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Heterosis for seed yield and its components in sesame (*Sesamum indicum* L.)

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Abstract
An experiment was conducted to know the nature and magnitude of heterosis for seed yield per plant and its eleven yield attributing components. The experimental material used in a study consisted of 37 test entries comprised of 28 hybrids developed from eight diverse parental lines and one standard check (G.TIL 4). The crosses were made in 8 x 8 diallel fashion without reciprocals, to obtain sufficient seeds of the 28 F_1 hybrids. The high, significant and positive standard heterosis for seed yield per plant and some of its component traits were recorded in the crosses viz. AT 347 x G.TIL 4, AT 377 x AT 396, AT 396 x AT 404 and AT 376 x AT 377, Such crosses could be exploited for practical heterosis breeding programme in sesame. On the basis of per se performance and high heterotic response involved in the expression of yield and its components, the four crosses viz., AT 347 x G.TIL 4, AT 377 x AT 396, AT 396 x AT 404 and AT 376 x AT 377 appeared to be most superior. These hybrids recorded 22.86, 22.77, 20.51 and 17.17 per cent higher yield respectively, over standard parent (G.TIL 4) in desirable direction for seed yield and some components traits of seed yield. Therefore, these four crosses could be exploited for heterosis breeding programme to boost the seed yield in sesame.

Keywords: Sesame, heterosis, heterobeltiosis, standard heterosis

Introduction

Sesamum indicum L. is known as sesame, til, gingelly, simsim, gergelim, etc. Sesame (*Sesamum indicum* L.) is a member of the order tubiflorae and family pedaliaceae which consists of 16 genera and about 36 species, of which several can be crossed with *Sesamum indicum* L. and a few are also cultivated for their seeds. It is self- pollinated annual diploid (2n=26) herb. Seed is the economical part which contains oil and protein. Although it originated in Africa, it spread early through West Asia to India, China and Japan which became secondary distribution centers themselves (Weiss, 1983) [35]. Sesame seeds are rich source of linoleic acid, vitamin E, A, B_1 and B_2; minerals including Ca and P. Sesame cake is nutritious feed for dairy cattle and it can also be used as fertilizer (Ashri, 1998) [2]. Commercial exploitation of heterosis is feasible only if the means of producing hybrid seeds economically could be made available. Commercial exploitation of heterosis was confined to self- pollinated group of plants with the success of hybrid rice, tomato etc. Efforts are under way to develop hybrids in sesame because in self-pollinated crop like sesame there is good scope for exploitation of heterosis.

Materials and Methods

The experimental material used in a study consisted of 37 test entries comprised of 28 hybrids developed from eight diverse parental lines and one standard check (G.TIL 4). The genotypes were AT 345, AT 347, AT 376, AT 377, AT 396, AT 404, G.TIL 3, G.TIL 4 and seeds of genotypes used as parents were planted at Sagdividi Farm, Department of Seed Science and Technology, Junagadh Agricultural University, Junagadh, during *kharif*- 2017. The crosses were made in 8 x 8 diallel fashion without reciprocals, to obtain sufficient seeds of the 28 F_1 hybrids and an experimental material was evaluated during summer-2018 at Instructional Farm, Department of Agronomy, Junagadh Agricultural University, Junagadh. Five plants from each plot were randomly selected for recording the observations on the following traits *viz.,* days to 50% flowering, plant height (cm), height to first capsule (cm), number of branches per plant, number of internodes per plant, length of capsule (cm), width of capsule (cm), number of capsules per plant, number of seeds per capsule, 1000- seed weight (g) and seed yield per plant (g). The analysis of variance was performed to test the significance of difference among the genotypes for all the characters following fixed effect model as suggested by Panse and Sukhatme (1985) [21]. Heterobeltiosis was estimated as per the procedure given by Fonseca and Patterson (1968) [6] using mean values for various characters over better parents. Standard heterosis referred as the superiority of F_1 over standard hybrid G.TIL 4 and it was estimated as per the formula given by Meredith and Bridge (1972) [14] for various characters over standard check.

Results and Discussion

The analysis of variance was performed to test the differences among the genotypes, parents, hybrids and parents *vs*. hybrids for all the eleven characters studied and is presented in Table 1. The analysis of variance for experimental design revealed that mean square due to genotypes and hybrids were significant for all the traits indicated sufficient amount of genetic variability present in material used. The mean square due to parents was also highly significant except width of capsule for characters studied. The mean square due to parents *vs* hybrids was also significant for all the traits studied except number of branches per plant, number of internodes per plant, length of capsule and seed yield per plant indicated substantial amount of heterotic effects in cross combinations for various traits.

In any plant breeding programme, the *per se* performance is an important criterion in the choice of parents and hybrids. In the present study, parents AT 345, G.TIL 4 and AT 377 and such crosees *viz.* AT 347 x G.TIL 4, AT 377 x AT 396, AT 396 x AT 404 and AT 376 x AT 377 exhibited high *per se* performance for one or more traits (Table 3). In the present investigation, seed yield per plant was found the most heterotic trait as it ranged from -35.63 to 31.26 per cent and -21.19 to 22.86 per cent over better parent and standard check, respectively (Table 4). Out of 28 hybrids, 3 and 4 crosses manifested significant and positive heterosis over better parent and standard check, respectively for seed yield per plant (Table 4). The cross AT 377 x AT 396 showed highest significant and positive heterobeltiosis (31.26%) and cross AT 347 x G.TIL 4 showed highest and positive standard heterosis (22.86%) for seed yield per plant along with maximum *per se* performance of AT 347 x G.TIL 4 (22.86%) followed by cross AT 377 x AT 396 (22.77%), AT 396 x AT 404 (20.51%) and AT 376 x AT 377 (17.17%). These four hybrids had also recorded high seed yield per plant on the basis of standard heterosis (Table 3). Similar findings have been reported by Jadhav and Mohrir (2013) [8], Jatothu *et al*. (2013) [9], Parimala *et al*. (2013) [22], Sakhiya (2013) [28], Salunke *et al*. (2013) [29], Vavdiya *et al*. (2014) [34], Chaudhari *et al*. (2015) [4], Kumar *et al*. (2015) [12], Nayak (2016) [19], Tripathy *et al*. (2016a) [33], Imran *et al.* (2017) [7], Karande *et al*. (2018) [10] and Myint (2018) [18].

In sesame, earliness in flowering is a desirable trait. Significant and desirable (negative) estimates of heterobeltiosis were observed in eleven cross, out of 28 crosses and none of hybrid exhibited significant and negative standard heterosis (Table 4). The heterobeltiosis ranged from -31.95 per cent (AT 345 x AT 396) to 24.19 per cent (AT 347 x G.TIL 4). The highest desirable heterobeltiosis was recorded in the cross AT 345 x AT 396 (-31.95%). The standard heterosis values varied from -8.01 per cent (AT 345 x AT 396) to 23.18 per cent (AT 347 x G.TIL 4 and AT 377 x AT 404) (Table 2). Negative and desirable estimation of heterosis for days to 50 per cent flowering was also reported by Mishra and Yadav (1996) [15], Alam *et al*. (1999) [1], Durga and Raghunandham (2001) [5] and Sumathi and Muralidharan (2008) [31] in sesame.

For plant height, Out of 28 crosses, thirteen crosses showed significant and positive heterotic effect over better parent, while eight hybrids showed significant and positive heterotic effect over standard check (Table 4). The estimate of heterobeltiosis for this trait ranged from -57.84 per cent (AT 345 x AT 404) to 32.58 per cent (AT 347 x G.TIL 3). The hybrid AT 347 x G.TIL 3 exhibited the highest heterobeltiosis (32.58%) in desirable direction followed by AT 376 x G.TIL 3 (31.16%) and AT 347 x AT 377 (29.09%). The estimate of standard heterosis for this trait ranged from -49.32 per cent (AT 345 x AT 404) to 19.68 per cent (AT 347 x G.TIL 4). The hybrid AT 347 x G.TIL 4 exhibited the highest significant and positive standard heterosis (19.68%) followed by AT 396 x G.TIL 3 (17.15%) and AT 377 x AT 404 (16.87%) (Table 2). Susmita and Sen (1992) [32], Ragiba and Reddy (2000a) [25], Reddy *et al*. (2001) [27], Krishnaiah *et al*. (2003) [11], Kumar and Ganesan (2004) [13], Mothilal *et al*. (2005) [17], Jadhav and Mohrir (2013) [8], Parimala *et al*. (2013) [22] and Sakhiya (2013) [28] also observed significant positive heterosis for plant height in sesame.

For height to first capsule, Significant and desirable (negative) heterobeltiosis were observed in five cross, out of 28 crosses and six cross exhibited significant and negative standard heterosis (Table 4).The estimates of heterobeltiosis for this trait ranged from -24.97 per cent (AT 345 x G.TIL 3) to 36.69 per cent (AT 376 x AT 377). The hybrid AT 345 x G.TIL 3 (-24.97) exhibited significant heterobeltiosis in desirable direction. The estimate of standard heterosis for this trait ranged from -25.03 per cent (AT 347 x AT 404) to 23.30 per cent (G.TIL 3 x G.TIL 4). The hybrid AT 347 x AT 404 exhibited the highest significant and desirable (negative) standard heterosis (-25.03%) followed by AT 376 x AT 404 (-20.20%) and AT 347 x AT 396 (-20.12%) (Table 2). Significant negative heterosis for height to first capsule has also been reported by Ragiba and Reddy (2000a) [25], Durga and Raghunandham (2001) [5], Jadhav and Mohrir (2013) [8] and Sakhiya (2013) [28].

For number of branches per plant, two hybrids over better parent and three hybrids over standard check exhibited significant and positive heterosis (Table 4). The estimates of heterobeltiosis ranged from -27.71 per cent (AT 396 x G.TIL 4) to 17.99 per cent (AT 345 x G.TIL 3). The hybrid AT 345 x G.TIL 3 exhibited highest desirable heterobeltiosis (17.99%) followed by AT 376 x AT 377 (16.08%). Heterotic effects over standard check ranged from -19.57 per cent (AT 345 x AT 347) to 23.52 per cent (AT 347 x G.TIL 4). The hybrid AT 347 x G.TIL 4 exhibited highest magnitude of standard heterosis (23.52%) followed by AT 376 x AT 377 and AT 377 x AT 396 (16.08%) (Table 2). High magnitude of desirable heterosis for this trait was also reported by Mishra *et al*. (2008) [16], Prajapati *et al*. (2010a) [24], Rao (2011) [26], Padmasundari and Kamala (2012) [20], Jatothu *et al.* (2013) [9], Parimala *et al*. (2013) [22], Sakhiya (2013) [28] and Tripathy *et al*. (2016a) [33].

For number of internodes per plant, four hybrids over better parent and three hybrids over standard check exhibited significant and positive heterosis (Table 4). The estimates of heterobeltiosis ranged from -34.78 per cent (AT 345 x AT 376) to 32.70 per cent (AT 347 x G.TIL 3). The hybrid AT 347 x G.TIL 3 exhibited highest desirable heterobeltiosis (32.70%) followed by AT 377 x AT 396 (19.80%) and AT 347 x AT 377 (16.87%). Heterotic effects over standard check ranged from -29.08 per cent (AT 345 x AT 376) to 17.18 per cent (AT 347 x G.TIL 4). The hybrid AT 347 x G.TIL 4 exhibited highest magnitude of standard heterosis (17.18%) followed by AT 396 x G.TIL 3 (10.59%) (Table 2). Significant positive heterosis for number of internodes per plant has also been reported by Sakhiya (2013) [28].

For length of capsule, seven hybrids over better parent and none hybrids over standard check exhibited significant and positive heterosis (Table 4). The estimates of heterobeltiosis ranged from -29.53 per cent (AT 345 x AT 396) to 17.15 per cent (AT 376 x AT 404). The hybrid AT 376 x AT 404 (17.15%) exhibited highest desirable heterobeltiosis followed by AT 347 x AT 377 (14.96%), AT 404 x G.TIL 3 (13.64%) and AT 376 x AT 377 (13.39%). The standard heterosis varied from -25.54 per cent (AT 396 x AT 404) to 6.11 per cent (AT 347 x G.TIL 4) (Table 2). Significant positive heterosis for length of capsule has also been reported by Reddy *et al*. (2001) [27], Krishnaiah *et al*. (2003) [11], Kumar and Ganesan (2004) [13], Prajapati *et al*. (2010a) [24], Jadhav and Mohrir (2013) [8], Jatothu *et al.* (2013) [9] and Sakhiya (2013) [28].

For width of capsule, none hybrid over better parent and one hybrid over standard check exhibited significant and positive heterosis (Table 4).The estimates of heterobeltiosis ranged from -12.65 per cent (G.TIL 3 x G.TIL 4) to 2.56 per cent (AT 377 x AT 404 and AT 404 x G.TIL 4). None of the cross exhibited significant and positive heterobeltiosis for this trait. The standard heterosis varied from -10.92 per cent (AT 396 x G.TIL 4) to 6.26 per cent (AT 404 x G.TIL 4). The hybrid AT 404 x G.TIL 4 (6.26%) exhibited highest magnitude of standard heterosis in desirable direction (Table 2). Significant positive heterosis for width of capsule has also been reported by Sakhiya (2013) [28].

For number of capsules per plant, out of 28 crosses, seven crosses showed significant and positive heterobeltiosis, while seven hybrids exhibited significant and positive standard heterosis (Table 4). The magnitude of heterobeltiosis varied from -39.30 per cent (AT 396 x G.TIL 4) to 28.98 per cent (G.TIL 3 x G.TIL 4). The highest, significant and positive heterobeltiosis was observed in the cross G.TIL 3 x G.TIL 4 (28.98%). The spectrum of variation for standard heterosis was from -27.75 per cent (AT 345 x AT 347) to 28.99 per cent (AT 396 x G.TIL 4). The hybrid AT 396 x G.TIL 4 ranked first by expressing the highest standard heterosis (28.99%) followed by AT 347 x AT 396 (23.71%) and AT 347 x AT 404 (18.78%) (Table 2). Similar findings have been reported by Banerjee and Kole (2010) [3], Prajapati *et al*. (2010a) [24], Padmasundari and Kamala (2012) [20], Jadhav and Mohrir (2013) [8], Parimala *et al*. (2013) [22], Sakhiya (2013) [28], Tripathy *et al*. (2016a) [33] and Imran *et al*. (2017) [7] that supported the findings.

For number of seeds per capsules, out of 28 crosses, significant and positive estimates of heterobeltiosis and standard heterosis were displayed in fourteen and eight crosses, respectively (Table 4). The heterobeltiosis ranged from -37.79 per cent (AT 345 x AT 347) to 50.97 per cent (AT 376 x AT 404). The hybrid AT 376 x AT 404 exhibited highest magnitude of heterobeltiosis (50.97%) followed by AT 404 x G.TIL 3 (39.17%) and AT 347 x AT 377 (37.82%) in desirable direction. The standard heterosis values varied from -32.72 per cent (AT 345 x AT 347) to 17.41 per cent (AT 347 x AT 377). The hybrid AT 347 x AT 377 exhibited highest magnitude of standard heterosis (17.41%) followed by AT 377 x G.TIL 4 (17.40%) (Table 2). Similar findings have been reported by Patel (1993) [23], Mishra and Yadav (1996) [15], Reddy *et al*. (2001) [27], Krishnaiah *et al*. (2003) [11], Kumar and Ganesan (2004) [13], Mothilal *et al*. (2005) [17], Singh *et al*. (2007) [30], Mishra *et al*. (2008) [16], Sumathi and Muralidharan (2008) [31], Banerjee and Kole (2010) [3], Prajapati *et al*. (2010a) [24], Jatothu *et al*. (2013) [9] and Sakhiya (2013) [28].

For 1000-seed weight, the estimates of heterosis over better parent showed that seven out of 28 crosses had significant and positive heterobeltiosis and nine cross combination exhibited significant and positive heterosis over standard check (Table 4). The heterobeltiosis varied from -24.54 per cent (AT 345 x AT 347) to 17.40 per cent (AT 347 x AT 377). The cross AT 347 x AT 377 exhibited highest magnitude of heterobeltiosis (17.40%) followed by AT 376 x AT 396 (15.59%) and AT 377 x G.TIL 3 (14.75%) in desirable direction. The estimates of standard heterosis ranged from -13.61 per cent (AT 345 x AT 347) to 17.75 per cent (AT 347 x AT 377). Hybrid AT 347 x AT 377 (17.75%) showed the highest standard heterosis in desirable direction followed by AT 376 x AT 396 (16.27%) and AT 377 x G.TIL 3 (15.09%) (Table 2). Similar findings have been reported by Susmita and Sen (1992) [32], Patel (1993) [23], Reddy *et al*. (2001) [27], Krishnaiah *et al*. (2003) [11], Kumar and Ganesan (2004) [13], Mothilal *et al*. (2005) [17], Singh *et al*. (2007) [30], Mishra *et al*. (2008) [16], Banerjee and Kole (2010) [3], Padmasundari and Kamala (2012) [20], Jadhav and Mohrir (2013) [8], Sakhiya (2013) [28] and Imran *et al*. (2017) [7].

For, seed yield per plant, Out of 28 crosses, three hybrids over better parent and four hybrids over standard check exhibited significant and positive heterosis (Table 4). The estimates of heterobeltiosis ranged from -35.63 per cent (AT 396 x G.TIL 4) to 31.26 per cent (AT 377 x AT 396). The hybrid AT 377 x AT 396 exhibited the highest heterobeltiosis (31.26%) in desirable direction followed by AT 376 x AT 377 (28.66%) and AT 377 x G.TIL 4 (17.70%). The spectrum of variation for standard heterosis was from -21.19 per cent (AT 345 x AT 347) to 22.86 per cent (AT 347 x G.TIL 4). The hybrid AT 347 x G.TIL 4 ranked first by expressing the highest standard heterosis (22.86%) followed by AT 377 x AT 396 (22.77%) and AT 396 x AT 404 (20.51%) (Table 2). Significant and positive heterosis and heterobeltiosis for seed yield per plant in sesame have been reported by Padmasundari and Kamala (2012) [20], Jadhav and Mohrir (2013) [8], Jatothu *et al*. (2013) [9], Parimala *et al*. (2013) [22], Sakhiya (2013) [28], Salunke *et al*. (2013) [29], Vavdiya *et al*. (2014) [34], Chaudhari *et al*. (2015) [4], Kumar *et al*. (2015) [12], Nayak (2016) [19], Tripathy *et al*. (2016a) [33], Imran *et al.* (2017) [7], Karande *et al*. (2018) [10] and Myint (2018) [18].

Table 1: Analysis of variance for experimental design for different characters in sesame

Source	d.f.	Days to 50% flowering	Plant height (cm)	Height to first capsule	Number of branches per plant	Number of internodes per plant
Replications	2	36.23**	52.09	0.11	0.08	4.39
Genotypes	35	43.99**	556.49**	122.27**	0.49**	29.16**
Parents	7	82.45**	479.54**	155.42**	0.67**	27.57**
Hybrids	27	34.61**	552.22**	100.57**	0.45**	30.65**
P. *vs* H.	1	28.06*	1210.29**	475.81**	0.43	0.00
Error	70	4.91	19.31	8.02	0.14	1.74
Total	107	18.28	196.63	45.24	0.25	10.76

Source	d.f.	Length of capsule (cm)	Width of capsule (cm)	Numbers of capsules per plant	Number of seeds per capsule	1000-seed weight (g)	Seed yield per plant (g)
Replications	2	0.035	0.007*	87.61*	1.17	0.01	0.33
Genotypes	35	0.253**	0.002*	289.70**	212.57**	0.17**	5.13**
Parents	7	0.325**	0.001	476.29**	178.48**	0.14**	9.12**
Hybrids	27	0.242**	0.002*	246.33**	201.88**	0.17**	4.28**
P. *vs* H.	1	0.022	0.009*	154.54**	739.76**	0.22**	0.27
Error	70	0.018	0.001	21.42	9.25	0.02	0.58
Total	107	0.095	0.002	110.41	75.60	0.07	2.07

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

Table 2: Estimates of heterobeltiosis (H) and standard heterosis (SH) for different characters in sesame

S. no.	Hybrids	Days to 50% flowering		Plant height (cm)		Height to first capsule (cm)		Number of branches per plant	
		H (%)	SH (%)	H (%)	SH (%)	H (%)	SH (%)	H (%)	SH (%)
1	AT 345 X AT 347	-23.66**	3.19	-31.26**	-17.37**	-23.25**	-16.70**	-23.66**	-19.57*
2	AT 345 X AT 376	-22.47**	4.80	-21.71**	-5.89	3.01	11.79*	-10.18	-5.36
3	AT 345 X AT 377	-24.24**	2.40	-13.46**	4.03	-7.45	0.44	5.08	10.72
4	AT 345 X AT 396	-31.95**	-8.01	-24.65**	-9.42*	-16.49**	-9.37	-18.57*	-14.20
5	AT 345 X AT 404	-20.11**	7.99	-57.84**	-49.32**	-2.70	5.59	-18.57*	-14.20
6	AT 345 X G.TIL 3	-19.53**	8.78*	-16.11**	0.84	-24.97**	-16.85**	17.99*	7.24
7	AT 345 X G.TIL 4	-28.99**	-4.00	-17.88**	-1.29	-14.85**	-7.59	-9.23	5.36
8	AT 347 X AT 376	-4.76	-4.00	5.79	-12.76**	21.23*	-19.39**	1.63	0.00
9	AT 347 X AT 377	-13.13**	-4.79	29.09**	6.87	13.28*	1.27	7.24	7.24
10	AT 347 X AT 396	-6.44	-7.19	-12.09**	-18.28**	-9.52	-20.12**	-14.68*	-6.9
11	AT 347 X AT 404	8.88*	7.99	-20.09**	-26.89**	-13.28	-25.03**	-5.45	-6.9
12	AT 347 X G.TIL 3	-7.35	0.79	32.58**	9.32*	-0.68	10.06	8.99	7.24
13	AT 347 X G.TIL 4	24.19**	23.18**	20.42**	19.68**	10.03	10.06	6.23	23.52**
14	AT 376 X AT 377	0.72	10.39*	28.64**	6.50	36.69**	22.20**	16.08*	16.08*
15	AT 376 X AT 396	-1.59	-0.82	7.19	-0.37	21.94**	7.64	-1.84	0.00
16	AT 376 X AT 404	2.38	3.19	-12.31**	-19.76**	-7.79	-20.20**	13.82	3.75
17	AT 376 X G.TIL 3	-11.76**	-4.00	31.16**	2.85	-7.49	9.99	13.82	3.75
18	AT 376 X G.TIL 4	11.12*	11.99**	7.68	7.01	10.81	10.84	-15.24*	-1.6
19	AT 377 X AT 396	-12.41**	-4.00	23.83**	15.10**	22.70**	9.69	13.94	16.08*
20	AT 377 X AT 404	12.39**	23.18**	27.74**	16.87**	5.90	-5.32	0.00	0.00
21	AT 377 X G.TIL 3	-0.74	8.78*	26.05**	4.36	-10.60*	-0.92	9.11	9.11
22	AT 377 X G.TIL 4	-13.14**	-4.79	16.96**	16.23**	8.96	8.99	-3.00	12.60
23	AT 396 X AT 404	6.46	5.59	-2.42	-9.29*	7.55	-5.05	-8.6	-6.9
24	AT 396 X G.TIL 3	13.33**	-6.40	26.04**	17.15**	3.22	14.38*	-3.42	-11.6
25	AT 396 X G.TIL 4	0.80	-0.81	12.25**	11.55**	16.09*	16.12**	-27.71**	-16.08*
26	AT 404 X G.TIL 3	-0.73	7.99	18.07**	8.63	1.27	12.23*	17.67	-5.36
27	AT 404 X G.TIL 4	8.88*	7.99	-3.14	-3.73	18.11*	18.14**	-15.24*	-1.6
28	G.TIL 3 X G.TIL 4	-6.61	1.58	16.49**	15.76**	11.26*	23.30**	-18.48*	-5.36
	SE±	1.81		3.59		2.31		0.31	

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

S. No.	Hybrids	Number of internodes per plant		Length of capsule (cm)		Width of capsule (cm)		Number of capsules per plant	
		H (%)	SH (%)	H (%)	SH (%)	H (%)	SH (%)	H (%)	SH (%)
1	AT 345 X AT 347	-28.94**	-22.73**	-29.19**	-24.10**	-8.53**	-1.31	-30.26**	-27.75**
2	AT 345 X AT 376	-34.78**	-29.08**	-23.46**	-17.98**	-7.31*	0.00	-21.68**	-18.86**
3	AT 345 X AT 377	-8.28*	-0.28	-4.70	2.16	-4.88	2.63	-2.21	1.32
4	AT 345 X AT 396	-28.72**	-22.5**	-29.53**	-24.46**	-4.88	2.63	-26.27**	-23.62**
5	AT 345 X AT 404	-24.08**	-17.46**	-27.18**	-21.94**	-9.76**	-2.63	-23.55**	-20.80**
6	AT 345 X G.TIL 3	-18.02**	-10.87*	-13.75**	-7.55	-8.53**	-1.31	-15.73**	-12.67*
7	AT 345 X G.TIL 4	-2.44	-6.35	-5.63	2.52	-3.66	3.95	-19.20**	-5.47
8	AT 347 X AT 376	6.31	-6.34	2.8	-7.55	-2.5	2.63	11.32	-9.96*
9	AT 347 X AT 377	16.87**	4.48	14.96**	5.03	-3.75	1.32	9.85	-2.74
10	AT 347 X AT 396	-9.93*	-18.25**	-12.69**	-18.34**	-7.5*	-2.63	-7.67	23.71**
11	AT 347 X AT 404	-7.04	-23.01**	-6.00	-15.46**	-11.25**	-9.33**	0.42	18.78**
12	AT 347 X G.TIL 3	32.70**	7.42	12.00**	0.72	-1.25	3.95	24.39**	0.61
13	AT 347 X G.TIL 4	7.50	17.18**	-2.32	6.11	0.00	5.26	-1.05	15.77**
14	AT 376 X AT 377	12.42*	0.51	13.39**	3.60	-5.06	-1.31	14.22*	1.14
15	AT 376 X AT 396	-3.80	-12.69**	0.38	-6.2	-2.53	1.32	-1.28	18.67**
16	AT 376 X AT 404	-12.29*	-22.73**	17.15**	0.72	-5.06	-1.31	15.89*	-10.67*
17	AT 376 X G.TIL 3	-7.20	-18.25**	8.79	-6.47	-1.26	2.63	9.72	15.42**
18	AT 376 X G.TIL 4	-24.53**	-17.73**	-12.58**	-5.03	-3.79	0.00	-15.36**	-0.98
19	AT 377 X AT 396	19.80**	8.73	13.07**	5.8	1.28	3.95	23.58**	9.42
20	AT 377 X AT 404	-7.37	-17.18**	-1.18	-9.71*	2.56	5.26	4.97	-7.05
21	AT 377 X G.TIL 3	-3.55	-13.76**	10.63*	1.08	-8.86**	-5.26	12.53*	-0.4
22	AT 377 X G.TIL 4	-12.37**	-4.48	-3.97	4.32	-10.12**	-6.58*	-9.54*	5.81

23	AT 396 X AT 404	-17.80**	-25.39**	-20.38**	-25.54**	-6.41	-3.95	-9.09	-25.37**
24	AT 396 X G.TIL 3	-1.48	10.59*	5.77	-1.08	-5.06	-1.31	15.90*	-4.22
25	AT 396 X G.TIL 4	-26.46**	-19.84**	-27.48**	-21.22**	-8.97**	-10.92**	-39.30**	28.99**
26	AT 404 X G.TIL 3	-25.70**	2.10	13.64**	-10.07*	-1.26	2.63	11.79	-22.29**
27	AT 404 X G.TIL 4	-9.97*	-1.86	-12.58**	-5.04	2.56	6.26*	-16.33**	-2.11
28	G.TIL 3 X G.TIL 4	-0.25	9.87*	-13.58**	-8.63*	-12.65**	-9.21**	28.98**	16.91**
	SE±	1.08		0.11		0.02		3.78	

S. No.	Hybrids	Number of seeds per capsule		1000-seed weight (g)		Seed yield per plant (g)	
		H (%)	SH (%)	H (%)	SH (%)	H (%)	SH (%)
1	AT 345 X AT 347	-37.79**	-32.72**	-24.54**	-13.61**	-31.89**	-21.19**
2	AT 345 X AT 376	-31.28**	-25.68**	-15.76**	-3.55	-24.85**	-13.05*
3	AT 345 X AT 377	-11.08*	-3.83*	-9.04**	4.14	-13.66*	-0.09
4	AT 345 X AT 396	-31.97**	-26.42**	-11.87**	0.89	-31.04**	-20.21**
5	AT 345 X AT 404	-31.28**	-25.68**	-11.63**	1.18	-30.62**	-19.72**
6	AT 345 X G.TIL 3	-22.72**	-16.43**	-11.11**	1.78	-17.47**	-4.51
7	AT 345 X G.TIL 4	2.52	10.87*	-6.72*	6.80*	-20.59**	2.55
8	AT 347 X AT 376	24.81**	2.46	6.25	5.62	3.16	-7.16
9	AT 347 X AT 377	37.82**	17.41**	17.40**	17.75**	8.84	-0.88
10	AT 347 X AT 396	9.68	-4.94	4.70	5.33	-9.65	-15.50*
11	AT 347 X AT 404	19.11**	-2.22	6.55	5.92	-5.01	-14.52*
12	AT 347 X G.TIL 3	27.84**	4.94	7.74*	7.10*	9.38	-1.57
13	AT 347 X G.TIL 4	5.12	11.35*	6.11	13.10**	-4.86	22.86**
14	AT 376 X AT 377	34.93**	14.94**	2.65	2.96	28.66**	17.17**
15	AT 376 X AT 396	17.09**	1.48	15.59**	16.27**	-1.36	-7.75
16	AT 376 X AT 404	50.97**	16.67**	8.53*	5.32	12.12	-1.96
17	AT 376 X G.TIL 3	27.96**	-1.11	7.62*	13.01*	5.16	-8.05
18	AT 376 X G.TIL 4	-1.40	4.44	6.11	9.43*	-26.82**	-5.5
19	AT 377 X AT 396	30.06**	12.72**	3.82	4.43	31.26**	22.77**
20	AT 377 X AT 404	22.17**	4.07	4.12	4.43	3.88	-5.4
21	AT 377 X G.TIL 3	31.30**	11.85*	14.75**	15.09**	10.02	0.19
22	AT 377 X G.TIL 4	10.84*	17.40**	6.94*	13.90**	17.70**	6.28
23	AT 396 X AT 404	-16.94**	-28.01**	-7.64*	-7.64*	15.00	20.51**
24	AT 396 X G.TIL 3	12.54*	-2.46	2.05	2.66	2.31	-4.31
25	AT 396 X G.TIL 4	-23.42**	-18.89**	-11.38**	-5.62	-35.63**	-16.88**
26	AT 404 X G.TIL 3	39.17**	0.00	3.99	0.29	8.77	-8.73
27	AT 404 X G.TIL 4	-4.67	0.10	-3.33	2.96	-25.76**	-4.12
28	G.TIL 3 X G.TIL 4	-15.85**	-10.87*	-8.05*	-2.07	-28.65**	-7.85
	SE±	2.48		0.11		0.62	

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

Table 3: Four most heterotic crosses (standard heterosis) for seed yield per plant along with *per se* performance and their heterotic effects for component characters in sesame

S. No.	Crosses	Mean seed yield per plant (g)	Seed yield per plant (g)	Plant height (cm)	Number of branches per plant
1.	AT 347 x G.TIL 4	9.63	22.86**	19.68**	23.52**
2.	AT 377 x AT 396	9.53	22.77**	15.10**	16.08*
3.	AT 396 x AT 404	8.55	20.51**	-9.29*	-6.90
4.	AT 376 x AT 377	9.28	17.17**	6.50	16.08*

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

S. No.	Crosses	Number of internodes per plant	Number of capsules per plant	Number of seeds per capsule	1000-seed Weight (g)
1.	AT 347 x G.TIL 4	17.18**	15.77**	11.35*	13.10**
2.	AT 377 x AT 396	8.73	9.42	12.72**	4.43
3.	AT 396 x AT 404	-25.39**	-25.37**	-28.01**	-7.64
4.	AT 376 x AT 377	0.51	1.14	14.94**	2.96

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

Table 4: Magnitude of heterobeltiosis (H) and standard heterosis (SH) in sesame

S. No.	Characters	Range of heterosis (%)		Number of crosses with significant heterosis			
		H (%)	SH (%)	H (%)	H (%)	SH (%)	SH (%)
				+Ve	-Ve	+Ve	-Ve
1.	Days to 50% flowering	-31.95 to 24.19	-8.01 to 23.18	6	11	6	0
2.	Plant height (cm)	-57.84 to 32.58	-49.32 to 19.68	13	10	8	8
3.	Height to first capsule (cm)	-24.97 to 36.69	-25.03 to 23.30	8	5	7	6
4.	Number of branches per plant	-27.71 to 17.99	-19.57 to 23.52	2	8	3	2
5.	Number of internodes per plant	-34.78 to 32.70	-29.08 to 17.18	4	14	3	15
6.	Length of capsule (cm)	-29.53 to 17.15	-25.54 to 6.11	7	11	0	11
7.	Width of capsule (cm)	-12.65 to 2.56	-10.92 to 6.26	0	10	1	4

8.	Number of capsules per plant	-39.30 to 28.98	-27.75 to 28.99	7	10	7	9
9.	Number of seeds per capsule	-37.79 to 50.97	-32.72 to 17.41	14	9	8	9
10.	1000-seed weight (g)	-24.54 to 17.40	-13.61 to 17.75	7	10	9	2
11	Seed yield per plant (g)	-35.63 to 31.26	-21.19 to 22.86	3	11	4	7

Conclusion

From the results and discussion, it can be concluded that considerable heterobeltiosis and standard heterosis observed for seed yield and other associated characters suggested the presence of large genetic diversity among the parents and also unidirectional distribution of allelic constitution contributing towards desirable heterosis in the present material. On the basis of *per se* performance and heterotic response involved in the expression of yield and its components, the four crosses *viz.*, AT 347 x G.TIL 4, AT 377 x AT 396, AT 396 x AT 404 and AT 376 x AT 377 appeared to be most superior. These hybrids recorded 22.86, 22.77, 20.51 and 17.17 per cent higher yield respectively, over standard parent (G.TIL 4) in desirable direction for seed yield and some components traits of seed yield. Therefore, these four crosses could be exploited for heterosis breeding programme to boost the seed yield in sesame.

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