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Exploitation of heterosis and inbreeding depression for seed yield and its component traits in sesame (*Sesamum indicum* L.)

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Abstract

An investigation was conducted with nine diverse parents to develop thirty-six F_1's and F_2's by using half-diallel mating design to estimate heterosis and inbreeding depression for seed yield and its components in sesame (*Sesamum indicum* L.). The analysis of variance revealed highly significant differences among parents, F_1's and F_2's for all the characters studied (except oil content in parents). The highest heterobeltiosis for seed yield per plant was recorded in the cross, IC-96127 x G.Til-10 followed by IC-96127 x IC-204169, AT-345 x G.Til-10 and AT-345 x IC-96127. Whereas, the highest standard heterosis for seed yield per plant was registered by the cross AT-345 x G.Til-10 followed by AT-345 x IC-96127, IC-96127 x G.Til-10 and AT-345 x AT-375. The crosses with high heterotic values for seed yield per plant and its important attributes also showed moderate to high inbreeding depression, suggesting that heterosis was mainly due to non-additive gene action for most of the characters. The cross combinations, IC-96127 x G.Til-10, AT-345 x G.Til-10 and AT-345 x IC-96127 were the most promising cross combinations for seed yield per plant, on the basis of their high heterobeltiosis and standard heterosis in F_1 generation and thus, can be utilized effectively in future breeding programmer.

Keywords: Heterobeltiosis, standard heterosis, inbreeding depression, half-diallel, and sesame

Introduction

Sesame (*Sesamum indicum* L.) belonging to the genus *Sesamum* and family Pedaliaceae, is one of the most ancient oilseed crops in the world. It is also known as til, gingelly, simsim or gergelim. India is considered to be the centre of domestication of the crop (Bedigian, 2004) [5]. According to Kobayashi *et al*. (1990) [12], 36 species have been identified of which 22 species are from Africa; five from Asia; seven from both Africa and Asia; and one species each from Crete and Brazil. There are three cytogenetic groups of which 2n = 26 consists of the cultivated *S. indicum* along with *S. alatum*, *S. capense*. *S. schenckii*, *S. malabaricum*; 2n = 32 consists of *S. prostratum*, *S. laciniatum*, *S. angolense*, *S. angustifolium*, while *S. radiatum*, *S. occidentale* and *S. schinzianum* belongs to 2n = 64.

Sesame is considered as the "Queen of oilseeds" owing to high levels of unsaturated fatty acids, namely linoleic acid, oleic acid and antioxidants like sesamol, sesamin, sesamolin and sesaminol (Mondal *et al*., 2010) [16]. Among the oilseed crops, sesame ranks first for its high oil content with 6335 kcal/kg of dietary energy in seeds (Kumar and Goel, 1994) [13], followed by 46-52 % oil, 20-26 % protein, 6-7 % moisture, 16% carbohydrate and 6-8 % crude fiber.

Sesame is pre-dominantly a self-pollinated crop and the scope of hybrid vigour depends on the direction and magnitude of heterosis. The success of developing commercial hybrids depends upon the choice of superior parents for high expression of heterosis by spotting the potentiality of good hybrid combinations. Hybrid technology has been widely acclaimed as a modern approach for the genetic improvement of yield in various crop species including sesame. However, the advantage of hybrid vigour is not so been exploited commercially, rather it is used to isolate a higher frequency of productive derivatives in their later generations. Inbreeding is the basic mechanism for providing the base material for selection. The nature and magnitude of inbreeding depression helps to the efficiency of selection. The present investigation was carried out to study the heterosis in F_1 over better parent, standard parent and inbreeding depression over F_2 segregating generation for seed yield and its component traits in sesame.

Materials and Methods

The initial experimental materials comprised of nine parental genotypes *viz.*, G. Til-4, U-76-10, AT-345, AT-375, AT-382, AT-338, IC-96127, IC-204169 and G.Til-10.A total of 36 crosses were made in half-diallel mating design (excluding reciprocal) during *Summer* 2021 and their F_2 generation was made during *Kharif* 2021. The final evaluation trial comprised of nine parents along with 36 F_1's, 36 F_2's and one standard check (G.Til-6) was carried out during *Summer* 2022 at the Sagdividi Farm, Department of Seed Science and Technology, College of Agriculture, Junagadh Agricultural University, Junagadh. The parents and F_1's were grown in single row and F_2's with four rows plot with a spacing 30 x 10 cm. The trial was conducted in Randomized Block Design (RBD) with three replications. Observations were recorded on five competitive plants excluding border ones and was selected randomly from single row plot of each parents and F_1's as well as 20 competitive plants of F_2's were selected in each replication for seed yield per plant and its components *viz.*, days to 50 per cent flowering, plant height, number of primary branches per plant, number of capsules per plant, number of seeds per capsule, length of capsule, days to maturity, 1000-seed weight, oil content and harvest index.

The analysis of variance was performed to test the significance of difference among the genotypes for the characters studied as suggested by Panse and Sukhatme (1985) [20]. Magnitude of heterobeltiosis and standard heterosis was calculated as the deviation of F_1 from the better parent and standard check, respectively (Fonseca and Patterson, 1968) [10]. The inbreeding depression was calculated as the deviation between F_1 and its corresponding F_2 for each character separately (Allard, 1960) [2].

Results and Discussion

The analysis of variance reveled highly significant differences among the genotypes for all the 11 traits studied. This indicated that experimental material used in present study had sufficient variability for different characters. Further, partitioning of the genotypic mean square into parents, F_1's and F_2's evinced that mean square due to parents were significant for all the traits except for oil content. Likewise, mean sum of square due to hybrids (F_1's) were also highly significant for seed yield and its components, revealing the existence of potential variability in the hybrid generated in the present study. The variation due to F_2's was also highly significant for all the characters. The mean square for parents versus F_1's comparison was significant for all the characters indicated substantial amount of heterosis in cross combinations in F_1 as a group heterosis. The mean square for parents versus F_2's contrast was also significant for plant height, number of primary branches per plant, number of seeds per capsule, length of capsule, seed yield per plant and harvest index. This indicated that among parents as a group and F_2's as a group showed significant differences and average heterosis existed for most of characters studied. Similar findings for seed yield and its component trait studied were reported by Abd El-Kader *et al.* (2017) [1], Kumari and Ganesamurthy (2017) [14], Virani *et al.* (2017) [25] and Daba *et al.* (2019) [8] in sesame.

Manifestation of heterosis

In the present investigations, most of the characters expressed either high or moderate range of heterosis. An overall appraisal of the Table 1 revealed range of heterobeltiosis and standard heterosis as well as showing number of significant and positive or significant and negative crosses over better parent and standard check for the characters under studied. In case of days to 50 per cent flowering, seventeen crosses exhibited heterobeltiosis in the desired direction, while fifteen crosses showed standard heterosis for earliness. This result was in agreement with the results of Suganthi *et al.* (2016) [24], Virani *et al.* (2017) [25], Daba *et al.* (2019) [8] and Lal *et al.* (2020) [15] in sesame. Whereas, for plant height, fourteen and thirteen crosses exhibited desirable heterosis over better parental value and standard check, respectively. Significant and positive heterosis for this trait was also reported by Patel *et al.* (2016) [21], Suganthi *et al.* (2016) [24], Virani *et al.* (2017) [25] and Nehra *et al.* (2021) [19] in sesame.

The number of cross combinations, which exceeded the better parent values for number of primary branches per plant was six and all the thirty-three significant crosses showed high standard heterosis. Similar findings were noticed by Patel *et al.* (2016) [21], Suganthi *et al.* (2016) [24], Virani *et al.* (2017) [25] and Nehra *et al.* (2021) [19] in sesame. Likewise, for number of capsules per plant, nineteen and eighteen crosses registered heterobeltiosis and standard heterosis, respectively. This result was in agreement with Suganthi *et al.* (2016) [24], Virani *et al.* (2017) [25], Anandan *et al.* (2019) [3] and Nehra *et al.* (2021) [19] in sesame.

With respect to number of seeds per capsule, sixteen cross combinations expressed significant and positive heterobeltiosis, while nine cross combinations showed significant and positive standard heterosis. Monpara and Pawar (2016) [17], Patel *et al.* (2016) [21], Suganthi *et al.* (2016) [24] and Virani *et al.* (2017) [25] in sesame reported significant and positive heterosis for this trait. For length of capsule, twenty crosses exhibited significant heterobeltiosis in desired direction, while nineteen crosses registered significant and positive standard heterosis. The results are in harmony with findings of Monpara and Pawar (2016) [17], Patel *et al.* (2016) [21] and Virani *et al.* (2017) [25] in sesame.

For days to maturity, nine crosses registered significant and negative heterobeltiosis, while twelve cross combinations expressed significant and negative standard heterosis. Monpara and Pawar (2016) [17], Patel *et al.* (2016) [21], Virani *et al.* (2017) [25] and Lal *et al.* (2020) [15] in sesame observed significant and negative heterosis for days to maturity. For seed yield per plant, twenty-two and eight crosses depicted significant and positive heterosis over better parent and standard check, respectively. The results of heterosis for seed yield per plant are in harmony with findings of Anandan *et al.* (2019) [3], Daba *et al.* (2019) [8], Dela and Sharma (2019) [9], Lal *et al.* (2020) [15] and Nehra *et al.* (2021) [19] in sesame.

In case of 1000-seed weight, eighteen and thirteen crosses expressed significant and positive heterobeltiosis and standard heterosis, respectively. Similar findings have been reported by Chaudhari *et al.* (2015) [6], Reddy *et al.* (2015) [22], Virani *et al.* (2017) [25] and Nehra *et al.* (2021) [19] in sesame. For oil content, only four crosses expressed significant and positive heterobeltiosis and this finding was in confirmation with the findings Banerjee and Kole (2011) [4], Patel *et al.* (2016) [21] and Lal *et al.* (2020) [15] in sesame for oil content. With regards to harvest index, fifteen and eleven crosses registered significant heterobeltiosis and standard heterosis, respectively in the desired direction. Similar type of results in desired direction were reported by Anandan *et al.* (2019) [3] and

Chauhan *et al.* (2019) [7] in sesame.

Seed yield per plant being a complex, polygenic trait and is a multiplicative end product of several basic component traits. In order to see comparative assessment of ten best heterobeltiosis crosses for seed yield along with their heterobeltiosis effects for yield components is presented in Table 2. The cross combination, IC-96127 x G.Til-10 recorded the highest heterobeltiosis (82.79 %) with higher mean seed yield per plant (14.20 g) followed by IC-96127 x IC-204169 (64.92 %), AT-345 x G.Til-10 (57.42 %), AT-345 x IC-96127 (55.60 %), AT-345 x AT-375 (47.02 %), AT-338 x IC-96127 (45.10 %), IC-204169 x G.Til-10 (44.64 %), U-76-10 x IC-96127 (40.09 %), AT-375 x IC-96127 (36.78 %) and AT-375 x G.Til-10 (34.35 %) with acceptable mean seed yield per plant.

In the present investigation, the top performing F_1 hybrids over the better parent (Table 2) for seed yield per plant also showed significant heterobeltiosis for other seed yield components. Four and one cross exhibited significant and desirable heterobeltiosis for the characters related to earliness in flowering and maturity, respectively. All the crosses had desirable heterotic effects for harvest index followed by nine crosses for number of capsules per plant; eight crosses for 1000- seed weight; seven crosses for plant height and number of seeds per capsule; six crosses for length of capsule; four crosses for number of primary branches per plant and only one cross for oil content.

Table 3 showed the comparative assessment of ten best standard heterotic crosses for seed yield per plant along with their standard heterotic effects for yield components. The cross combination, AT-345 x G.Til-10 recorded the highest standard heterosis (51.14 %) with highest mean seed yield per plant (14.63 g) followed by AT-345 x IC-96127 (49.38 %), IC-96127 x G.Til-10 (46.66 %), AT-345 x AT-375 (41.15 %), IC-96127 x IC-204169 (22.38 %), IC-204169 x G.Til-10 (16.05 %), AT-375 x IC-96127 (16.01 %), AT-375 x G.Til-10 (13.95 %), AT-345 x IC-204169 (9.26 %) and AT-345 x AT-382 (8.20 %) with acceptable mean seed yield per plant.

Out of ten heterotic crosses over standard check, three heterotic crosses namelyAT-345 x G.Til-10, AT-345 x AT-375 and AT-345 x AT-382 exhibited significant and desirable standard heterosis for days to 50 per cent flowering, while only one cross AT-345 x AT-375 showed significant and desirable standard heterosis for days to maturity. With respect to component traits, seven crosses *viz.,* AT-345 x G.Til-10, AT-345 x IC-96127, IC-96127 x G.Til-10, AT-345 x AT-375, AT-375 x IC-96127, AT-375 x G.Til-10 and AT-345 x IC-204169 had significant and positive standard heterosis for plant height, number of primary branches per plant, number of capsules per plant, number of seeds per capsule, 1000-seed weight and harvest index (except plant height in cross AT-375 x IC-96127 and AT-345 x IC-204169 and number of seeds per capsule in cross AT-375 x G.Til-10). Four crosses showed significant and positive standard heterosis for length of capsule.

While comparing the relationship among heterobeltiosis of seed yield with other traits (Table 2), it was observed that significant and positive association of heterobeltiosis of seed yield was observed with plant height, number of capsules per plant, number of seeds per capsule, 1000-seed weight and harvest index. Similarly, for standard heterosis, significant and positive correlation of standard heterosis of seed yield (Table 3) was reported with plant height, number of primary branches per plant, number of capsules per plant, number of seeds per capsule, 1000-seed weight and harvest index. This indicated that genetic improvement in these characters would increase standard heterosis and heterobeltiosis for seed yield per plant in sesame.

Magnitude of inbreeding depression

The estimation of inbreeding depression provides information about the nature of gene actions involved in the expression of seed yield and its component characters. The heterotic crosses for seed yield as discussed earlier have also exhibited higher values of inbreeding depression. This might be attributed to either dominance effect or dominance x dominance epistatic effect in the F_1 crosses, which dissipate in F_2 generation due to reduction in heterozygosity. This type of behavior was observed in most of the heterotic crosses for different traits as presented in Table 4.

The significant, positive and high inbreeding depression for seed yield per plant were recorded by all the ten crosses. For days to 50 per cent flowering, five crosses *viz.,* IC-96127 x G.Til-10, G.Til-4 x AT-345, AT-345 x AT-375, G.Til-4 x AT-375 and AT-338 x IC-96127 exhibited significant, negative and low to moderate inbreeding depression and for days to maturity, five crosses *viz*., AT-345 x G.Til-10, AT-345 x IC-96127, G.Til-4 x AT-345, IC-204169 x G.Til-10 and AT-338 x G.Til-10 exhibited significant, negative and low inbreeding depression. For plant height, seven crosses *viz*., AT-345 x G.Til-10, IC-96127 x G.Til-10, AT-345 x AT-375, G.Til-4 x AT-375, AT-382 x G.Til-10, AT-338 x IC-96127, IC-204169 x G.Til-10 and AT-338 x G.Til-10; and for number of primary branches per plant six crosses *viz*., AT-345 x G.Til-10, IC-96127 x G.Til-10, G.Til-4 x AT-345, AT-345 x AT-375, AT-382 x G.Til-10, IC-204169 x G.Til-10 and AT-338 x G.Til-10 showed significant, positive and moderate inbreeding depression.

All the crosses (except G.Til-4 x AT-375 and AT-338 x IC-96127) exhibited significant, positive and low to moderate inbreeding depression for number of capsules per plant. Likewise, for number of seeds per capsule, top five crosses showed significant, positive and moderate inbreeding depression. Four crosses *viz*., AT-345 x IC-96127, G.Til-4 x AT-345, AT-345 x AT-375 and IC-204169 x G.Til-10 exhibited significant, positive and moderate inbreeding depression for length of capsule. Similarly, four crosses *viz*., AT-345 x G.Til-10, AT-345 x IC-96127, IC-96127 x G.Til-10 and AT-345 x AT-375 showed significant, positive and moderate inbreeding depression for 1000-seed weight and only one cross AT-345 x AT-375 for oil content. All the crosses registered significant, positive and moderate to high inbreeding depression (except cross G.Til-4 x AT-375 for harvest index).

The results indicated that the pathways for releasing inbreeding depression varied from one cross to the other. Therefore, the present findings revealed that plant height, number of branches per plant, number of capsules per plant, number of seeds per capsule, length of capsule, 1000-seed weight and harvest index were main contributing traits for inbreeding depression in seed yield per plant in sesame. Significant and high inbreeding depression was observed in sesame by Gaikwad and Lal (2010) [11], Banerjee and Kole (2011) [4] and Sapara *et al.* (2018) [23] for seed yield per plant and harvest index. Likewise, Gaikwad and Lal (2010) [11] reported negative inbreeding depression for days to 50 per cent flowering and days to maturity. Gaikwad and Lal (2010) [11], Banerjee and Kole (2011) [4], Sapara *et al.* (2018) [23] and Mori *et al.* (2019) [18] also reported low to moderate inbreeding depression for plant height, number of branches per plant, number of capsules per plant, number of seeds per capsule, length of capsule, 1000-seed weight and oil content. Inbreeding depression of seed yield (Table 4) exhibited significant and positive correlation with plant height, number of capsules per plant, number of seeds per capsule, 1000-seed weight and harvest index which indicated that high to moderate in inbreeding depression of these yield contributing traits will lead to increase inbreeding depression for seed yield per plant in sesame.

Table 1: Range of heterobeltiosis and standard heterosis with number of significant crosses in positive and negative direction over better parent and standard check for various characters in sesame

Sr. No.	Characters	Desirable aspect	Range		Number of crosses with significant heterosis			
			H (%)	SH (%)	H (%)		SH (%)	
					+ ve	-ve	+ ve	-ve
1	Days to 50 per cent flowering	Early	-16.51to 15.65	-20.18 to 19.30	3	17	4	15
2	Plant height (cm)	Long	-12.93 to 24.6	-18.17 to 29.55	14	-2	13	-4
3	Number of primary branches per plant	High	-35.00to 55.26	8.33to 191.67	6	3	33	-
4	Number of capsules per plant	High	-13.76to 21.74	-21.95 to 31.91	19	5	18	8
5	Number of seeds per capsule	High	-14.07 to 24.11	-19.40 to 21.61	16	4	9	6
6	Length of capsule (cm)	Long	-9.39 to 30.35	-10.54 to 43.55	20	-	19	-
7	Days to maturity	Early	-11.72 to 9.68	-14.01 to 7.00	7	9	4	12
8	Seed yield per plant (g)	High	-13.7to 82.79	-42.63 to 51.14	22	-	8	9
9	1000-seed weight (g)	High	-21.65 to 21.15	-22.38 to 14.30	18	10	13	13
10	Oil content (%)	High	-4.72 to 5.95	-8.97 to 4.31	4	1	-	2
11	Harvest index (%)	High	-22.04 to 42.66	-24.11 to 28.17	15	5	11	7

Table 2: Comparative study of ten most heterobeltiosis crosses for seed yield per plant with their heterobeltiosis effects for yield components in sesame

Sr. No.	Crosses	Mean Seed yield per plant (g)	Percent of heterosis over better parent (Heterobeltiosis)										
			Seed yield per plant (g)	Days to 50 per cent flowering	Plant height (cm)	Number of primary branches per plant	Number of capsules per plant	Number of seeds per capsule	Length of capsule (cm)	Days to maturity	1000-seed weight (g)	Oil Content (%)	Harvest index (%)
1	IC-96127 x G.Til-10	14.20	82.79**	0.00	19.22**	13.11	21.74**	19.91**	-1.82	6.18**	14.81**	-1.43	42.66**
2	IC-96127 x IC-204169	11.85	64.92**	-11.29**	16.86**	21.74*	20.10**	24.11**	3.60	4.63*	16.16**	-2.29	21.81**
3	AT-345 x G.Til-10	14.63	57.42**	0.95	24.60**	14.75	19.54**	14.91**	-3.63	-3.97	13.48**	1.47	20.91**
4	AT-345 x IC-96127	14.46	55.60**	3.81	13.47*	21.57*	20.51**	21.66**	30.35**	1.93	8.13	1.54	24.94**
5	AT-345 x AT-375	13.66	47.02**	-10.48**	19.07*	29.41**	5.23*	20.89**	27.54**	-11.72**	12.65**	5.92*	20.94**
6	AT-338 x IC-96127	10.42	45.10**	0.00	15.55**	15.22**	16.65**	10.17	10.86*	1.54	11.78**	2.24	28.24**
7	IC-204169 x G.Til-10	11.23	44.64**	-6.35*	-10.00	8.20	13.03**	0.39	18.25**	3.79	-12.66**	1.31	29.83**
8	U-76-10 x IC-96127	10.06	40.09**	-7.44**	5.23	4.35	2.09	12.70*	26.06**	-3.16	12.46**	-2.13	18.21**
9	AT-375 x IC-96127	11.23	36.78**	-1.77	8.35	13.04	15.29**	16.28**	25.17**	-2.34	14.39*	-1.61	16.49*
10	AT-375 x G.Til-10	11.03	34.35**	-0.88	17.12**	-11.48	17.05**	5.21	-9.39	-1.17	16.95**	3.89	25.34**
Correlation of H (Heterobeltiosis) of seed yield with other traits (n = 36)				0.166	0.597**	0.195	0.671**	0.587**	0.080	0.087	0.474**	-0.022	0.651**

*, ** Significant at 5 % and 1 % levels, respectively

Table 3: Comparative study of ten most standard heterotic crosses for seed yield per plant with their standard heterotic effects for yield components in sesame

Sr. No.	Crosses	Mean Seed yield per plant (g)	Per cent heterosis over standard check (Standard heterosis)										
			Seed yield per plant (g)	Days to 50 per cent flowering	Plant height (cm)	Number of primary branches per plant	Number of capsules per plant	Number of seeds per capsule	Length of capsule (cm)	Days to maturity	1000-seed weight (g)	Oil Content (%)	Harvest index (%)
1	AT-345 x G.Til-10	14.63	51.14**	-7.02*	29.55**	191.67**	29.53**	14.86**	6.14	3.50	14.30**	-0.99	24.04**
2	AT-345 x IC-96127	14.46	49.38**	-4.39	16.07**	158.33**	21.95**	21.61**	43.55**	2.72	8.91*	-0.92	28.17**
3	IC-96127 x G.Til-10	14.20	46.66**	8.77*	23.95**	187.50**	31.91**	13.54*	-5.21	7.00**	10.88*	-6.09**	26.65**
4	AT-345 x AT-375	13.66	41.15**	-17.54**	21.79**	175.00**	6.49*	20.84**	40.46**	-12.06**	13.47**	4.31	24.07**
5	IC-96127 x IC-204169	11.85	22.38**	-3.51	10.17	133.33**	19.05**	17.52**	0.02	5.45*	7.25	-7.80**	8.13
6	IC-204169 x G.Til-10	11.23	16.05*	3.51	-6.42	175.00	22.47**	-7.11	6.80	6.61**	-15.65**	-3.49	13.90*
7	AT-375 x IC-96127	11.23	16.01*	-2.63	9.73	116.67**	14.27**	10.10*	28.45**	-2.72	9.53*	-3.11	13.41*
8	AT-375 x G.Til-10	11.03	13.95*	-1.75	21.76**	125.00**	26.83**	-1.72	-7.02	-1.56	12.95**	2.32	22.03**
9	AT-345 x IC-204169	10.58	9.26	-0.88	10.79	129.17**	7.42**	10.48*	3.78	0.78	10.57*	-4.14	17.11*
10	AT-345 x AT-382	10.02	8.20	-14.91**	8.49	83.33**	8.98**	5.30	36.42**	-9.34	-15.65**	-3.62	-8.20
Correlation of SH (Standard heterosis) of seed yield with other traits (n = 36)				0.126	0.785**	0.798**	0.832**	0.673**	0.293	0.268	0.516**	0.069	0.732**

*, ** Significant at 5 % and 1 % levels, respectively

Table 4: Comparative study of ten crosses involving high inbreeding depression for seed yield per plant with their inbreeding depression for its components traits in sesame

Sr. No.	Crosses	Seed yield per plant (g)	Magnitude of inbreeding depression									
			Days to 50 per cent flowering	Plant height (cm)	Number of primary branches per plant	Number of capsules per plant	Number of seeds per capsule	Length of capsule (cm)	Days to maturity	1000-seed weight (g)	Oil content (%)	Harvest index (%)
1	AT-345 x G.Til-10	33.11**	8.49*	11.09**	24.64**	17.82**	12.31*	-1.75	-7.52**	17.32**	4.00	28.10**
2	AT-345 x IC-96127	32.99**	5.50	1.84	12.50	16.54**	13.27**	25.22**	-7.20**	13.80**	0.82	29.51**
3	IC-96127 x G.Til-10	32.50**	-8.06*	13.95**	18.12**	18.36**	13.87**	2.17	-4.36	13.46**	-0.24	32.06**
4	G.Til-4 x AT-345	32.21**	-18.95**	7.22	30.00**	10.05*	17.18**	10.23*	-9.28**	8.51	0.43	27.76**
5	AT-345 x AT-375	31.28**	-17.02**	10.62*	21.97**	17.84**	13.77**	20.05**	0.44	19.00**	7.00**	29.22**
6	G.Til-4 x AT-375	30.31**	-20.88**	11.59**	-2.84	9.11	5.05	8.01	-3.62	8.74	1.01	12.74
7	AT-382 x G.Til-10	29.75**	14.71**	23.63**	4.55	19.18**	6.90	-1.78	-1.53	-4.89	-1.22	36.01**
8	AT-338 x IC-96127	29.65**	-13.04**	13.30**	30.66**	4.53	9.91	2.29	-1.90	7.23	1.50	31.84**
9	IC-204169 x G.Til-10	27.33**	-1.69	-16.67**	16.29**	9.68*	-8.10	10.42*	-5.47*	8.85	0.85	32.45**
10	AT-338 x G.Til-10	26.08**	9.77**	9.98*	3.64	20.89**	7.18	1.92	-6.42**	5.85	-2.14	31.65**
Correlation of ID (Inbreeding Depression) of seed yield with other traits (n=36)			0.050	0.494**	0.285	0.541**	0.413*	0.149	0.137	0.323*	0.016	0.506**

*, ** Significant at 5 % and 1 % levels, respectively

Conclusion

The highest heterobeltiosis for seed yield per plant was recorded in the cross, IC-96127 x G.Til-10 followed by IC-96127 x IC-204169, AT-345 x G.Til-10 and AT-345 x IC-96127. Whereas, the highest standard heterosis for seed yield per plant was registered by cross AT-345 x G.Til-10 followed by AT-345 x IC-96127, IC-96127 x G.Til-10 and AT-345 x AT-375. High heterosis for seed yield per plant was reflected through high heterosis in plant height, number of primary branches per plant, number of capsules per plant, number of seeds per capsule, 1000-seed weight and harvest index in most of crosses. The crosses with high heterotic values for seed yield per plant and its important attributes also showed moderate to high inbreeding depression. Such crosses could be exploited in future breeding programmers for development of varieties with increased seed yield by genetic improvement of individual trait.

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