sup>
Sohag1 x N.A. 96	-11.8 <sup>***</sup>	-5.5	-16.48 <sup>***</sup>	-16.9 <sup>***</sup>	-10.8 <sup>***</sup>	-12.9 <sup>***</sup>	-11.8 <sup>***</sup>	-5.5	-8.71	-11.63 <sup>***</sup>	-5.98	-8.94 <sup>***</sup>
Sohag1 x H.68 Family 21	-0.7	1.6	-8.05	5.2 <sup>*</sup>	20.0 <sup>***</sup>	10.8 <sup>***</sup>	-0.7	1.6	0.38	20.16 <sup>***</sup>	21.37 <sup>***</sup>	20.73 <sup>***</sup>
Sohag1 x H.88 Family 17	-4.4 <sup>*</sup>	-7.8 <sup>***</sup>	-15.71 <sup>***</sup>	-4.0 <sup>*</sup>	11.1 <sup>***</sup>	1.7	-4.4 <sup>*</sup>	-7.8 <sup>***</sup>	-6.06	0.00	2.56	1.22
Sohag1 x N.A. 652	-1.5	-2.3	-34.1 <sup>***</sup>	3.1	21.1 <sup>***</sup>	9.9 <sup>*</sup>	-1.5	-2.4	-1.89	4.65 <sup>***</sup>	5.98	5.28 <sup>***</sup>
Shandaweel 3 x N.A. 372	12.5 <sup>***</sup>	7.1 <sup>*</sup>	-69.54 <sup>***</sup>	12.9 <sup>***</sup>	34.9 <sup>***</sup>	21.3 <sup>***</sup>	12.3 <sup>***</sup>	7.1 <sup>*</sup>	9.91	32.46 <sup>***</sup>	34.62 <sup>***</sup>	31.67 <sup>***</sup>
Shandaweel 3 x Local 166	3.1	4.9	-8.76	-0.4	-1.2	-0.7	3.1	4.9	3.98	-16.67 <sup>***</sup>	-11.43 <sup>***</sup>	-14.93 <sup>***</sup>
Shandaweel 3 x Local 176	-4.0	10.7 <sup>***</sup>	2.73	-4.9 <sup>*</sup>	-2.4	-3.9	-4.0	10.7 <sup>***</sup>	2.95	16.67 <sup>***</sup>	10.38 <sup>***</sup>	13.12 <sup>***</sup>
Shandaweel 3 x N.A. 96	0.0	-4.4	39.49 <sup>***</sup>	3.3	8.1 <sup>*</sup>	10.8 <sup>*</sup>	0.0	-4.4	-2.00	-17.95 <sup>***</sup>	-18.42 <sup>***</sup>	-18.18 <sup>***</sup>
Shandaweel 3 x H.68 Family 21	-3.8	-10.5 <sup>***</sup>	58.28 <sup>***</sup>	7.0 <sup>***</sup>	23.0 <sup>***</sup>	15.4 <sup>***</sup>	-3.8	-10.5 <sup>***</sup>	-7.03	34.17 <sup>***</sup>	30.36 <sup>***</sup>	32.33 <sup>***</sup>
Shandaweel 3 x H.88 Family 17	-4.2	-4.5	-41.18 <sup>***</sup>	-4.9 <sup>*</sup>	8.4 <sup>*</sup>	0.2	-4.2	-4.5	-4.31	35.96 <sup>***</sup>	34.31 <sup>***</sup>	32.13 <sup>***</sup>
Shandaweel 3 x N.A. 652	4.2	0.0	410.0 <sup>***</sup>	-2.7	14.5 <sup>***</sup>	3.9	4.2	0.0	2.16	15.79 <sup>***</sup>	21.57 <sup>***</sup>	15.84 <sup>***</sup>
Shandaweel 2000 x N.A. 372	7.5 <sup>***</sup>	7.6 <sup>**</sup>	12.55 <sup>*</sup>	39.5 <sup>***</sup>	56.4 <sup>***</sup>	46.2 <sup>***</sup>	7.5 <sup>***</sup>	7.6 <sup>**</sup>	7.55	26.61 <sup>***</sup>	23.08 <sup>***</sup>	24.88 <sup>***</sup>
Shandaweel 2000 x Local 166	-10.2 <sup>***</sup>	-8.1 <sup>***</sup>	-12.12 <sup>**</sup>	2.8	3.5	3.1	-10.1 <sup>***</sup>	-8.1 <sup>***</sup>	-9.16	2.70	6.67	4.63 <sup>*</sup>
Shandaweel 2000 x Local 176	0.0	2.7	27.71 <sup>***</sup>	24.4 <sup>***</sup>	44.9 <sup>***</sup>	32.5 <sup>***</sup>	0.0	2.7	1.27	39.80 <sup>***</sup>	29.25 <sup>***</sup>	34.58 <sup>***</sup>
Shandaweel 2000 x N.A. 96	-17.0 <sup>***</sup>	-7.0 <sup>*</sup>	-15.58 <sup>***</sup>	10.9 <sup>***</sup>	0.6	7.7	-17.0 <sup>***</sup>	-6.9 <sup>*</sup>	-12.40 <sup>*</sup>	-0.85	-4.39	-2.60
Shandaweel 2000 x H.68 Family 21	4.6 <sup>**</sup>	-3.2	-36.80 <sup>***</sup>	17.9 <sup>***</sup>	-4.6	8.8 <sup>*</sup>	4.6 <sup>**</sup>	-3.2	0.78	-1.67	1.79	0.00
Shandaweel 2000 x H.88 Family 17	3.6	0.0	-76.47 <sup>***</sup>	23.5 <sup>***</sup>	35.9 <sup>***</sup>	28.4 <sup>***</sup>	3.6	0.0	1.83	8.57 <sup>***</sup>	5.94	7.28 <sup>***</sup>
Shandaweel 2000 x N.A. 652	27.8 <sup>***</sup>	20.8 <sup>***</sup>	48.48 <sup>***</sup>	26.9 <sup>***</sup>	30.8 <sup>***</sup>	28.4 <sup>***</sup>	27.8 <sup>***</sup>	20.8 <sup>***</sup>	24.30 <sup>***</sup>	47.00 <sup>***</sup>	22.45 <sup>***</sup>	34.85 <sup>***</sup>

\*, \*\* Significant at 0.05 and 0.01 probability levels, respectively.

TABLE 5. Cont.

Crosses	Seed oil content %			Seed yield plant <sup>-1</sup> (g)		
	2013	2014	Comb.	2013	2014	Comb.
	Giza32 x N.A.372	14.15 <sup>***</sup>	13.27 <sup>***</sup>	8.54 <sup>*</sup>	177.94 <sup>***</sup>	24.41 <sup>***</sup>
Giza 32 x Local 166	-0.73	-41.25 <sup>***</sup>	-21.66 <sup>***</sup>	-7.44	-58.50 <sup>***</sup>	18.52
Giza 32 x Local 176	-3.11 <sup>***</sup>	-26.03 <sup>***</sup>	-16.97 <sup>***</sup>	87.55 <sup>***</sup>	-18.19 <sup>***</sup>	147.28 <sup>***</sup>
Giza 32 x N.A. 96	-15.89 <sup>***</sup>	-17.86 <sup>***</sup>	-11.76 <sup>***</sup>	59.82 <sup>***</sup>	-15.47 <sup>***</sup>	64.13 <sup>***</sup>
Giza 32 x H.68 Family 21	0.53	1.49	0.92	97.11 <sup>***</sup>	17.56 <sup>***</sup>	139.30 <sup>***</sup>
Giza 32 x H.88 Family 17	9.88 <sup>***</sup>	9.57 <sup>***</sup>	6.74	84.04 <sup>***</sup>	-22.68 <sup>***</sup>	118.89 <sup>***</sup>
Giza 32 x N.A. 652	6.85 <sup>***</sup>	6.64 <sup>***</sup>	4.04	138.56 <sup>***</sup>	-9.84 <sup>*</sup>	164.93 <sup>***</sup>
Sohag1 x N.A. 372	45.01 <sup>***</sup>	44.56 <sup>***</sup>	38.58 <sup>***</sup>	53.13 <sup>***</sup>	-33.71 <sup>***</sup>	107.50 <sup>***</sup>
Sohag1 x Local 166	10.41 <sup>***</sup>	10.71 <sup>***</sup>	6.27	43.67 <sup>***</sup>	-35.71 <sup>***</sup>	92.30 <sup>***</sup>
Sohag1 x Local 176	8.45 <sup>***</sup>	8.33 <sup>***</sup>	8.39	9.08	-55.71 <sup>***</sup>	63.60 <sup>***</sup>
Sohag1 x N.A. 96	-19.14 <sup>***</sup>	-20.87 <sup>***</sup>	-15.08 <sup>***</sup>	34.02 <sup>***</sup>	-43.36 <sup>***</sup>	16.80 <sup>***</sup>
Sohag1 x H.68 Family 21	10.55 <sup>***</sup>	10.30 <sup>***</sup>	6.86	137.12 <sup>***</sup>	2.14	190.50 <sup>***</sup>
Sohag1 x H.88 Family 17	7.30 <sup>***</sup>	27.47 <sup>***</sup>	16.90 <sup>***</sup>	61.26 <sup>***</sup>	-36.71 <sup>***</sup>	153.30 <sup>***</sup>
Sohag1 x N.A. 652	-1.05 <sup>***</sup>	-0.53	-4.40	37.02 <sup>***</sup>	-42.29 <sup>***</sup>	143.30 <sup>***</sup>
Shandaweel 3 x N.A. 372	22.36 <sup>***</sup>	23.02 <sup>***</sup>	21.23 <sup>***</sup>	120.09 <sup>***</sup>	110.80 <sup>***</sup>	191.90 <sup>***</sup>
Shandaweel 3 x Local 166	7.62 <sup>***</sup>	7.34 <sup>***</sup>	7.48	19.05 <sup>***</sup>	-8.97	52.90 <sup>***</sup>
Shandaweel 3 x Local 176	19.88 <sup>***</sup>	19.74 <sup>***</sup>	19.71 <sup>***</sup>	8.98	-12.62 <sup>*</sup>	48.40 <sup>***</sup>
Shandaweel 3 x N.A. 96	-17.73 <sup>***</sup>	-19.92 <sup>***</sup>	-13.84 <sup>***</sup>	126.0 <sup>***</sup>	-2.92	208.90 <sup>***</sup>
Shandaweel 3 x H.68 Family 21	-23.14 <sup>***</sup>	-21.52 <sup>***</sup>	-22.30 <sup>***</sup>	108.18 <sup>***</sup>	76.36 <sup>***</sup>	176.90 <sup>***</sup>
Shandaweel 3 x H.88 Family 17	17.96 <sup>***</sup>	18.77 <sup>***</sup>	16.96 <sup>***</sup>	27.72 <sup>***</sup>	2.82	93.50 <sup>***</sup>
Shandaweel 3 x N.A. 652	1.89 <sup>***</sup>	2.24 <sup>***</sup>	2.76	82.63 <sup>***</sup>	60.13 <sup>***</sup>	170.70 <sup>***</sup>
Shandaweel 2000 x N.A. 372	9.15 <sup>***</sup>	-16.23 <sup>***</sup>	-15.72 <sup>***</sup>	101.56 <sup>***</sup>	91.39 <sup>***</sup>	205.40 <sup>***</sup>
Shandaweel 2000 x Local 166	-20.01 <sup>***</sup>	-39.26 <sup>***</sup>	-30.59 <sup>***</sup>	17.34 <sup>*</sup>	4.38	84.30 <sup>***</sup>
Shandaweel 2000 x Local 176	9.39 <sup>***</sup>	-16.31 <sup>***</sup>	-16.31 <sup>***</sup>	108.73 <sup>***</sup>	178.76 <sup>***</sup>	225.20 <sup>***</sup>
Shandaweel 2000 x N.A. 96	-6.75 <sup>***</sup>	-26.34 <sup>***</sup>	-22.22 <sup>***</sup>	29.09 <sup>***</sup>	-43.21 <sup>***</sup>	129.40 <sup>***</sup>
Shandaweel 2000 x H.68 Family 21	-5.99 <sup>***</sup>	-20.38 <sup>***</sup>	-17.30 <sup>***</sup>	87.81 <sup>***</sup>	-20.13 <sup>***</sup>	237.80 <sup>***</sup>
Shandaweel 2000 x H.88 Family 17	-6.68 <sup>***</sup>	-17.49 <sup>***</sup>	-19.10 <sup>***</sup>	127.29 <sup>***</sup>	107.96 <sup>***</sup>	206.10 <sup>***</sup>
Shandaweel 2000 x N.A. 652	-27.67 <sup>***</sup>	-27.35 <sup>***</sup>	-27.01 <sup>***</sup>	163.56 <sup>***</sup>	35.62 <sup>***</sup>	226.00 <sup>***</sup>

\* , \*\* Significant at 0.05 and 0.01 probability levels, respectively.

one cross only showed highly significant positive heterosis. The four crosses Giza 32 × N.A. 372, Shandaweel 2000 × Local 176, Shandaweel 2000 × H.68 Family 21 and Shandaweel 2000 × N.A.652 had the maximum desirable heterotic effect. In general, the four crosses Giza32 × N.A.372, Shandaweel 2000 × Local 176, Shandaweel 2000 × H. 68 Family 21 and Shandaweel 2000 × N.A.652 were found to be the heaviest in most of the studied traits compared to their better parents. These results are agreement with those obtained by Shabana *et al.* (1996), EL-Ahmar *et al.* (1996), Mishra & Sikarwar (2001), Krishna *et al.* (2002), El-Shakhess (2003), Uzun *et al.* (2004), El-Shakhess & Khalifa (2007), El-Shakhess *et al.* (2009), Abdelaziz *et al.* (2010) and Sedeck & Shafie (2013).

#### *Combining ability*

Concerning the variances of GCA and SCA, it is known according to Line × tester method that variance of females and males considered equivalent to GCA (additive) and variance of females × males considered equivalent to SCA (non additive). The analysis of variance pointed out that contributors of crosses (females, males and females × males) were highly significant or significant for most studied traits in both seasons. Data belonging to partitioning sum of squares of crosses to their attributers (females, males and females × males) for the studied traits showed that; for days to 50% flowering, accounted GCA as calculated from the parents were 31.11 and 4.01 % and 29.84 and 4.46, while SCA as accounted from female × male interaction reached 0.12 and 0.28 % in both seasons, respectively, while the SCA reached 3.08 and 3.12 in both seasons, respectively. Regarding height of the first capsule, GCA accounted for 32.27 and 24.82 % and 11.06 and 7.87%, while SCA reached 7.54 and 10.59 % in both seasons, respectively. Concerning plant height accounted GCA were 31.84 and 2.96 % and 40.99 and 6.85%, while SCA recorded 1.37 and 2.53 % in both seasons, respectively. For length of fruiting zone accounted GCA were 9.34 and 0.67 % and 23.14 and 4.09 %, while SCA estimated 0.90 and 0.54 in both seasons, respectively. With regard to number of branches per plant GCA accounted for 11.57 and 10.99 % and 12.37 and 11.84%, while SCA reached 0.11 and 0.18 % in both seasons, respectively. For number of capsules plant<sup>-1</sup> GCA accounted for 83.82 and 42.95 % and 20.69 and 2.04%, while SCA recorded 29.77 and 26.12 % in both seasons, respectively. With respect to capsule length GCA accounted for 24.29 and 22.48 % and 2.70 and 10.60%, while SCA reached 2.33 and 0.58 % in both seasons, respectively. Concerning 1000 seed weight accounted GCA were 3.92 and 5.04 % and 4.09 and 3.51%, while SCA estimated 0.19 and 0.29 % in both seasons, respectively. For seed oil content % GCA accounted for 36.18 and 6.46 % and 43.80 and 4.09 %, while SCA reached 1.85 and 4.71 % in both seasons, respectively. With regard to seed yield plant<sup>-1</sup> accounted GCA as also calculated from the parents were 2.23 and 1.38 % and 24.59 and 26.04 %, while SCA as also accounted from female × male interaction reached 0.12 and 0.28 % in both seasons, respectively. The previous results proved that both additive and non additive gene actions controlled most studied traits and the additive gene action played the major role in the inheritance of these traits.

TABLE 6. Mean squares for line × tester analysis for the studied traits in sesame during 2013 growing season.

Source of variation	Degrees of freedom	Mean squares									
		Flowering	Height of first capsule (cm)	Plant height (cm)	Length of fruiting zone (cm)	Number of branches plant <sup>-1</sup>	Number of capsules plant <sup>-1</sup>	Capsule length (cm)	1000-seed weight (g)	Seed oil content %	Seed yield plant <sup>-1</sup> (g)
Reps.	2	0.69	191.91	12.83	21.78	0.95	905.88	0.06	0.72***	1.64	201.79
Genotypes (G)	38	38.58***	1916.88**	1464.45**	1622.26**	7.81**	3203.09**	0.54**	1.17**	194.02**	1037.04**
Parents (P)	10	30.46***	1623.76**	1397.85**	1883.68**	8.16**	1021.26**	0.43**	1.19**	187.73**	736.51***
Crosses (C)	27	31.24	2833.61**	1365.27**	555.14**	4.99**	436.23**	0.57**	0.29**	225.39**	74.09
P vs. C	1	329.72**	663.83	4254.47**	5235.05**	26.59**	50980.99**	3.11**	9.35**	50.15**	18780.66**
Lines (L)	6	42.64**	2357.65**	2002.97**	792.08**	4.25**	3852.05**	0.47**	0.21**	305.61**	73.78
Tester (T)	3	10.97**	3627.78**	372.22	113.89	8.07**	3947.22**	0.87**	0.54**	109.11**	91.52
L x T	18	25.33**	3306.82**	518.25	457.25**	0.24	8208.35**	0.27	0.06	93.55**	23.64
Error	76	3.12	185.53	272.48	48.94	0.48	296.71	0.11	0.03	2.43	74.60

\*\*\* Significant at 0.01 probability level.

TABLE 7. Mean squares for line × tester analysis for the studied traits in sesame during 2014 growing season.

Source of variation	Degrees of freedom	Mean squares									
		Days to 50 % flowering	Height of first capsule (cm)	Plant height (cm)	Length of fruiting zone (cm)	Number of branches plant <sup>-1</sup>	Number of capsules plant <sup>-1</sup>	Capsule length (cm)	1000-seed weight (g)	Seed oil content %	Seed yield plant <sup>-1</sup> (g)
Reps.	2	2.64	9.33	23.93	51.83	0.49	709.03	0.36	2.11***	0.15	162.41*
Genotypes (G)	38	36.50***	1034.74**	899.47***	2945.85***	4.61***	1761.72***	1.55***	0.72***	84.44**	385.78***
Parents (P)	10	30.07***	1156.13***	760.17***	3115.31***	4.87***	1164.05***	1.73***	0.76***	73.64**	318.91***
Crosses (C)	27	30.80***	791.46***	1066.82***	2781.36***	3.21***	793.39*	0.65***	0.16	100.86***	502.75***
P vs. C	1	267.0***	190.34	29870.03***	15.32	11.65***	27582.19**	5.77***	5.43***	211.34***	1006.24***
Lines (L)	6	40.38***	575.60***	1402.38***	3243.65***	2.71***	1083.86***	0.21	0.14	143.74**	352.94***
Tester (T)	3	12.08	818.75***	468.75	1147.22***	5.19***	213.19	1.65***	0.24	27.09***	747.29***
L x T	18	29.46***	2004.68***	847.65	4910.07***	0.20	791.15	0.29	0.01	64.86**	667.93***
Error	76	5.42	65.87	335.34	235.60	0.93	314.68	0.21	0.23	0.42	36.24

\* , \*\* , \*\*\* Significant at 0.05 and 0.01 probability levels, respectively.

*General combining ability (GCA) effects*

The general combining ability (GCA) effects of both female and male lines in 2013, 2014 seasons and their combined are listed in Table 8. Based on general combining ability (GCA) effects, the female lines Local 166 and Local 176 and the male parent Sohag1 were good general combiners for earliness, whereas they had negative GCA effects over the two years. Among the parents, the female line H.68 family 21 and the male parent Shandaweel 2000 had significant positive GCA effect in 2013 and 2014 seasons and their combined for height of the first capsule. Thus it could be considered these parental lines as a source of favor gene for shortness of the first capsule. The parents H.68 family 21 in 2013 and 2014 seasons and their combined and Shandaweel 2000 in 2013 season expressed significant positive GCA effects for plant height. So, it could be seemed a good general combiners for increasing plant height. In contrary, the male parent Local 166 was found to be good general combiners in two seasons and their combined for shortness.

For length of fruiting zone, the male parent Giza 32 was found to be good general combiners in two years and their combined. In contrast, significant negative and GCA effects for this trait were obtained by Shandaweel 2000 and Shandaweel 1 in the two seasons and their combined.

For number of branches plant<sup>-1</sup>, the female parent N.A.652 in two seasons 2013 and 2014 seasons and their combined and the male parent Giza32 in 2013 season had positive and significant GCA effects.

Results of number of capsules plant<sup>-1</sup> showed that the female parent N.A. 372 had positive and significant GCA effect in 2013 and 2014 seasons and their combined, while, the female line Local166 had negative and significant GCA effects.

For capsule length, the GCA effect of parents revealed that the female line N.A. 372 in the first season only and the male parent Giza 32 in the two seasons and their combined had positive and significant values.

The results also indicated that the female lines N.A.372, H.68 family 21 in the two years and their combined, N.A. 652 in 2014 and the combined data and N.A. 96 in 2014 only gave positive and significant GCA effects for 1000-seed weight. Thus, it could be considered these parental lines as a source of genes for heavier 1000-seed weight.

Regarding seed oil content percentage, the GCA effects of parents showed that the female lines N.A. 372 and N.A. 96 in the two seasons and their combined and N.A. 652 in 2014 only had positive and highly significant values. In addition, the two parents Sohag1 and Shandaweel 1 in the two years and their combined and Giza 32 in 2014 only gave positive and highly significant values.

TABLE 8. Estimates of general combining ability effects for parents for the studied traits in 2013 and 2014 growing seasons and their combined data.

Genotypes	Days to 50% flowering			Height of first capsule (cm)			Plant height (cm)			Length of fruiting zone (cm)			
	2013	2014	Combined	2013	2014	Combined	2013	2014	Combined	2013	2014	Combined	
Females	Intro.372	1.99***	1.84***	-18.03***	-5.36*	-11.70*	-6.23	-3.56	-3.56	7.89***	5.56	6.73	
	Local 166	-3.68***	-2.89***	-9.05*	-6.19***	-7.62	-15.40***	-13.77*	-13.77*	-8.11***	-5.69	-6.90	
	Local 176	-1.26**	-1.31	-1.29***	8.04*	2.81	5.42	-5.89	-5.27	-5.27	-7.36	-9.81	
	Intro. 96	-0.35	-0.06	-0.02	4.29	-0.44	1.92	9.94*	7.23	7.23	2.98	4.48	
	H. 68 family 21	4.07***	4.11***	4.09***	32.62***	26.98***	29.80***	27.02***	24.11***	24.11***	-1.44	-3.77	-2.61
	H.88 family 17	-0.84	-0.48	-0.66*	0.54	-0.11	0.21	0.69	-1.98	-1.98	-1.02	-1.94	-1.48
Males	Intro.652	0.07	-1.06	-0.49	-18.38***	-17.69***	-18.04***	-10.14*	-6.77	-6.77	11.98***	7.23	9.60
	Giza 32	-0.23	-1.21*	-0.72***	-8.42***	-7.87***	-8.14*	-1.12	-2.91	-2.91	30.08***	45.80***	37.94***
	Sohag 1	-1.23***	-0.83	-1.03***	-8.23***	-3.01	-5.62	-9.07*	-7.48	-7.48	-8.54***	-13.71***	-11.13*
	Shandaweel 3	0.63	0.31	0.47*	3.63	-1.16	1.24	2.55	2.26	2.26	-8.49***	-11.11***	-9.80*
	Shandaweel 2000	0.82*	1.74***	1.28***	13.01***	12.04***	12.52***	7.64*	8.14	8.14	-13.06***	20.96***	-17.01***

\*, \*\*\*, Significant at 0.05 and 0.01 probability levels, respectively.

TABLE 8. Cont.

Genotypes	Number of branches plant <sup>-1</sup>			Number of capsules plant <sup>-1</sup>			Capsule length			1000-seed weight		
	2013	2014	combined	2013	2014	combined	2013	2014	combined	2013	2014	combined
Intro.372	0.32***	0.23	-0.91***	14.81***	17.44***	16.13***	0.32***	0.23	0.23	0.50***	0.46***	0.48***
Local 166	-0.08	-0.07	0.11	-10.11*	-14.73***	-12.42***	-0.08	-0.07	-0.07	-0.67***	-0.52***	-0.59***
Local 176	-0.11	0.09	0.13	-3.19	-6.81	-5.00	-0.11	-0.09	-0.09	-0.13***	-0.15	-0.14***
Intro. 96	-0.06	-0.23	0.16	-12.69***	-7.56	-10.13	-0.06	-0.23	-0.23	-0.49***	0.36*	-0.43***
H. 68 family 21	0.01	0.01	0.13	14.81***	4.44	9.62	0.01	0.01	0.01	0.46***	0.42***	0.44***
H.88 family 17	-0.22	-0.15	-0.76***	-6.61	1.11	-2.75	-0.22***	-0.15	-0.15	0.02	-0.03	-0.01
Intro.652	0.14	0.12	1.14***	2.98	6.11	4.54	0.14	0.12	0.12	0.31***	0.17	0.24***
Giza 32	0.29***	1.17***	1.59***	-6.69	15.56***	4.44	0.29***	1.17***	1.17***	0.06	0.04	0.05
Sohag 1	0.04	-0.20*	-0.68***	1.21	-8.49*	-3.64	0.04	-0.20*	-0.20*	-0.12***	-0.07	-0.10***
Shandaweel 3	-0.09	-0.46***	-0.49***	-6.36	-8.06*	-7.21	-0.09	-0.46***	-0.46***	0.09	0.07	0.08*
Shandaweel 2000	-0.34	-0.51***	-0.41***	11.83***	0.99	6.41	-0.24***	-0.51***	-0.51***	-0.03	-0.04	-0.04

\* , \*\*\* Significant at 0.05 and 0.01 probability levels, respectively.

TABLE 8.Cont.

Genotypes	Seed oil content %			Seed yield plant <sup>-1</sup>			
	2013	2014	Combined	2013	2014	Combined	
Females	N.A. 372	4.11***	3.93***	3.21 *	11.41***	8.39***	9.77***
	Local 166	-4.23***	0.08	-1.68	-18.80***	-10.57***	-14.69***
	Local 176	-2.66***	-0.27	-1.41	-8.04***	-2.89	-5.47
	N. A. 96	1.83***	1.17***	1.08	2.09	2.23	2.16
	H. 68 family 21	-1.82***	-3.13***	-2.33	17.91***	6.13***	12.02***
	H.88 family 17	-0.31	-2.03***	-0.57	-5.10*	-3.04	4.07
Males	N. A. 652	3.08***	0.24	1.70	0.81	-0.24	0.28
	Giza 32	-0.11	1.14***	1.07	1.80	6.14***	3.97
	Sohag 1	4.39***	1.29***	2.61***	-2.90	-1.29	-2.09
	Shandaweel 3	3.79***	0.72***	3.23***	0.31	-1.24	-0.47
	Shandaweel 2000	-8.06***	-3.15***	-6.91***	0.79	-3.61***	-1.41

\* , \*\*\* Significant at 0.05 and 0.01 probability levels, respectively.

The results of GCA effects of parental lines showed that the female lines N.A. 372 and H. 68 family 21 in the two seasons and their combined were the best general combiners for increasing seed yield plant<sup>-1</sup>. Among male parents Giza32 in 2014 season was good general combiners. From the results obtained here, it can be concluded that N.A. 372 and H. 68 family 21 among female parents and Giza 32 among male parents were good general combiners for improvement most studied traits. Similar results were obtained by Mishra & Sikarwar (2001), Krishna *et al.* (2002), El-Shakhess (2003), Uzun *et al.* (2004), El-Shakhess & Khalifa (2007), El-Shakhess *et al.* (2009), Abdelaziz *et al.* (2010), Sedeck & Shafie (2013) and Hassan & Sedeck (2015). They found that significant general combining ability effects in some parental lines for some studied traits.

#### *Specific combining ability (SCA) effects*

Estimates of specific combining ability (SCA) effects for crosses for the studied traits in 2013, 2014 seasons and their combined are listed in Table 9. Results of combined data over the two years for days to 50 % flowering showed that the best combinations were Shandaweel 3 x Local 176 (-3.77\*\*), Shandaweel 2000 x N.A.96 (-3.16\*\*) and Sohag 1 X N.A. 372 (-2.89\*\*) had significant negative SCA values. These results suggested that these crosses may be considered earlier than the other combinations. Among crosses, Shandaweel 2000 x H.88 Family 17 (-19.50\*) was found to the best combination over two seasons for height of first capsule. For plant height, the cross Shandaweel 3 x local 176 recorded significant negative SCA estimate (-24.40\*) over the seasons. Estimates of SCA for length of fruiting zone over seasons indicate that the best cross was Shandaweel 3 x N.A.96. Results also revealed that the crosses Shandaweel 2000 x N.A.372, Sohag 1 x H.88 family 17 and Shandaweel 2000 x local 176 were the better over seasons for number of capsules plant<sup>-1</sup>. However, highly significant and significant negative effects over two years were by Sohag 1 x local 166 (-30.40\*\*) and Shandaweel 2000 x H. 68 Family 21 (-21.08\*). Data over two seasons also indicated that, the cross Giza 32 x N.A 372 was the best for capsule length. Out of the 28 crosses, Shandaweel 2000 x Local 176, Shandaweel 3 x H.88 Family 17, Shandaweel 3 x H.68 Family 21, Sohag 1 x H.68 Family 21, Sohag 1 x Local 166, Giza 32 x N.A. 96 and Giza 32 x N.A.372 were the desirable combinations over two seasons for 1000- seed weight. On the other side, negative SCA effects over two seasons ranged from significant to high significant were obtained by four crosses for seed oil content percentage. Concerning seed yield plant<sup>-1</sup>, the crosses Shandaweel 3 x N.A.96, Shandaweel 2000 x Local 176, Giza 32 x N.A. 372, Sohag1 x Local 166, Sohag 1 x H.68 Family 21, Shandaweel 2000 x H.88 Family 17 and Giza 32 x Local 176 were the best combinations over two seasons. Generally, it can be clearly noticed that desirable SCA effects were obtained for most studied traits. On the other side, the parents involved in most the best crosses were found to have high x high, high x low, low x high and low x low GCA status. In this concern, desirable significant SCA effects were also obtained by Kadhusudan & Nadaf (2009) for some studied traits.

TABLE 9. Estimates of specific combining ability effects for crosses for all studied traits in 2012 and 2013 growing seasons and their combined data.

Crosses	Days to 50% flowering			Height of the first capsule			Plant height (cm)		
	2013	2014	Comb.	2013	2014	Comb.	2013	2014	Comb.
Giza 32 x N.A. 372	2.39**	2.55	2.47***	5.00	4.12	4.56	-11.96	-15.30	-13.63
Giza 32 x Local 166	-1.61	-0.54	-1.07	-2.00	-1.38	-1.69	-3.46	-4.05	-3.66
Giza 32 x Local 176	0.98	-1.45	-0.24	-10.42	-10.38*	-10.40	2.37	10.12	6.24
Giza 32 x N.A. 96	-0.94	-2.04	-1.49*	6.67	13.87***	10.27	-8.13	-7.38	-7.76
Giza32 x H.68 Family 21	-1.02	-0.54	-0.78	-7.00	-10.55**	-8.77	-1.21	-4.05	-2.63
Giza 32 x H.88 Family17	0.56	0.71	0.64	-2.25	-6.80	-4.52	14.52	8.45	11.45
Giza 32 x N.A.652	-0.36	1.30	0.47	10.00	11.12**	10.56	7.95	12.20	10.07
Sohag1 x N.A. 372	-2.61*	-3.17*	-2.89***	6.15	2.93	4.54	18.65	4.23	11.44
Sohag1 x Local166	2.39*	2.08	2.24***	-2.86	-1.24	-2.05	2.49	3.81	3.15
Sohag1 x Local 176	-1.02	-0.17	-0.60	5.39	8.76	7.08	9.66	4.64	7.15
Sohag1 x N.A.96	-0.27	-0.08	-0.18	0.81	19.68***	10.24	-21.9*	0.48	-10.69
Sohag1 x H.68 Family 21	1.98	1.42	1.70***	-16.2*	-17.1***	-16.63	2.07	5.48	3.77
Sohag1 x H.88 Family17	0.56	0.00	0.28	-1.11	0.68	-0.21	-10.26	-10.36	-10.31
Sohag1 x N.A. 652	-1.02	-0.08	-0.55	7.81	-13.7***	-2.96	-0.76	-8.27	-4.52
Shandaweel 3 x N.A. 372	0.20	0.36	0.28	-7.05	1.74	-2.50	2.04	16.37	9.20
Shandaweel 3 x Local 166	0.20	-0.06	0.07	-7.71	-0.76	-4.24	-16.80	-12.38	-14.59
Shandaweel 3 x Local 176	-4.21***	-3.31*	-3.77***	4.54	-8.10	-1.78	-20.6*	-28.2***	-24.4**
Shandaweel 3 x N.A. 96	4.54***	5.11***	4.82***	-17.1*	-14.9***	-15.95	2.87	15.95	9.41
Shandaweel 3 x H.68 Family 21	-0.21	0.27	0.03	-4.71	-7.92	-6.32	24.79*	12.62	18.70
Shandaweel 3 x H.88 Family17	-2.30*	-1.14	-1.72***	36.1***	12.5***	24.26*	24.79*	0.12	12.45
Shandaweel 3 x N.A.652	1.79	-1.23	0.28	-4.05	17.4***	6.68	-17.05	-4.46	-10.76
Shandaweel 2000 x N.A. 372	0.01	0.26	0.14	-4.10	-8.79	-6.44	-8.73	-5.30	-7.01
Shandaweel 2000 x Local 166	-0.99	-1.49	-1.64*	12.57	3.38	7.98	17.17	12.62	15.20
Shandaweel 2000 x Local 176	4.26***	4.93***	4.60***	0.49	9.71*	5.10	8.61	13.45	11.03
Shandaweel 2000 x N.A. 96	-3.32***	-2.99*	-3.16***	9.57	-18.7***	-4.57	27.1***	-9.05	9.03
Shandaweel 2000 x H.68 Family 21	-0.74	-1.16	-0.95	27.9***	35.6***	31.7***	-25.6***	-14.05	-19.85
Shandaweel 2000 x H.88 Family17	1.18	0.43	0.80	-32.7***	-6.37	-19.5*	-29.0***	1.79	-13.60
Shandaweel 2000 x N.A.652	-0.41	0.01	-0.20	-13.76	-14.8***	-14.27	9.86	0.54	5.20

\*, \*\*, \*\*\* Significant at 0.05 and 0.01 probability levels, respectively.

TABLE 9. Cont.

Crosses	Length of fruiting zone (cm)			Number of branches plant <sup>-1</sup>			Number of capsules plant <sup>-1</sup>		
	2013	2014	Comb.	2013	2014	Comb.	2013	2014	Comb.
Giza 32 x N.A. 372	18.75***	-14.13	-16.44	0.54***	0.66**	0.24	7.52	0.94	4.27
Giza 32 x Local 166	-4.75	-1.21	-2.98	-0.06	-0.54**	-0.35	-20.9*	-0.56	-10.73
Giza 32 x Local 176	23.08***	17.12	20.10	-0.01	-0.17	-0.44	12.19	1.52	6.86
Giza 32 x N.A. 96	-20.50***	-19.55*	-20.02	0.28	-0.12	-0.56**	13.36	-2.73	5.32
Giza 32 x H.68 Family 21	-3.42	3.54	0.06	-0.6***	-0.18	0.04	2.52	5.27	3.90
Giza 32 x H.88 Family 17	18.50***	11.70	15.10	0.01	0.31	0.94***	-7.06	-1.39	-4.23
Giza 32 x N.A. 652	5.83	2.54	4.19	-0.15	0.04	0.12	-7.69	-3.06	-5.35
Sohag 1 x N.A. 372	6.54	5.39	5.96	0.09	-0.27	-0.31	-33.7***	-27.01**	-30.4***
Sohag 1 x Local 166	14.54***	4.98	9.76	-0.01	0.03	0.95***	15.54	10.16	12.85
Sohag 1 x Local 176	-1.63	1.64	0.01	-0.05	0.07	-0.9***	-4.38	-9.49	-6.91
Sohag 1 x N.A. 96	-26.88***	-20.02*	-23.45**	-0.31	0.12	0.17	-16.21	-11.68	-13.95
Sohag 1 x H.68 Family 21	7.20	19.73*	13.46	0.13	0.19	0.56**	11.29	15.99	13.64
Sohag 1 x H.88 Family 17	-4.55	-8.77	-6.66	0.19	-0.05	1.12***	9.70	5.99	7.85
Sohag 1 x N.A. 652	4.79	-2.94	0.92	-0.03	-0.09	-1.6***	17.79	15.99	16.89
Shandaweel 3 x N.A. 372	16.16***	12.77	14.46	-0.05	-0.10	-1.6***	10.52	9.23	9.88
Shandaweel 3 x Local 166	-11.85***	-12.64	-12.24	0.25	0.50	-0.31	8.11	-3.61	2.24
Shandaweel 3 x Local 176	-22.01***	-19.31*	-20.66	-0.13	0.17	0.14	-11.48	-18.19	-14.83
Shandaweel 3 x N.A. 96	31.41***	27.36***	29.38**	0.32	0.02	0.88***	16.36	17.56	16.96
Shandaweel 3 x H.68 Family 21	20.82***	22.11*	21.46	-0.01	-0.18	0.67**	-2.81	13.89	5.54
Shandaweel 3 x H.88 Family 17	-14.60***	-9.73	-12.16	-0.18	-0.15	-0.24	-8.06	-11.11	-9.58
Shandaweel 3 x N.A. 652	-19.93***	-20.56*	-20.24	-0.20	-0.26	0.46	-12.64	-7.77	-10.21
Shandaweel 2000 x N.A. 372	-3.94	-4.04	-3.99	-0.6***	-0.29	1.66***	15.67	16.85	16.26
Shandaweel 2000 x Local 166	2.06	8.88	5.47	-0.17	0.01	-0.30	-2.75	-5.99	-4.37
Shandaweel 2000 x Local 176	0.56	0.55	0.55	0.19	-0.08	1.21***	3.67	26.10*	14.88
Shandaweel 2000 x N.A. 96	15.98***	12.21	14.10	-0.30	-0.03	-0.48	-13.50	-3.16	-8.33
Shandaweel 2000 x H.68 Family 21	-24.61***	-45.37***	-34.99***	0.50*	0.17	-1.3***	-11.00	-35.16***	-23.08*
Shandaweel 2000 x H.88 Family 17	0.64	6.80	3.72	-0.03	-0.11	-1.8***	5.42	6.51	5.96
Shandaweel 2000 x N.A. 652	9.31*	20.96*	15.14	0.38	0.32	1.00***	2.50	-5.16	-1.33

\*, \*\* Significant at 0.05 and 0.01 probability levels, respectively.

TABLE 9. Cont.

Crosses	Capsule length (cm)			1000-seed weight (g)		
	2013	2014	Comb.	2013	2014	Comb.
	Giza 32 x N.A. 372	0.54***	0.60**	0.60*	0.43***	0.35
Giza 32 x Local 166	-0.06	-0.54**	-0.30	-0.01	-0.07	-0.04
Giza 32 x Local 176	-0.01	-0.17	-0.09	-0.39***	-0.27	-0.31***
Giza 32 x N.A. 96	0.28	-0.12	0.08	0.52***	0.41	0.46***
Giza32 x H.68 Family 21	-0.62***	-0.18	-0.40	-0.23**	-0.24	-0.24***
Giza32 x H.88 Family 17	0.01	0.31	0.16	-0.36***	-0.32	-0.34***
Giza32 x N.A. 652	-0.15	0.04	-0.06	-0.01	0.14	0.06
Sohag1 x N.A. 372	0.09	-0.27	-0.09	-0.39***	-0.37	-0.38***
Sohag1 x Local 166	-0.01	0.03	0.01	0.38***	0.18	0.28***
Sohag1 x Local 176	-0.06	0.07	0.01	-0.72***	-0.50	-0.61***
Sohag1 x N.A. 96	-0.31	0.12	-0.09	0.11	0.12	0.11
Sohag1 x H.68 Family 21	0.13	0.19	0.16	0.52***	0.40	0.46***
Sohag1 x H.88 Family 17	0.19	-0.05	0.07	0.10	0.12	0.11
Sohag1 x N.A. 652	-0.03	-0.09	-0.06	0.01	0.05	0.03
Shandaweel 3 x N.A. 372	-0.05	-0.10	-0.08	0.14	0.16	0.15
Shandaweel 3 x Local 166	0.25	0.50	0.37	-0.56***	-0.43	-0.50***
Shandaweel 3 x Local 176	-0.13	0.17	0.02	0.17	-0.02	0.08
Shandaweel 3 x N.A. 96	0.32	0.02	0.17	-0.71***	-0.59**	-0.65***
Shandaweel 3 x H.68 Family 21	-0.01	-0.18	-0.09	0.51***	0.40	0.46***
Shandaweel 3 x H.88 Family 17	-0.18	-0.15	-0.17	0.75***	0.55	0.65***
Shandaweel 3 x N.A. 652	0.20	-0.26	-0.23	-0.31***	-0.09	-0.20**
Shandaweel 2000 x N.A. 372	-0.57***	-0.29	-0.43	-0.18	-0.14	-0.16
Shandaweel 2000 x Local 166	-0.17	0.01	-0.08	0.19**	0.32	0.25***
Shandaweel 2000 x Local 176	0.19	-0.08	0.05	0.89***	0.77***	0.83***
Shandaweel 2000 x N.A. 96	-0.30	-0.03	-0.16	0.09	0.06	0.07
Shandaweel 2000 x H.68 Family 21	0.50**	0.17	0.34	-0.80***	-0.56**	-0.68***
Shandaweel 2000 x H.88 Family 17	-0.03	-0.11	-0.07	-0.80***	-0.34	-0.42***
Shandaweel 2000 x N.A. 652	0.38	0.32	0.35	0.31***	-0.11	0.10

\*, \*\*, \*\*\* Significant at 0.05 and 0.01 probability levels, respectively.

TABLE 9. Cont.

Crosses	Seed oil content %			Seed yield plant <sup>1</sup> (g)		
	2013	2014	Comb.	2013	2014	Comb.
	Giza 32 x N.A. 372	-1.22***	2.85***	0.92	16.01***	6.54
Giza 32 x Local 166	-1.17***	-12.34***	-6.73**	-11.52*	-9.59***	-8.88*
Giza 32 x Local 176	-4.42***	-8.45***	-6.07*	8.08	-0.21	8.79*
Giza 32 x N.A. 96	-1.69***	2.14**	1.06	-2.73	-1.36	-2.69
Giza32 x H.68 Family 21	1.08***	4.34***	2.99	-5.72	5.91	-4.87
Giza32 x H.88 Family17	2.91***	5.47***	3.88	-4.42	-1.96	-4.37
Giza32 x N.A. 652	4.51***	5.89***	3.93	0.30	0.67	-1.13
Sohag1x N.A.372	2.01***	1.66	1.92	-11.83*	-7.77*	-12.38***
Sohag1 x Local 166	3.76***	8.40***	4.86	14.62***	10.26***	12.89***
Sohag1x Local 176	-2.46***	-0.11	-0.15	-8.88	-6.75	-8.36*
Sohag1 x N.A. 96	-3.6***	-4.16***	-2.23	-7.90	-6.10	-7.50*
Sohag1x H.68 Family 21	5.33***	3.98***	4.10	13.99***	11.23***	12.81***
Sohag1 x H.88 Family17	-5.64***	-7.53***	-5.98*	7.41	2.26	5.82
Sohag1 x N.A. 652	0.60	-2.24*	-1.77	-7.41	-3.14	-3.24
Shandaweel3 x N.A.372	-0.66	-0.91	0.03	3.25	3.55	5.48
Shandaweel 3 x Local 166	3.05***	7.37***	4.81	-1.02	-1.52	-0.88
Shandaweel 3 x Local 176	2.70***	5.42***	4.01	-15.27***	-9.94***	-15.54***
Shandaweel 3 x N.A. 96	-2.27***	-2.99***	-2.22	24.10***	11.75***	23.57***
Shandaweel 3 x H.68 Family21	-8.91***	-10.35***	-9.77***	-0.07	0.31	-0.81
Shandaweel 3 x H.88 Family17	3.53***	1.71	2.02	-11.85*	-6.69	-10.73***
Shandaweel 3 x N.A. 652	2.56***	-0.42	1.12	0.87	2.55	-0.69
Shandaweel 2000 x N.A. 372	-0.13	-3.60***	-2.14	-7.42	-2.32	-5.75
Shandaweel 2000 x Local 166	-5.64***	-3.43***	-2.95	-2.08	0.85	-3.10
Shandaweel 2000 x Local 176	4.17***	3.13***	2.21	16.07***	16.90***	15.11***
Shandaweel 2000 x N.A. 96	7.57***	5.02***	3.42	-13.47***	-4.28	-13.47***
Shandaweel 2000 x H.68 Family 21	2.50***	2.03**	2.68	-8.20	-17.45***	-7.13
Shandaweel 2000 x H.88Family17	0.80**	0.25	0.07	8.87	6.38	9.28*
Shandaweel 2000 x N.A. 652	-7.67***	-3.40***	-3.29	6.24	-0.08	5.06

\*, \*\*\*, Significant at 0.05 and 0.01 probability levels, respectively.

### Conclusion

Finally, it can be concluded that the parents N. A. 372, H.68 family 21 and Giza 32 were good combiners for improvement most studied traits. Also, desirable SCA effects were obtained for most studied traits. The crosses; Shandaweel 3 × N. A. 96, Shandaweel 2000 × Local 176, Giza 32 × N. A. 372, Sohag 1 × Local 166 and Sohag 1 × H. 68 Family 21 had most desirable SCA effects for seed yield plant<sup>-1</sup>.

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### تحليل السلالة × الكشاف لصفة المحصول ومكوناته في السمسم

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نفذ هذا البحث في محطة البحوث الزراعية بشندويل - سوهاج - مصر بهدف دراسة القدرة على الانتلاف وقوة الهجين في السمسم . في الموسم الأول خلال صيف 2012 م. تم التهجين بنظام السلالة × الكشاف بين سبعة تراكيب وراثية من السمسم (أمهات) وأربعة آباء اختبارية (كشافات). قيمت الإباء وهجنها الاختبارية في الجيل الأول مع الصنف شندويل 3 خلال موسمين زراعيين متتاليين (2013 و 2014 م).

أظهر التحليل المشترك للتباين عبر الموسمين معنوية عالية بين التراكيب الوراثية والسنوات لكل الصفات تحت الدراسة عدا صفتي وزن الألف بذرة ونسبة الزيت. كما كان تباين التفاعل بين التراكيب الوراثية والسنوات عالي المعنوية لكل الصفات تحت الدراسة ما عدا صفات عدد الأيام حتى 50% تزهير، عدد الافرع/النبات ووزن الألف بذرة. كما أظهر التحليل تباين عالي المعنوية بين الهجن والأمهات لكل الصفات تحت الدراسة عبر الموسمين وكذلك الكشافات لكل الصفات تحت الدراسة ما عدا وزن الألف بذرة. كما أشار التحليل إلى وجود تباينات عالية المعنوية للتفاعل بين الأمهات × الكشافات عبر الموسمين لكل الصفات تحت الدراسة. فضلا عن ذلك أظهر التحليل المجمع للبيانات معنوية التفاعل بين الهجن × السنوات (لكل الصفات ما عدا طول المنطقة الثمرية، عدد الافرع/النبات ووزن الألف بذرة) ، الكشافات × السنوات ( لكل الصفات ما عدا صفات ارتفاع اول كبسولة، عدد الافرع/النبات ووزن الألف بذرة ) و الإباء × الهجن × السنوات (لكل الصفات ما عدا صفات عدد الأيام حتى 50% تزهير، عدد الافرع/النبات ووزن الالف بذرة ونسبة الزيت). بصفة عامة أشارت نتائج قوة الهجين إلى تفوق الهجن الأربعة 372 × N.A. Giza 32 و Local × Shandaweel 2000 و 176 × H. 68 Family 21 و Shandaweel 2000 و Shandaweel 2000 × N.A.652 في معظم الصفات تحت الدراسة مقارنة بأفضل الأباء. كما أشارت النتائج إلى وجود قدرة انتلافية عالية للأمهات 372 N. A. و 68 H. family 21 والأب Giza 32 لتحسين معظم الصفات تحت الدراسة. كما أظهرت النتائج وجود تأثيرات مرغوبة للقدرة الخاصة على الانتلاف للهجن مع معظم الصفات تحت الدراسة. وسجل الهجينين: local × Shandaweel 3 و 176 و 96 N. A. × Shandaweel 2000 أعلى تأثير للقدرة الخاصة على الانتلاف للتبكير في التزهير بينما أعطت الهجن: N. × Shandaweel 3 و 96 A. و 176 Local × Shandaweel 2000 و 372 N. A. × Giza 32 و 166 Local × Sohag 1 و 68 Family 21 × Sohag 1 التأثير الأعلى لصفة محصول البذور للنبات.