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CORRELATION, PATH COEFFICIENT ANALYSIS AND GENETIC VARIABILITY FOR ASSESSMENT OF YIELD AND ITS COMPONENTS IN F_1 HYBRID POPULATION OF SESAME (*Sesamum indicum* L.)

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ABSTRACT

The current work was done during the two successive summer seasons 2016 and 2017 at Experimental farm of Agricultural Research Center, Ismailia, Egypt. Five genetically diverse sesame genotypes namely; A1B5(P1), H133A4(P2), line 363(P3), Shandaweel -3(P4), and Sohag(P5) were crossed in a half diallel breeding pattern to obtain ten F1 hybrids excluding reciprocals and were evaluated during summer season of 2017. The 15 genotypes viz, the 5 parents and 10 F_1s were raised in a randomized complete block (RCB) design with three replications. Highly significant differences were observed among genotypes for all studied traits. The performance of the parents P_3, P_4, P_5, and the crosses $P_3 \times P_4$, P_3 X P_5, $P_4 \times P_5$ and $P_2 \times P_3$ were the best genotypes for yield and its components. Mean squares for both general (GCA) and specific (SCA) combining ability were significantly higher for all the studied characters. The ratios of GCA/SCA were less than unit for plant height; capsules weight plant^{-1}, 1000-seed weight and seed yield plant^{-1}. While, in case of remaining characters the magnitude of SCA was higher than GCA. This indicates presence of adequate amount of variation in parents and crosses. The three parentsP$_3$, P_4 and P_5 could be considered as the best general combiners for seed yield. However, the crosses $P_2 \times P_5$, $P_3 \times P_4$, and $P_3 \times P_5$ had the most desirable SCA effects for seed yield plant^{-1} and the most studied traits and the same crosses also showed the highest heterosis percentage over the mid-parent values for seed yield. The association between seed yield and its contributing characters indicated that the seed yield had positive and significant association with the most studied traits. Path coefficient analysis revealed maximum positive direct effect of 1000-seed weight per plant (0.781), number of seeds per capsule on seed yield followed by seed oil content (0.442), capsules weight per plant (0.427) and plant height (0.414) showed high positive direct effects on seed yield. Selection for the traits with positive association and direct effects will be useful for the improvement in yield of sesame through breeding program. High heritability in broad sense was observed for all studied traits.

Keywords: Sesame, diallel crossing, correlation, path analysis, genetic variability

INTRODUCTION

Sesame (*Sesamum indicum* L.) is the most important oilseed crop in the world after soybean, rapeseed, sunflower and groundnut (Alpaslan et. al., 2001). It's known with various names such as sesamum, gingelly, til, simsim, etc (Prajapat et. al., 2014). It belongs to Pedaliaceae family having chromosome number as (2n=26) and is a self-pollinated crop with an average cross pollination may be to an extent of 4 to 5 percent. It is one of the world's oldest spice as well as oilseed crop and it is native to tropic and sub tropic regions as well as adapted to temperate climatic zones of the world . It is cultivated in Asia from a period of over 5000 years (Ashri, 2007; Bedigian, 2010a; Troncoso et al., 2011).

Egypt and Sudan are the most important sesame producers in Africa (FAO, 2016). In Egypt, sesame is cultivated in an area of 40,239 Feddan (16284.14 hectares), with a production of 20.3 thousand tons and with an average productivity of about 500 kg (FAOSTAT,2015). Sesame is grown mainly for its seeds that contain about 50% oil and 25% protein (Burden, 2005). Sesame oil is highly resistant to oxidative deterioration even though oleic acid (43%), linoleic acid (35%), are the predominant fatty acids (about 80%) of sesame oil (Sharma et al., 2014 and Tripathi et al., 2017). **Hence**, it is called as the "Queen of Oilseeds" because of its excellent qualities of the seed oil (Uzun et al., 2007).

The diallel technique or half diallel and lines × tester are in common use for evaluating genotypes in terms of their genetic parameters and combining ability. However, the diallel mating design had been used to quantify the nature of gene action which control traits and also to estimate GCA and SCA of parents and their crosses, respectively (Gao et al., 2013). The concept of GCA and SCA (Sprague, 1966) helps the plant breeder to evaluate the GCA and SCA effects of the parents and their crosses, and select superior combiners for heterosis breeding.

Information on the magnitude and nature of the genetic engineering, heritability of the major traits associated with yield and correlations among characters are essential to improve the efficiency of crop breeding programs. The genotypic and phenotypic correlation coefficients should be partitioned into direct and indirect effects through path coefficient analysis. Path coefficient analysis measures the direct influence of one variable upon the other. It allows separating the direct effects and their indirect effects through other attributes by apportioning the correlations for better interpretation of cause and effect relationship (Mahmoud et al.,2015).

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The principal aims of the present study, i) to estimate the general combining ability and specific combining ability of parental lines and their hybrids respectively, in a half diallel analysis ii) to study the nature and magnitude of heterosis, and iii) to study correlation, path analysis and genetic variability for assessment of yield and its components in sesame.

MATERIALS AND METHODS

The experiments were conducted in the Department of oil seed crops research. All the possible crosses were made to obtain F1 hybrids excluding reciprocals through a 5×5 diallel fashion. Evaluation study was conducted during summer season 2017 at experimental farm of agricultural research center, Ismailia, Egypt. The details of pedigree and source of the parental lines used are given in Table (1).

The 15 genotypes viz, the 5 parents and progeny from 10 F1 crosses were raised in a randomized complete block (RCB) design with three replications. Each plot consisted of 2 rows, 3 m long adopting a spacing of 0.5 × 0.15 m. Plots were over-planted and thinned at 21 days after sowing to a final stand of approximately 21 plants in each row. Cultural practices for sesame production were conducted as recommended.

Table 1: The source of the parental lines

Parents numbers	Name	Source
P_1	**A1B5**	**USA**
P_2	**H133A4**	**Egypt**
P_3	**Line 363**	**USA**
P_4	**Shandaweel -3**	**Egypt**
P_5	**Sohag**	**Egypt**

Data recorded:

Plant height, Fruit zone, number of branches/plant, number of capsules /plant, capsule weight/plant, 1000–seed weight, seed yield /kg, SPAD values and seed oil content. All data were collected on 10 random plants in each of the F1s and their parents.

Statistical analysis

Analysis of variance (ANOVA): The data collected for each quantitative trait were subjected to ANOVA for randomized complete block (RCB) design with 3 replications. Analysis of variance was done using Co-stat software version 6.311. Means were tested for significance at 5% level of

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least significance difference (LSD). Diallel analysis was conducted by the combining ability estimates determined according to Model I (fixed effect), Method II proposed by **Griffing (1956**). Computer program software dial 98 (version, 2) analysis was used for estimating GCA and SCA parameters **(Ukai, 2002).** The magnitude of heterosis was estimated for all studied traits, as the deviation of F1 mean from mid parent (M.P) and expressed as percentage.

Estimation of variance components: Genotypic (rg) and phenotypic (rp) correlation coefficients were calculated according to the formula suggested by Johnson et al. (1955) and Singh and Chaudhary (1999)**.** Heritability estimates were calculated according to **Lush (1949),** whereas path coefficients analysis was made according to **Dewey and Lu (1959).**

RESULTS AND DISCUSSION

Mean performance of parents and their F_1 crosses

Mean performance of the five parents and their F_1 crosses for all studied characters are listed in Table (2). The parents P_1, P_3, $P_5$and the hybrids $P_2×P_4$ (193.33), $P_3×P_5$ (189.67) $P_2×P_3$ (168.33) and P_1XP_3 (155.67) were the tallest, while the parent P_4 and the cross $P_1×P_4$ were the shortest. For fruit zone length, the parents P_3, P_5 and P_1 had the highest values, while P_2 had the shortest fruit zone. With regard to the crosses: the tallest fruit zone was achieved by $P_1×P_5$, $P_2×P_3$ and $P_3×P_5$ while the hybrid $P_2×P_5$ and $P_4×P_5$ had the shortest. With regard to number of branches / plant, the parent P_3 was observed with the highest number of branches, while parents P_2 and P_4 haven't produced branches. With respect to the hybrids; the maximum nunmber of branches/plant was obtained from the crosses $P_2×P_5$, $P_1×P_4$ and P_3 x P_5 while the hybrids $P_2×P_4$, $P_1×P_5$ and $P_1×P_3$ haven't produced any branches.

The number of capsules / plant were greatest in the parents P_4, P_5 and P_3, while the parent P_1 gave the least. The crosses $P_3×P_4$, $P_3×P_5$, $P_4×P_5$ and $P_2×P_3$ had a greater number of capsules / plant, while $P_1×P_5$ and $P_2×P_4$ had few number of capsules / plant. With regard to capsule's weight / plant, the heaviest parents were P_5, P_4 and P_3 while the lightest was parent P_1. With respect to the hybrids; the maximum capsule's weight/plant was obtained from the cross $P_1×P_4$, $P_1×P_3$, $P_2×P_3$ and $P_4 × P_5$ while the minimum was recorded by the hybrids $P_1×P_4$, $P_1×P_3$ and P2 × P5. With regard to 1000-seed weight, the heaviest was achieved by P_5, P_1 and P_4 while, the lowest was observed from parent P_2. The heaviest seed weight of sesame cross was obtained from the cross $P_2×P_3$, $P_3×P_4$ and $P_4×P_5$ while; the relatively lightest was from cross P1×P4. The highest seed yield/kg was achieved by parents P_5, P_4 and P_3, while P_1 had the lowest yield. Regarding the hybrids, the hybrids $P_3×P_4$, P xP_5, $P_4 × P_5$ and $P_2 × P_3$ recorded the high values than others. However, the lowest seed yield/kg was obtained from the cross $P_1 × P_3$. For SPAD values, the parents P_1, P_2, P_3, and the crosses $P_1 × P_5$, $P_1 × P_2$ and $P_1 × P_3$ recorded the high

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values for this trait. For oil content, the highest per cent values were achieved by parents P_3, P_4, P_5 and the hybrids P_3 X P_4, P_3 X $P_5$and P_2 X P_5.

Table 2: Mean performance of parents and F_1 hybrids

Geno-types	Plant height (cm)	Fruit zone (cm)	No. of branches/ plant	No. of capsules/ plant	Capsules weight/ plant (g)	1000-seed weight (g)	Seed yield/ kg	SPAD value	Seed oil %
P_1	148.33^{de}	75.33^{a}	2.93^{ef}	69.33^{e}	18.33 ^{i}	3.97 ^{bc}	300 ^{g}	48.57 ^{g}	51.68 ^{f}
P_2	145.33de	31.00f	0.00^{h}	72.53^{e}	19.20 ^{i}	3.00 ^{fg}	348 ^{ef}	49.20 ^{f}	44.49 ^{g}
P_3	155.67cd	76.67a	4.27^{b}	94.87 ^{bcd}	23.73 ^{gh}	3.33 ^{de}	404 ^{d}	50.50 ^{e}	61.35 ^{b}
P_4	113.57 f	61.43cd	0.00 ^{h}	127.37 ^{a}	26.50 ^{fg}	3.90 ^{c}	424 ^{fg}	46.40 ^{i}	52.79 ^{def}
P_5	180.67ab	76.00a	3.60 ^{cd}	96.67 ^{f}	29.93 ^{ef}	4.23 ^{ab}	516 ^{b}	46.34 ^{i}	63.54^{a}
$P_1 \times P_2$	137.73e	35.33ef	3.33 ^{cde}	84.73 ^{d}	30.60^{e}	3.93 ^{c}	356 ^{ef}	52.81 ^{b}	52.46 ^{def}
$P_1 \times P_3$	155.67cd	56.33cd	0.00^{h}	68.20 ^{e}	20.43 ^{hi}	3.43 ^{d}	324 ^{cd}	51.56 ^{c}	61.64 ^{b}
$P_1 \times P_4$	112.33f	36.33ef	4.47^{b}	88.93 ^{cd}	19.77 ^{hi}	2.73 ^{g}	352 ^{ef}	45.68 ^{j}	53.51 ^{de}
$P_1 \times P_5$	148.67de	42.80e	0.00^{h}	53.67 ^{f}	30.57^{e}	3.93 ^{c}	348 ^{ef}	55.06 ^{a}	52.69 ^{def}
$P_2 \times P_3$	168.33bc	74.00a	3.07^{def}	97.73^{bc}	41.40 ^{bc}	4.50 ^{a}	408 ^{d}	41.99 ^{k}	57.82 ^{c}
$P_2 \times P_4$	193.33a	53.67d	0.00 ^{h}	66.27^{ef}	35.40^{d}	3.57 ^{d}	360 ^{e}	51.00 ^{d}	52.07 ^{def}
$P_2 \times P_5$	115.00f	30.30f	5.60^{a}	88.53 ^{cd}	28.00^{ef}	3.10 ^{ef}	364 ^{e}	47.99 ^{h}	62.52 ^{ab}
$P_3 \times P_4$	153.67d	74.33a	2.27 ^{g}	103.80 ^{b}	48.07^{a}	4.47 ^{a}	576 ^{a}	49.03 ^{f}	63.70 ^{a}
$P_3 \times P_5$	189.67a	70.67ab	3.63 ^{c}	103.53 ^{b}	43.00^{b}	3.93 ^{c}	524 ^{b}	50.98 ^{c}	62.88 ^{ab}
$P_4 \times P_5$	115.67f	63.67bc	2.63^{fg}	100.40^{b}	38.17^{cd}	3.97 ^{bc}	456 c	42.98 ^{l}	53.67 ^{d}
Mean parents	**148.71**	**64.09**	**2.16**	**82.15**	**23.54**	**3.69**	**398.4**	**48.20**	**54.77**
Mean crosses	**149.01**	**53.74**	**2.50**	**85.58**	**33.54**	**3.76**	**406.8**	**48.91**	**57.30**
L.S.D (0.05)	**12.82**	**8.32**	**0.56**	**10.51**	**3.97**	**0.291**	**12.78**	**0.37**	**1.58**

Any cultivar or F_1 hybrid seed from a cross or an inbred or pure line to be accepted by the farmers for commercial cultivation, it should possess significant superiority in seed yield and it`s components over the best existing cultivar or F1hybrid from a superior cross or an inbred or pure line. In the present study, the performance of the parents P_5, P_4 and P_3 and the crosses $P_3 \times P_4$, P_3 x P_5, $P_4 \times P_5$ and $P_2 \times P_3$ were the best for yield and the most of the yield components studied. These results are in harmony with the results for seed yield / plant obtained by earlier researchers

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in sesame (Muhammad & Sedeck, 2015; Shobha Rani et al., 2015; Pawar & Monpara, 2016; Ghule et al.,2017; Karthickeyan et al., 2017 and Karande et al., 2018).

Combining ability analysis

Analysis of variance for combining ability revealed that the mean squares due to GCA and SCA were highly significant for all studied traits (Table. 3). This indicated that both additive and non-additive gene action played a role in determining various characters in sesame hybrids studied. Thus, the importance of these two components of genetic variance cannot be underestimated for the improvement of sesame.

Table 3: Mean square data of sesame F_1 hybrids

	Mean Square data			
	GCA	**SCA**	**GCA/SCA**	**Error**
D.F	**4**	**10**		**28**
Plant height	674.72*	741.54*	0.91	19.61
Fruit zone	393.35*	284.89*	1.38	8.58
No. of branches	1.09*	4.71*	0.23	0.04
No. of capsules/ plant	627.79*	398.59*	1.58	13.18
Capsules weight/ plant	35.36*	108.43*	0.33	1.88
1000-seed weight	0.116*	0.338*	0.34	0.010
Seed yield per kg	8.19*	14.57*	0.56	0.016
SPAD value	80.82*	15.62*	5.17	0.299
Seed oil %	1.04*	0.22*	4.73	0.011

This suggests that the parents selected were potential due to observations with adequate amount of variability existed among the hybrids for most of the traits studied. The GCA / SCA ratio was less than unity for plant height, capsules weight / plant, 1000-seed weight and seed yield/plant. While, in case of remaining characters the magnitude of SCA was higher than GCA. This indicates presence of adequate amount of variation in parents and crosses. Also, both kinds of gene effects were important in controlling the inheritance of all the characters studied. These results accepted with Mungala et al. (2017), Tripathy et al. (2017) and Pandey et al. (2018).

Combining ability effects

Estimates of the GCA effects of the parents and the SCA effects of the F_1s are given in Table 4. Positive GCA effects for all characters studied are desirable. The parent 1 had highly significant positive GCA effect for fruit but highly significant negative GCA effect was found for plant height, number of capsules / plant, SPAD value, seed oil content and seed yield per kilogram. The parent 2 had highly significant positive GCA effect for capsule weight / plant, but highly significant negative GCA effect was found for fruit zone / plant, 1000-seed weight, SPAD values and per cent seed oil (%). The parent 3 had significant positive GCA effect for all studied characters. The parent 4 had highly negative significant GCA effect for plant height, fruit zone, capsules weight / plant, seed yield/ kg and SPAD values. The parent 5 had highly significant positive GCA effect for plant height, fruit zone, 1000-seed weight, seed yield /kg, SPAD value and per cent seed oil (%), but highly significant negative GCA effect was recorded for plant height, number of capsules/ plant and capsules weight/ plant. These results are in agreement with Abd El-Kader et al. (2017), Mungala et al. (2017), Tripathy et al. (2017) and Pandey et al. (2018).

Table 4: General combining ability effects of parental genotypes in sesame

Characters	P1	P2	P3	P4	P5	gca(j)
Plant height	-6.06**	1.66	12.17**	-13.05**	5.27**	**1.49**
Fruit zone	5.46**	-8.5**	7.71**	-7.45**	2.78**	**0.97**
No. Of branches	-0.08	-0.46	0.24	-0.24	0.54	**0.07**
No. Of capsules/ plant	-3.06*	0.95	5.33**	10.94**	-14.16**	**1.23**
Capsules weight/ plant	-0.45	1.43**	2.77**	-3.15**	-0.60**	**0.463**
1000-seed weight	-0.06	-0.19**	0.09*	0.02	0.14**	**0.034**
Seed yield fed	-0.34**	0.02	0.35**	-1.51**	1.47**	**0.043**
SPAD value	-2.16**	-3.56**	4.3**	-1.46**	2.88**	**0.184**
Seed oil %	-0.53**	-0.29**	0.26**	0.20**	0.36**	**0.035**

The estimates of SCA effect and mean performance for the cross combination of various traits are given in Table 5.

Of the ten crosses for plant height, four crosses showed significant positive and four crosses showed significant negative SCA effects. The highest positive SCA effect was revealed from the cross **$P_2 \times P_4$** (55.81) followed by **$P_3 \times P_5$** (23.32), **$P_2 \times P_3$** (5.59) and **$P_3 \times P_4$** (5.63). The highest negative GCA effect was observed in **$P_2 \times P_5$** (-40.84) followed by **$P_4 \times P_5$** (-25.47), **$P_1 \times P_4$** (-17.47) and **$P_2 \times P_3$** (-6.78). For fruit zone, five crosses exhibited significant positive SCA effect and five crosses showed significant negative SCA effects. The highest positive significant GCA effects was recorded in **$P_2 \times P_3$** (17.60) followed by **$P_2 \times P_4$** (12.43), **$P_1 \times P_2$** (9.52), **$P_1 \times P_5$** (8.90) and **$P_3 \times P_5$**

(2.98). The highest negative SCA effects was recorded in **P_2×P_5** (-21.17) followed by **P_1×P_4** (-18.86), **P_4×P_5** (-17.19), **P_3×P_4** (-14.65) and **P_1×P_3** (-14.03). Amongst hybrid combinations, 5 crosses showed significantly positive SCA effects and 5 crosses showed significantly negatives effects. The crosses **P_2×P_4** (2.78), **P_3×P_5** (2.43), **P_1×P_3** (1.72), **P_4×P_5** (0.95) and **P_1×P_5** (0.76) were having significantly positive SCA effects.

Of the 10 crosses, five hybrids expressed positive and significant SCA effects and thus those were good cross combinations, while, five crosses had significant and negative values for the trait “number of capsules / plant”. On the basis of SCA effects, the cross **P_2×P_5** (32.75) followed by **P_1×P_2** (18.07), **P_1×P_3** (16.83), **P_4×P_5** (7.31) and **P_2×P_3** (7.02) were the best promising hybrids for this trait. The highest negative SCA effect was observed in **P_2×P_4** (-30.06) followed by **P_3×P_4** (-15.97), **P_1×P_5** (-13.55) **P_3×P_5** (-7.41) and **P_1×P_4** (-3.38). Out of 10 crosses, seven crosses exhibited positive SCA effects for capsules weight/ plant. The crosses **P_1×P_2** (16.88) followed by **P_1×P_3** (10.48), **P_2×P_3** (6.99), **P_2×P_4** (6.91), **P_3×P_5** (5.79), **P_1×P_5** (1.41) and **P_3×P_4** (0.77) were having highly significant SCA effects. Whereas three crosses were having significantly negative SCA effects. For 100-seed weight, four crosses exhibited significant positive SCA effect and three crosses showed significant negative SCA effects. The highest positive significant GCA effect was recorded inP_2×P_3 (0.87) followed by **P_3×P_4** (0.63), **P_1×P_2** (0.45) and **P_1×P_5** (0.12). The highest negative SCA effect was recorded in **P_1×P_4** (-0.96) followed by **P_2×P_5** (-0.59) and **P_1×P_3** (-0.32).

The scrutiny of SCA effects for seed yield/kg found that three crosses recorded significant positive SCA effects. While, seven crosses were shows significant and negative SCA effect. The crosses **P_3×P_4** (0.98), **P_1×P_2** (0.41) and **P_3×P_5** (0.39) were having significantly positive SCA effects and they considered the best promising hybrids for this trait. For SPAD values, 6 crosses showed significantly positive SCA effects and 4 crosses showed significantly negatives effects. The crosses **P_1×P_5** (5.29), **P_2×P_4** (3.81), **P_1×P_2** (2.66), **P_3×P_5** (2.27), **P_3×P_4** (1.51) and **P_1×P_3** (1.10) were having significantly positive SCA effects for this trait. The perusal of specific combining ability effects revealed that seven hybrids exhibited significant positive effects for seed oil content. While, three crosses were shows significant and negative SCA effect. The hybrids **P_2×P_5** (6.75), **P_3×P_4** (4.42), **P_1×P_3** (3.02), **P_1×P_2** (1.71), **P_1×P_4** (0.67), **P_2×P_3** (0.63) and **P_2×P_4** (0.61) were promising for this quality trait. These results are in agreement with **Ahmed and Adam (2015)**, **Abd El-Kader et al. (2017), Mungala et al. (2017), Tripathy et al. (2017) and Pandey et al. (2018).**

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Table 5: Specific combining ability effects of F_1 progenies in sesame									
F_1 Hybrid	**Plant height**	**Fruit zone**	**No. of branches**	**No. of capsules/ plant**	**Capsules weight/ plant**	**1000-seed weight**	**Seed yield/kg**	**SPAD value**	**Seed oil (%)**
P1×P2	-6.78**	9.52**	-1.85**	18.07**	16.88**	0.45**	0.41**	2.66**	1.71**
P1×P3	0.64	-14.03**	1.72**	16.83**	10.48**	-0.32**	-0.40**	1.10**	3.02**
P1×P4	-17.47**	-18.86**	-2.06**	-3.38*	-6.84**	-0.96**	-0.10*	-2.94**	0.67**
P1×P5	0.54	8.90**	0.76**	-13.55**	1.41*	0.12*	-0.30*	5.29**	-4.49**
P2×P3	5.59**	17.60**	-2.17**	7.02**	6.99**	0.87**	0.06	-7.05**	0.63*
P2×P4	55.81**	12.43**	2.78**	-30.06**	6.91**	0.00	-0.28**	3.81**	0.61*
P2×P5	-40.84**	-21.17**	-2.47**	32.57**	-3.04**	-0.59**	-0.40**	-0.36**	6.75**
P3×P4	5.63**	-14.65**	-2.39	-15.97**	0.77	0.63**	0.98**	1.51**	4.42**
P3×P5	23.32**	2.98*	2.43**	-7.41**	5.79**	-0.03	0.39**	2.27**	-0.74**
P4×P5	-25.47**	-17.19**	0.95**	7.31**	-6.02**	0.07	-0.12*	-3.86**	-4.19**
sca(ii)	***3.87***	***2.51***	***0.17***	***3.17***	***1.20***	***0.088***	***0.09***	***0.112***	***0.478***
sca(ij)	***1.93***	***1.25***	***0.08***	***1.58***	***0.60***	***0.044***	***0.05***	***0.056***	***0.239***

ESTIMATION OF HETEROSIS

The aim of estimation of hybrid vigour (heterobeltiosis) in this study was to find out the superior combinations of parents giving the high score for useful traits with heterosis, for example seed yield and its components, for their future use in sesame breeding program. The magnitude of heterosis was measured in the current experiment as percent increase (+) or decrease (-) of F_1 value through mid-parental (MP) values for all the nine characters presented in table 6.

Significant positive direction of heterosis is desirable goal for all the studied traits except plant height because short plant height is suitable for mechanical harvesting and lodging resistance.

The desirable hybrids for plant height were (P_2×P_4), (P_3×P_4), (P_3×P_5) and (P_2×P_3),based on mid parent heterosisfor fruiting zone length were (P_2×P_3), (P_1×P_2), (P_2×P_4) and (P_1×P_5), number of branches/plant were (P_2×P_5), (P_1×P_4) and (P_1×P_2) and for number of capsules/plant were (P_2×P_5), (P_1×P_2), (P_1×P_3) and (P_2×P_3). The desirable hybrids for capsules weight/plant were (P_1×P_2), (P_1×P_3), (P_2×P_3) and (P_2×P_4), based on mid parent heterosis. For 1000-seed weight, the desirable hybrids were (P_2×P_3), (P_3×P_4) and (P_1×P_2). In case of seed yield/kg, the superior hybrids were (P_3×P_4), (P_3 ×P_5), (P_1×P_2) and (P_2×P_3) based on mid parent heterosis. For SPAD values, among 10 hybrids, 6 hybrids showed positive and significant heterosis over mid-parent and three hybrids showed significant negative heterosis for this trait. The best hybrids were P_1×P_5, P_1×P_2,

$P_2 \times P_4$, $P_3 \times P_5$, $P_1 \times P_3$ and $P_3 \times P_4$. For seed oil content, the maximum positive heterosis value was found in cross combinations $P_2 \times P_5$ (15.74%), $P_3 \times P_4$ (11.62%), $P_2 \times P_3$ (9.23%), $P_1 \times P_2$ (9.08%), $P_1 \times P_3$ (8.99%) and $P_2 \times P_4$ (7.03%).

It can be concluded that the most desirable heterotic effects were shown by $P_3 \times P_4$, $P_3 \times P_5$, $P_1 \times P_2$ and $P_2 \times P_3$ exhibiting highly significant positive SCA effects for seed/ yield/kg and most of its components. It is relevant to note that the crosses of parents with either poor × poor or good × poor general combining abilities also had significant heterosis though their average yields were lower as compared to the hybrids resulted from both parents with good general combing abilities and exhibited lower heterosis. It would, therefore, be desirable to select cross combinations based on mean values rather than based only on extent of heterosis. These results are accepted with observed results by **Abd El-Kader et al. (2017), Chaudhari et al. (2017), Nayak et al. (2017), Karande et al. (2018) and Pandey et al. (2018).**

Table 6: Heterosis of F_1 progenies of sesame over mid parental value

Parental details of the F_1 hybrid	Plant height (cm)	Fruit zone (cm)	No. of branches	No. of capsules/ plant	Capsules weight/ plant	1000-seed weight (g)	Seed yield /fed (kg)	SPAD value	Seed oil (%)
P1×P2	-6.20	19.75**	2.82*	41.54**	156.13**	12.92**	9.88*	8.08**	9.08**
P1×P3	2.41	-25.88**	-3.45**	26.11**	104.44**	-5.94	-7.95	4.21**	8.99**
P1×P4	-14.22**	-46.87**	3.42**	-9.57**	-11.82	-30.51**	-2.76	-3.76**	2.46
P1×P5	-9.63**	-1.76	-3.62**	-7.47	26.66**	-4.07	-14.71**	16.12**	-8.56**
P2×P3	11.85**	37.46**	1.43	16.77**	92.86**	42.11**	8.51*	-15.72**	9.23**
P2×P4	49.35**	16.12**	0.00	-33.70**	54.92**	3.38	-6.74	6.69**	7.03**
P2×P5	-29.45**	-43.36**	3.47	74.16**	13.98	-14.29**	-15.74**	0.49	15.74**
P3×P4	14.15**	-38.02**	1.03	-23.74**	21.83**	23.50**	39.13**	1.24**	11.62**
P3×P5	12.78**	-7.42	0.53	-3.63	42.24**	3.96	13.91**	5.30**	0.67
P4×P5	-21.38**	-48.58**	1.08	1.74	-27.58**	-2.46	-2.98	-7.33**	-7.71**
SE of Midparent	***5.42***	***3.51***	***2.50***	***4.44***	***1.67***	***0.12***	***0.12***	***0.15***	***0.67***

Phenotypic (p) and Genotypic (g) correlation coefficients:

Sesame seed yield is the result of many characters which were interdependent. Breeders always look for genetic variation among variables to select desirable types. Some of these variables are highly associated among themselves and with seed yield. In general, the genotypic correlation coefficients (rg) were slightly higher than the phenotypic correlation coefficients (rp), indicating the masking effect of the environment in the total expression of the genotypes (Table 7).

The association between seed yield and its component characters indicated that the seed yield per feddan had positive and significant association with plant height, number of branches/plant, number of capsules/plant, 1000-seed weight and seed oil content (%). This clearly indicates that increased capsules per plant will increase seed yield and hence while making selection for yield more emphasis should be given to this character. Among inter genotypic correlations; plant height has positive and significant association with fruit zone, days to maturity, number of branches /plant and 1000-seed weight. Fruit zone has positive and significant association with number of capsules/ plant, capsules weight/plant, 1000-seed weight, SPAD values and per cent seed oil content. Capsules weight/plant has significant positive association with 1000-seed weight, SPAD values and per cent seed oil content.

Similar results were also observed by **Saxena and Bisen (2017), Nayak et al. (2017), Karande et al. (2018) and Pandey et al. (2018).**

Table 7: Phenotypic (rp) and genotypic (rg) correlation coefficients between nine traits in F_1 progeny of sesame parental genotypes

variables	Type of Correlation	Fruit zone (cm)	No. of branches	No. of capsules/ plant	Capsules weight/ plant	1000-seed weight (g)	Seed yield /fed (kg)	SPAD value	Seed Yield/ fed
plant height	rp	0.52*	-0.16	-0.56*	0.43*	0.36*	0.27*	0.27*	0.26*
	rg	0.56*	-0.17	-0.61*	0.45*	0.39*	0.29*	0.30*	0.29*
fruit zone	rp		-0.02	0.25*	0.34*	0.52*	0.23*	0.21*	0.02
	rg		-0.01	0.26*	0.35*	0.53*	0.24*	0.23*	0.06
no. of branches/ plant	rp			0.05	-0.09	-0.08	-0.32*	0.48*	0.21*
	rg			0.07	-0.1	-0.09	-0.32*	0.49*	0.22*
no. of capsules / plant	rp				0.13	-0.17	-0.26*	0.04	0.43*
	rg				0.15	-0.15	-0.27*	0.05	0.45*
capsules weight/ plant	rp					0.35*	0.31*	0.32*	0.06
	rg					0.40*	0.33*	0.33*	0.09
1000-seed weight	rp						-0.15	0.27*	0.52*
	rg						-0.16	0.30*	0.57*
SPAD value	rp							-0.04	-0.24*
	rg							-0.05	-0.26*
Seed	rp								0.57*

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oil %	**rg**								0.59*

Path coefficient analysis

The results of path coefficient analysis based on genotypic correlation coefficients are presented in Table 8.

1000-seed weight/ plant (0.781) followed by seed oil content (0.442), capsules weight per plant (0.427) and plant height (0.414) showed highly positive direct effects on seed yield/ feddan at genotypic correlation. However, number of branches/plant (0.106) and numbers of capsules/plant (0.152) exhibited positive direct effect of low magnitude on seed yield per feddan. Whereas the fruit zone (-0.526) showed negative direct effects on seed yield /plant and non-significant positive correlation with seed yield/feddan. In this study, the residual effect (0.5197) was high value in magnitude which showed that some other important yield contributing characters which contributed to yield had to be included.

The indirect effects between characters showed positive and negative effects with low magnitude on seed yield per feddan. The indirect effects had not only supported the low magnitude direct effect but also resulted in high significant positive correlation with seed yield. Similar results were in harmony by Ibrahim and Khidir (2012), Bamrotiya et al. (2016) and Saxena and Bisen (2017).

Table 8: Estimates of direct (bold diagonal) and indirect effect (off diagonal) at genotypic level for different characters on seed yield of in 10 F_1 progenies of sesame genotypes

Characters	Plant height (cm)	Fruit zone (cm)	No. of branches	No. of capsules/ plant	Capsules weight/ plant	1000-seed weight (g)	Seed yield /fed (kg)	SPAD value	Seed yield/ fed kg
Plant height	**0.414**	-0.292	-0.018	-0.093	-0.193	0.307	0.032	0.131	0.29*
Fruit zone	0.230	**-0.526**	-0.002	-0.039	-0.148	0.418	0.027	0.101	0.06
No. of branches	-0.069	0.008	**0.106**	0.011	0.043	-0.069	-0.036	0.218	0.22*
No. of capsules/ plant	-0.253	0.136	0.008	**0.152**	-0.066	-0.119	-0.030	0.021	0.45*
Capsules weight/ plant	0.187	-0.183	-0.011	0.023	**0.427**	0.311	0.036	0.148	0.09
1000-seed	0.163	-0.281	-0.009	-0.023	-0.170	**0.781**	-0.018	0.131	0.57*

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weight									
SPAD value	0.118	-0.126	-0.034	-0.041	-0.140	-0.126	**0.110**	-0.020	-0.26*
Seed oil (%)	0.123	-0.120	0.052	0.007	-0.143	0.232	-0.005	**0.442**	0.59*
RESIDUE=0.5197									

Variability and heritability parameters

Estimates of genotypic (σ^2g), phenotypic (σ^2p) and environmental (σ^2e) variances and phenotypic coefficients of variation (PCV) and genotypic coefficients of variation (GCV) are given in Table 9. The phenotypic coefficients of variation (PCV) ranged from 7.35 for seed oil % to 81.13 for number of branches per plant. Similarly, genotypic coefficients of variation (GCV) ranged from 7.33 for seed oil % to 79.89 for number of branches per plant.

According to Deshmukh et al. (1986), PCV and GCV values less than 10% are considered to be low, whereas values greater than 20% are regarded as high and values between 10% and 20% to be medium. Based on this delineation, phenotypic coefficient of variation (PCV) were recorded highest for number of branches/plant (81.13) followed by fruit zone (31.88), capsule weight/ plant (31.63), no. of capsules / plant (26.23) and SPAD Values (20.45) whereas, comparatively moderate for plant height (18.53), 1000-seed weight (14.55) and seed yield / feddan (10.46) and lower for seed oil % (7.35).

The highest GCV were observed for the number of branches/plant (79.89) followed by fruit zone (30.67), capsule weight/ plant (30.64), number of capsules/plant (25.15) and SPAD values (19.79) whereas, comparatively moderate for plant height (17.80), 1000-seed weight (13.78) and seed yield/feddan (10.32) and lower for seed oil % (7.33). In this study the genotypic coefficient of variation (GCV) values were lower than that of PCV, indicating that the environment had an important role in the expression of these characters. Generally, quantitative characters are highly influenced by the environment. These results are in agreement with observations made by Siva et al., (2013), Tripathy et al. (2016) and Saxena and Bisen (2017).

Heritability estimates for characters under study are given in Table 9. Heritability values are helpful in predicting the expected progress to be achieved through the process of selection. Genetic coefficient of variation along with heritability estimate provides a reliable estimate of the amount of genetic advance to be expected through phenotypic selection. Heritability ranged from 89.74% for 1000-seed weight to 99.61% for seed oil content. According to Singh (2001), heritability values greater than 80% are very high, values from 60-79% are moderately high,

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values from 40-59% are medium and values less than 40% are low. High heritability was observed for seed oil content (99.61%), seed yield/feddan (97.42%), number of branches/ plant (96.96%), capsules weight/ plant (93.83%), SPAD values (93.29%), fruit zone (92.55), plant height (92.28%) number of capsules /plant (91.94%), seed yield/plant (91.94%) and 1000- seed weight (89.74%). The results are in agreement with the observations made by Siva et al., (2013), Saxena et al. (2016), Tripathy et al. (2016).

The estimates of expected genetic advance (Table 9) revealed that the maximum genetic advance was revealed from plant height (52.46), number of capsules/ plant (41.94) and fruit zone (34.76).The moderate genetic advance was observed for capsules weight/ plant (18.47) and seed yield per feddan (11.85), while 1000-seed weight (1.00), SPAD values (1.33), no. of branches per plant (3.87) and seed oil content (7.34) were reported to be with low genetic advance. Similar results were also reportedby Siva et al., (2013), Saxena et al. (2016) and Tripathy et al. (2016).

Table 9: Estimates of phenotypic (PCV) and genotypic (GCV) coefficient of variability, broad sense heritability (H^2), expected genetic advance (GA) and genetic advance as percent of the mean (GA%) for 9 characters for F1 sesame genotypes.

	Plant height	Fruit zone	No. of branches	No. of capsules/ plant	Capsules weight/ plant	1000-seed weight	Seed yield / feddan	SPAD value	Seed oil (%)
PV	761.67	332.39	3.75	490.44	91.31	0.30	34.85	0.48	12.78
GV	702.84	307.62	3.64	450.89	85.68	0.26	33.95	0.44	12.73
PCV	18.53	31.88	81.13	26.23	31.63	14.55	10.46	20.49	7.35
GCV	17.80	30.67	79.89	25.15	30.64	13.78	10.32	19.79	7.33
h^2	92.28	92.55	96.96	91.94	93.83	89.74	97.42	93.29	99.61
GA %	52.46	34.76	3.87	41.94	18.47	1.00	11.85	1.33	7.34
GAM	35.23	60.78	62.05	49.67	61.15	26.90	20.99	39.38	15.07
S.E.	4.43	2.87	0.19	3.63	1.37	0.10	0.55	0.10	0.13
C.D. (5%)	12.84	8.33	0.56	10.53	3.97	0.29	1.59	0.30	0.37
CV (%)	5.15	8.70	14.14	7.45	7.86	4.66	1.68	5.31	0.46

CONCLUSIONS

Additive and non-additive types of gene action were playing the major role in inheritance of all the studied traits in sesame. Most of F_1 crosses were higher than their parents in their performance for most studied traits. The three parental P_3, P_4, and P_5, could be considered as the preferable general combiners for seed yield. However, the crosses $P_2 \times P_5$, $P_3 \times P_4$, and $P_3 \times P_5$

had the most desirable specific combining abilities (S.C.A effects) for seed yield/plant and most studied characters and the same crosses also showed the highest heterosis percentage over the mid-parental values for seed yield. The indirect effects between characters showed positive and negative effects with low magnitude on seed yield/feddan. High heritability in broad sense was observed for all studied traits.

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