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Research Note

Evaluation of hybrids for heterosis breeding in sesame (*Sesamum indicum* L.)

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Abstract
The 8x8 half-diallel sesame hybrids were evaluated for their performance of yield and component traits. Average heterosis was the highest for primary branches followed by seed yield, biological yield and plant height. Substantial amount of, better parent and standard parent heterosis was observed for majority of the characters studied. The hybrids RT 54 x ABT 33, AT 158 x ABT 33, AT 158 x AT192 , AT 192 x G.Til 1and AT 158 x AT 177 were the best heterotic hybrids and recorded 70.43, 62.61, 61.74, 53.04 and 48.70 per cent standard heterosis, respectively for yield over the standard check ???. They also showed significant standard or better or mid parent heterosis for component traits; early maturity, capsule length, seeds per capsule and biological yield in desirable direction. The AT 158 x ABT 33, AT 192 x G.Til 1 and AT 158 x AT 177 with higher standard heterosis for yield offered greater scope for exploitation of the hybrid vigour on commercial scale.

Key words
Seed yield, F_1 hybrids, half diallel, average heterosis, standard heterosis.

Sesame (*Sesamum indicum* L.) is one of the ancient oilseed crops and very famous for its superior oil quality and nutritive value (Sharmila *et al.*, 2007), hence it is regarded as "the queen of oil seeds". Seeds of sesame are rich source of oil (44 to 52 per cent) and protein (19 to 21 per cent). Oil is resistant to oxidation and rancidity under normal storage conditions. International demand for sesame whole seed and its export is steadily increasing and India's share in world's exports of hulled sesame is around 60%. Seed with uniform size, lustrous, white, bold, sweet, free from flash, low free fatty acids (<2%), and free from pesticide residues is preferred in the global markets (Gopinath *et al.*, 2011).

The sesame crop, by virtue of its short duration, fits well into inter-cropping systems. It is sixth most important oil seed crop in India, covering 1.86 million hectare area and accounting for 0.64 million tonnes production with productivity of 342 kg/ha (FAO, 2013). The average productivity is very low as compared to other sesame growing countries. The low productivity is mainly due to, cultivation in poor soils and low yielding varieties. Even though the considerable variability exists in sesame crop, the progress in yield improvement is very slow and almost stagnant during the last few years. Exploitation of heterosis is the better option to augment sesame production per unit area.

Being an autogamous crop, sesame has not so far been amenable for heterosis breeding due to lack of economic methods for large scale seed production. For commercial exploitation of heterosis, the basic requirements are identification of parents which show good heterosis and development of male sterility system to reduce the cost of hybrid seed. However, stable male sterile lines have not yet been developed in India (Ranganatha *et al.*, 2012). Nevertheless, manual emasculation and pollination for the production of hybrids in sesame is the preferred route. This is possible because of epipetatious flower, easy emasculation and pollination, high number of seeds produced per flower, low seed rate and high multiplication ratio for manual seed production (Jadhav and Mohir, 2013). Identifying parental combinations with better yield heterosis is the important step in developing sesame hybrids. Heterosis is the complex phenomenon depending upon the balance of additive, dominance and their interacting components as well as distribution of genes in parental lines. Heterosis for seed yield in sesame is due to simultaneous heterotic effects of more than one component (Jatothu *et al.*, 2013). Hence, it is important to measure the magnitude of heterosis in sesame hybrids with due emphasis on contribution of different morphological traits. From plant breeding point of view, standard heterosis is of practical significance. To exploit commercially viable heterosis, the new crosses are compared with released varieties, so that the crosses with high heterotic potential could be identified. Hence, the present study was undertaken to determine the nature and magnitude of heterosis in order to develop high yielding hybrids in sesame.

The experiment was conducted at the Agricultural Research Station, Amreli, Gujarat, India (latitude 21°35′79″N, longitude 71°12′82″E and altitude 130 m amsl). Eight diverse genotypes namely AT 158, AT 177, AT 192, G. Til 1, RT 54, TKG 22, ABT 33 and G.Til 2 were selected on the basis of different phenotypic expression and crossed manually in diallel fashion without reciprocals to produce 28 F_1 hybrids. Seeds of 28 successful F_1 along with their parents were grown in a randomized complete block design with three replications. Each experimental unit was a single-row plot with a row-to-row spacing of 0.60 m and

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row length of 3.5 m. The distance between two adjacent plants was 0.10 m with even plant density in all the plots. All the package of practices recommended for sesame was adopted to produce successful crop.

Biometric data were recorded for 13 quantitative characters from five randomly selected plants of each cross and parents. The characters studied were: days to 50% flowering, days to maturity, reproductive period, plant height (cm), primary branches per plat, capsule length (cm), seeds per capsule, 1000 seed weight (g), oil content (%), biological yield per plant (g), seed yield per plant (g) and harvest index (%). The characters like days to 50% flowering, days to maturity and 1000- seed weight (g) were recorded on plot basis. Oil content (%) was determined from seed samples taken from each plot by Nuclear Magnetic Resonance (NMR). Reproductive period was computed as duration from days to 50% flowering to days to physiological maturity (Olowe, 2007). The performance of F_1 hybrids was evaluated on the basis of relative heterosis, heterobeltiosis and standard heterosis as per cent increase (+) or decrease (-) of F_1 over mid parent (MP), better parent (BP) and standard parent (SP) Here, released variety G. Til 2 (one of the diallel parents) was used as a standard parent for calculation of standard heterosis.

Analysis of variance: Analysis of variance (Table 1) revealed significant differences due to genotypes for all the traits, suggesting the existence of substantial genetic variability. The total variation due to genotypes was partitioned into three components *viz.*, variation due to parents, hybrids and parents *versus* hybrids. Variances due to parents were significant for all the traits observed, except days to 50% flowering. This indicates that parents selected for the study were of greater divergence. Significant differences due to hybrids indicated the presence of substantial variability among the crosses. The interaction between parents and hybrids showed significant differences for all the traits except reproductive period, capsules per plant, 1000-seed weight and oil content. Several earlier workers also reported similar observations in sesame (Thiyagu *et al.*, 2007; Jadhav and Mohrir, 2013; Parimala *et al*, 2013).

Parents and their interaction with hybrids (P *vs.* H) contributed more than 80 per cent of total variance for plant height, primary branches per plant, biological yield per plant and seed yield per plant, while contribution of parents was high for days to maturity, capsule length, seeds per plant, 1000-seed weight and harvest index (Table 2). For, oil content and reproductive period, contribution of both parents and hybrids was almost equally important, High contribution of P *vs.* H interaction for plant height (81.73%), primary branches per plant (85.95%), biological yield per plant (93.12%) and seed yield per plant (82.23%) was also reflected in high average heterotic response. Jatothu *et al.* (2013) also reported high average heterotic response for seed yield per plant and primary branches per plant in sesame. Higher contribution of parental variance than those due to hybrids and P *vs.* H interaction was observed for days to maturity, capsule length, seeds per plant, 1000-seed weight and harvest index may be the indicative of partial dominance in manifestation of heterosis of these characters.

The range of heterosis, number of crosses showing a desirable heterotic response and the best hybrid with the highest relative heterosis, heterobeltiosis and standard heterosis for all the studied characters are presented in Table 3. A wide range of heterosis was observed for seed yield per plant, biological yield per plant, harvest index, plant height, primary branches per plant, capsules per plant, 1000-seed weight and seeds per capsule. Of the twenty eight hybrids, twelve, eight and ten hybrids showed significant desirable MP, BP and SP heterosis for seed yield per plant, respectively. The hybrid AT 158 x AT 177 expressed the highest MP heterosis (110.11 %) and BP heterosis (94.79%) for this character. The highest of all the three heterosis was recorded for plant height in the cross AT 177 x G.Til 2 and for biological yield per plant in AT 177 x RT 54. For primary branches per plant, fifteen, four and nine hybrids expressed significant desirable MP, BP and SP heterosis, respectively. The highest MP and SP heterosis was observed in the AT 177x G.Til 2, while the RT 54 x ABT 33 showed the highest BP heterosis.

The situation like absence or very low heterosis, as observed for days to 50% flowering, reproductive period and oil content, may arise when parental lines were unable to show much heterosis. Jatothu *et al.* (2013) also reported no desirable average or standard heterosis for oil content in sesame. Substantial heterosis in either side of the parents for different characters have been reported earlier by many workers in sesame (Shekhat *et al*., 2008; Anuradha and Reddy, 2008; Padmasundari and Kamala, 2012; Parimala *et al.*, 2013; Jadhav and Mohrir, 2013).

For development of early maturing hybrids, negative heterosis for earliness related traits are desirable .. In the present study, out of 28 hybrids, 11,17 and 21 hybrids exhibited significant negative heterosis for days to maturity over mid, better and standard parents, respectively. The highest negative heterosis for this character was recorded in by AT 177 x TKG 22(-8.95%) over standard parent. For days to 50% flowering, the cross AT 177 x RT 54 exhibited significant negative SP heterosis (-4.42%). All these hybrids are important

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to exploit heterosis for earliness in sesame. Saravanan *et al.* (2000) also noticed considerable heterosis for earliness related traits in sesame. Plant height and branches per plant largely determine the capsule bearing surface and were considered as important attributes of biological yield. Higher the plant height and branches on the main stem, the chances for the number of capsules per plant will be higher (Ranganatha *et al.*, 2012). The hybrid AT 177 x G.Til 2 recorded the highest heterosis for plant height and primary branches per plant and AT 177 x RT 54 recorded the highest heterosis for biological yield per plant. The harvest index showed a range of MP heterosis from -35.51 to 75.56 per cent, BP heterosis from -41.57to 71.57 per cent and SP heterosis from -46.77 to 37.31 per cent. The highest SP heterosis was recorded in AT 192 x G.Til 1(39.37%). Higher seeds per capsule are generally associated with more capsule length and *vice-versa*. Therefore, both are considered as important attributes for higher seed yields in sesame hybrids. Twenty eight hybrids for capsule length and twenty four hybrids for seeds per capsule manifested significant positive SP heterosis. The hybrid AT 177 x AT 192 was found to be superior and manifested the highest SP heterosis for both the characters (52.90% for capsule length and 65.00% for seeds per capsule).

For thousand seed weight, seven hybrids for MP heterosis, three hybrids for BP heterosis and seven hybrids for SP heterosis exhibited superiority in desirable direction. The cross involving RT 54 as one of the parents manifested significantly the highest heterosis of 25.37 % (RT 54 x G.Til 2) over mid parent, 12.33 % (AT 177 x RT 54) over better parent and 29.16 % (AT 158 x RT 54) over standard parent. Padmasundari and Kamala (2012) and Parimala *et al.* (2013) have reported superiority of sesame hybrids for 1000-seed weight over mid and better parent.

The evaluation of hybrids for heterosis breeding based on consideration of standard heterosis would be more meaningful.Best five hybrids based on seed yield SP heterosis (Table 4) indicated that high yielding heterotic hybrids also manifested significant heterotic response for other characters too. The hybrids RT 54 x ABT 33,AT 158 x AT 177 and AT 192 x G.Til 1 expressed significant desirable SP heterosis for six characters including seed yield per plant, The hybrid AT 158 x AT192 for five characters and AT 158 x ABT 33 for seven characters found significantly superior for SP heterosis. Further, it is noted that parent AT 158 appeared in three out of five best hybrids.

To conclude, the hybrids *viz.*, AT 158 x ABT 33 followed by AT 192 x G.Til 1 and AT 158 x AT 177 with higher standard heterosis for seed yield offers greater scope for exploitation of the hybrid vigour on commercial scale. These hybrids need to be tested at large scale in multi-location trials to circumvent the environmental effects with better yield sustainability.

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Table 1. Analysis of variances (mean squares) for thirteen characters in sesame

Source	df	Days to 50% flowering	Days to maturity	Reproductive period	Plant height (cm)	Primary branches/ plant	Capsules/ plant	Capsule length (cm)	Seeds/ capsule	1000 seed wt. (g)	Oil content (%)	Biological yield/ plant (g)	Seed yield/ plant (g)	Harvest index (%)
Genotypes	35	5.47**	22.65**	29.84**	428.78**	1.47**	99.33**	0.14**	82.08**	0.33**	42.09**	495.78**	90.27**	581.60**
Parents	7	1.42	32.55**	34.52*	323.43**	0.82*	92.14**	0.29**	129.27**	0.50**	42.38**	187.14**	19.64**	173.43**
Hybrids	27	5.77**	20.84**	29.65**	358.89**	1.22**	126.56**	0.10**	71.83**	0.30**	42.36**	333.19**	92.67**	76.14**
P *vs.* H	1	25.67**	2.38*	2.30	3053.23**	12.48**	19.31	0.16**	28.33*	0.13	32.99	7046.09**	519.76**	166.21*
Error	70	0.99	0.41	14.41	28.73	0.35	12.29	0.02	5.75	0.04	10.53	59.21	23.06	26.82

*, **, significant at 5 and 1 per cent levels, respectively

Table 2. Proportional contribution to total variance, average performance of parents, hybrids, and average heterosis for thirteen characters in sesame

Characters	Per cent contribution			Average performance		Average heterosis (%)
	Parents	Hybrids	P *vs.* H	Parents	Hybrids	
Days to 50% flowering	4.32	17.56	78.12	37.21	38.38	3.14
Days to maturity	58.36	37.37	4.27	81.04	81.89	1.05
Reproductive period	51.93	44.61	3.46	43.83	43.51	-0.73
Plant height (cm)	8.66	9.61	81.73	84.06	95.88	14.06
Primary branches/plant	5.65	8.40	85.95	2.34	3.16	35.04
Capsules/plant	38.71	53.17	8.11	44.29	40.74	-8.02
Capsule length(cm)	52.73	18.18	29.09	2.52	2.43	-3.57
Seeds/ capsule	56.34	31.31	12.35	42.63	43.81	2.77
1000 seed wt (g)	53.76	32.26	13.98	2.91	2.92	0.34
Oil content (%)	36.00	35.98	28.02	47.26	45.93	-2.81
Biological yield/ plant(g)	2.47	4.40	93.12	84.17	103.60	23.08
Seed yield/ plant (g)	3.11	14.66	82.23	17.44	22.71	30.22
Harvest index (%)	41.71	18.31	39.98	20.86	21.97	4.07

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Table 3. Range of heterosis, number of crosses showing significant heterosis and the best cross for thirteen characters in sesame

Characters	Range of heterosis			No. of crosses showing significant and desirable heterosis			The best performing cross		
	MP	BP	SP	MP	BP	SP	MP	BP	SP
Days to 50% flowering	-1.79 to 10.41	-3.48 to 7.96	-4.42 to 7.96	-	-	1	AT 177 x G. Til 1	AT 158 x ABT 33	AT 177 x RT 54
Days to maturity	-6.09 to 4.68	-8.88 to 3.78	-8.95 to 0.78	11	17	21	G. Til 1 x G.Til 2	AT 177 x ABT 33	AT 177 x TKG 22
Reproductive period	-16.88 to 17.13	-18.04 to 12.90	-18.75 to -2.79	2	-	-	RT 54 x ABT 33	RT 54 x ABT 33	-
Plant height (cm)	-19.17 to 39.12	-23.92 to 34.93	-9.63 to 34.93	21	11	16	AT 177 x G. Til 2	AT 177 x G.Til 2	AT 177 x G. Til 2
Primary branches/plant	-15.07 to137.74	-27.91 to 68.75	-36.84 to 65.79	15	4	9	AT 177 x G. Til 2	RT 54 x ABT 33	AT 177 x G. Til 2
Capsules/plant	-28.80 to 35.65	-43.46 to 17.88	-39.34 to 16.43	4	2	1	RT 54 x G.Til 2	AT 177x TKG 22	RT 54 x G.Til 2
Capsule length (cm)	-18.16 to 18.34	-28.22 to 9.50	14.86 to 52.90	3	-	28	AT 158 x G. Til 1	AT 158 x G.Til 2	AT 177 x AT 192
Seeds/ capsule	-19.55 to 23.53	-24.31 to 13.33	7.00 to 65.00	10	1	24	AT 192 x G. Til 2	TKG 22 x ABT 33	AT 177 x AT 192
1000 seed wt (g)	-23.88 to 25.37	-36.50 to 12.33	-18.83 to 29.16	7	3	7	RT 54 x G. Til 2	AT 177 x RT 54	AT 158 x RT 54
Oil content (%)	-21.00 to 10.14	-28.12 to 4.33	-31.44 to 2.24	-	-	-	RT 54 x TKG 22	AT 192 x TKG 22	AT 158 x AT 177
Biological yield/ plant (g)	-14.65 to 59.73	-19.73 to 52.97	-8.88 to 39.38	21	13	20	AT 177 x RT 54	AT 177 x RT 54	AT 177 x RT 54
Seed yield/ plant (g)	-32.09 to 110.11	-39.17 to 94.79	-36.52 to 70.43	12	8	10	AT 158 x AT 177	AT 158 x AT 177	RT 54 x ABT 33
Harvest index (%)	-35.51 to 75.56	-41.57to 71.57	-46.77 to 37.31	5	3	1	AT 158 x G. Til 1	AT 158 x G.Til 1	AT 192 x G. Til 1

Table 4. Best five crosses based on standard heterosis for seed yield per plant and their performances for other characters in sesame

Characters	RT 54 x ABT 33	AT 158 x AT 177	AT 192 x G Til 1	AT 158 x AT 192	AT 158 x ABT 33
Seed yield/ plant (g)	70.43**	62.61**	61.74**	53.04**	48.70*
Days to 50% flowering	2.05	-0.88	5.30**	-2.65	-1.77
Days to maturity	-0.39	-7.00**	-3.89**	-5.06**	-3.50**
Reproductive period	-2.79	-11.79	-11.13	-8.33	-4.85
Plant height (cm)	12.29*	4.46	11.35*	4.78	3.76
Primary branches/plant	42.11*	31.58*	5.26	36.84	39.47*
Capsules/plant	-3.44	-21.06*	9.14	-9.66	-4.77
Capsule length(cm)	31.88**	40.94**	25.72**	25.36**	27.90**
Seeds/ capsule	33.00**	39.00**	7.00	30.00**	28.00**
1000 seed wt. (g)	8.75	3.89	4.98	0.00	15.55**
Oil content (%)	-15.86**	2.24	-11.86*	1.09	0.11
Biological yield/ plant(g)	36.68**	22.78**	17.76*	26.25**	25.48**
Harvest index (%)	24.68	32.43	37.31*	21.18	18.48

*, ** Significant at 5 and 1 per cent levels, respectively