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Research Article

Heterosis for yield and its components in sesame [*Sesamum indicum* L.] over environments

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Abstract

A set of diallel crosses involving 9 parents was made in sesame to measure the extent of heterosis over better parent and standard heterosis for yield and yield contributing characters under four different environments. The results showed that AT 238 × GT 1 (90.70 %), AT 255 × Nesadi Selection (82.91 %) and AT 164 × AT 238 (76.29 %) in E_1; AT 238 × GT 1 (109.97 %), AT 255 × Nesadi Selection (103.94 %) and AT 164 × AT 238 (98.34 %) in E_2; AT 255 × Nesadi Selection (57.24 %), AT 238 × GT 1 (45.27 %) and AT 164 × AT 238 (40.45 %) in E_3; AT 238 × GT 1 (70.35 %), AT 255 × Nesadi Selection (67.39 %) and AT 164 × AT 238 (65.01 %) in E_4; and AT 238 × GT 1 (94.43 %), AT 255 × Nesadi Selection (94.24 %) and AT 164 × AT 238 (83.30 %) in pooled over environments were the best three cross combinations with respect to heterobeltiosis. None of the cross combination noted significant and positive standard heterosis in E_3 and E_4 environment, while AT 238 × AT 345 (15.48 %), AT 282 × GT 10 (14.83 %) and AT 238 × GT 1 (13.28 %) in E_1 and AT 238 × AT 345 (41.23 %), AT 282 × GT 10 (26.64 %), AT 238 × GT 1 (24.73%) and AT 164 × AT 238 (18.45 %) in E_2 environment manifested the significant and positive standard heterosis. On pooled basis, AT 238 × AT 345 (11.69 %) was the best cross manifested significant and positive standard heterosis for seed yield per plant. This cross also manifested significant standard heterosis in desired direction for yield components like number of branches per plant, height to first capsule and biological yield per plant. Therefore, the cross AT 238 × AT 345 could be exploited further for yield advancement in sesame.

Key words
Heterobeltiosis, sesame, standard heterosis

Introduction

Sesame (*Sesamum indicum* L. Family: Pedaliaceae) is one of the oldest oilseed crops grown throughout the tropical and sub-tropical regions of the world. Sesame oil is considered as the queen of high quality vegetable oil (44-58% of dry seed weight) for human consumption, as it contains high levels of unsaturated fatty acids and antioxidants e.g., sesamol, sesamin, sesamolin and sesaminol (Nupur *et al.*, 2010). India is the second largest producer of sesame in the world, but suffers a serious setback in terms of productivity (368kg/ha) as compared to world average (489kg/ha). Low productivity of sesame in India is mainly due to cultivation of varieties with poor yield potential and inconsistent yield performance under varied environmental conditions. Hence, there is a need to augment the productivity of crop through crop improvement programme.

Hybrid technology has been widely acclaimed as a modern approach for the genetic improvement of yield in various crop species including sesame. The magnitude of heterosis in a crop relies on its exploitation, utilization and practicability of hybrid seed production. Though sesame is self-pollinated crop, the large degree of out crossing to the extent of 65 per cent (Brar and Ahuja, 1979), availability of male sterility (Mazzani, 1985; Ramalingam *et al.*, 1994), easiness to crossing through a massive manual hybridization technique (Yadav and Mishra, 1991), number of seeds produced per pollination, the number of seeds sown per unit area and the upper limit of price in relation to production cost of seed, has caught the attention of research workers for studying the extent of heterosis in sesame and for developing commercial hybrids. However, heterosis may not be worthwhile in sesame, unless it is tenable to utilize it through the development of hybrids. So, in sesame heterosis is used to select desirable crosses to obtain superior segregants in advance generations for additional enrichment of grain yield.

The experimental materials comprised of 46 genotypes (Nine diverse sesame genotypes, their 36 F_1 diallel hybrids and a standard check GT 3) were evaluated in a Randomized Block Design with three replications in four different environments [two locations, Junagadh and Nana Kandhasar and two dates of sowing, February 20 and March 10, 2016 at Junagadh and February 22 and March 12, 2016 at Nana Kandhasar] during *summer* 2016-

2017. Each entry was sown in single row of 3.0 m length with a spacing of 45 cm between row and 15 cm between plants within the row. Five competitive plants per genotype in each replication in each environment were selected randomly for recording observations on different characters *viz*., days to flowering, days to maturity, plant height (cm), number of branches per plant, number of capsules per plant, height to first capsule (cm), length of capsule (cm), width of capsule (cm), number of capsules per leaf axil, number of seeds per capsule, 1000 seed weight (g), seed yield per plant (g), biological yield per plant (g), harvest index (%) and oil content (%). Analysis of variance for all the characters in individual environments as well as pooled over environments was done as per the method suggested by Panse and Sukhatme (1985). The heterobeltiosis and standard heterosis were estimated as deviation of F_1 value from the better-parent and standard parent, as suggested by Fonseca and Patterson (1968) and Meredith and Bridge (1972), respectively.

Results and Discussion

The analysis of variance for experimental design was carried out to ascertain the genuine differences among genotypes, parents and F_1s in individual environments as well as pooled over environments for 15 different quantitative characters. The results indicated that mean squares due to genotypes were significant for all the traits in all the environments, except for oil content in all the individual environments. Further, partitioning of the genotypic mean squares into parents and F_1 evinced that mean squares due to parents were significant for all the traits in all the environments, except for oil content in E_1, E_3 and E_4. Mean squares due to hybrids were significant for all the traits in all the environments, except for days to flowering in E_4; for plant height in E_2; and for oil content in all the four environments. Mean squares due to parents *vs*. hybrids were significant for all the characters in all the individual environments, except for number of capsules per plant, 1000 seed weight and oil content in E_1; for days to flowering, plant height, number of branches per plant, height to first capsule, 1000 seed weight, harvest index and oil content in E_2; for days to maturity, number of capsules per plant, height to first capsule, width of capsule, 1000 seed weight and oil content in E_3; and for days to flowering, days to maturity, number of branches per plant, width of capsule and oil content in E_4. Pooled analysis of variance over environments (Table 2) revealed significant differences among genotypes, parents and F_1s for all the characters. The comparison of parents *vs*. hybrids was found significant for all the characters, except for number of branches per plant, number of seeds per capsule, 1000 seed weight and oil content. The mean squares due to hybrids x environments was significant for all the characters. Parents *vs*. hybrids x environments interaction was found significant for all the characters, except for days to maturity, height to first capsule and oil content.

With respect to heterobeltiosis recorded for different cross combinations for seed yield per plant, it was observed that AT 238 × GT 1 (90.70 %), AT 255 × Nesadi Selection (82.91 %) and AT 164 × AT 238 (76.29 %) in E_1; AT 238 × GT 1 (109.97 %), AT 255 × Nesadi Selection (103.94 %) and AT 164 × AT 238 (98.34 %) in E_2; AT 255 × Nesadi Selection (57.24 %), AT 238 × GT 1 (45.27 %) and AT 164 × AT 238 (40.45 %) in E_3; AT 238 × GT 1 (70.35 %), AT 255 × Nesadi Selection (67.39 %) and AT 164 × AT 238 (65.01 %) in E_4; and AT 238 × GT 1 (94.43 %), AT 255 × Nesadi Selection (94.24 %) and AT 164 × AT 238 (83.30 %) in pooled over environments were the best three cross combinations. The heterobeltiosis for seed yield per plant ranged in between -25.16 per cent (AT 345 × Nesadi Selection) to 90.70 per cent (AT 238 × GT 1) in E_1, -21.54 per cent (AT 345 × Nesadi Selection) to 109.97 per cent (AT 238 × GT 1) in E_2, -56.57 per cent (AT 345 × Nesadi Selection) to 57.24 per cent (AT 255 × Nesadi Selection) in E_3, -39.13 per cent (AT 345 × Nesadi Selection) to 70.35 per cent (AT 238 × GT 1) in E_4 and -33.16 per cent (AT 345 × Nesadi Selection) to 94.43 per cent (AT 238 × GT 1) in pooled over environments (Table 1).

The overall performance of hybrids over four environments for seed yield per plant indicated that fifteen cross combinations showed significant positive heterosis over better parent. The top ranked cross combination across the environments with respect to heterobeltiosis for seed yield per plant, AT 238 × GT 1 noted the significant and desirable heterobeltiosis in all the individual environments with the highest and significant heterobeltosis of 109.97 per cent in E_2 followed by 90.70 per cent in E_1, 70.35 per cent in E_4 and 45.27 per cent in E_3 environment. On pooled basis, this cross exhibited significant and desirable heterobeltiosis for plant height, length of capsule and biological yield per plant. Similarly, the second and third best cross combinations across the environments with respect to heterobeltiosis for seed yield per plant, AT 255 × Nesadi Selection and AT 164 × AT 238 also exhibited the significant and desirable heterobeltiosis in all the individual environments. These crosses also manifested the significant and desirable heterobeltiosis for important yield components across the environments. The top ranked cross combination across the environments with respect to *per se* performance for seed yield per plant, AT 238 × AT 345 noted the significant and positive heterobeltiosis of 32.24 per cent across the environments. It also exhibited the significant and positive heterobeltiosis of 31.95, 61.75 and 25.05 per cent in E_1, E_2 and E_4, respectively, and also the positive but non-significant heterobeltiosis of 7.82 per cent in E_2. This hybrid also noted significant and desirable heterobeltiosis on pooled basis for days to maturity, height to first capsule, length of capsule, width of capsule and biological yield per plant. These results are in agreement with the results for seed yield per plant obtained by earlier workers Chaudhari *et al.* (2015), Patel *et al.* (2016), Chaudhari *et al.* (2017), Nayak *et al.* (2017), Tripathy *et al.* (2017), Virani *et al.* (2017), Karande *et al.* (2018) and Pandey *et al.* (2018) in sesame. With respect to standard heterosis, none of the cross combination noted significant and positive standard heterosis in E_3 and E_4 environment, while AT 238 × AT 345 (15.48 %), AT 282 × GT 10 (14.83 %) and AT 238 × GT 1 (13.28 %) in E_1; AT 238 × AT 345 (41.23 %), AT 282 × GT 10 (26.64 %), AT 238 × GT 1 (24.73%) and AT 164 × AT 238 (18.45 %) in E_2 and AT 238 × AT 345 (11.69 %) on pooled basis were the best significant and positive cross combinations with respect to standard heterosis for seed yield per plant. The standard heterosis for seed yield per plant ranged in between -51.78 per cent (AT 164 × GT 1) to 15.48 per cent (AT 238 × AT 345) in E_1, -54.13 per cent(AT 164 × GT 1) to 41.23 per cent (AT 238 × AT 345) in E_2 , -65.13 per cent (AT 164 × GT 1) to -11.31 per cent (AT 282 × GT 10) in E_3, -54.68 per cent (AT 238 × AT 255) to 2.66 per cent (AT 238 × AT 345)and -56.07 per cent (AT 164 × GT 1) to 11.69 per cent (AT 238 × AT 345) in pooled over environments(Table 1). These results are in agreement with the results for seed yield per plant obtained by Chaudhari *et al.* (2015), Patel *et al.* (2016), Virani *et al.* (2017) and Karande *et al.* (2018) in sesame.

The top ranked cross combination across the environments with respect to *per se* performance for seed yield per plant, AT 238 × AT 345 noted the significant and desirable standard heterosis in E_1, E_2 and pooled over environments, but it had non-significant but desirable standard heterosis in E_4. This hybrid also noted significant and desirable standard heterosis on pooled basis for number of branches per plant, height to first capsule and biological yield per plant. On pooled basis, one cross combination each for length of capsule and seed yield per plant, 8 cross combinations for days to flowering, 3 for days to maturity, 9 for plant height, 5 for number of branches per plant, 6 each for number of capsules per plant and biological yield per plant, 11 for height to first capsule, 7 for number of capsules per leaf axil and 4 cross combinations for number of seeds per capsule registered significant and standard heterosis in desired direction, while for width of capsule, 1000 seed weight, harvest index and oil content, none of the cross combination manifested significant desirable standard heterosis. In individual environments as well as on pooled basis, it was observed that majority of hybrids exhibited low to moderate heterobeltosis for seed yield per plant as well as for important yield contributing characters. As observed in the present study, Vavdiya *et al.* (2013), Chaudhari *et al.* (2015), Monpara and Pawar (2016), Patel *et al.* (2016), Ghule *et al.* (2017), Virani *et al.* (2017) and Karande *et al.* (2018) also reported the presence of considerable heterosis for seed yield per plant and some of the important yield components in sesame.

From commercial cultivation point of view, the superiority of new hybrid should be judged by comparing their performance with the best cultivated variety/hybrid. Variety GT 3 released for general cultivation in Gujarat was, therefore, used as the standard check in order to obtain information regarding superiority of new hybrids over best cultivated variety. The top ten cross combinations across the environments with respect to *per se* performance for seed yield per plant are listed in Table 2 along with their values of heterobeltosis, standard heterosis, sca effect as well as component traits showing significant and desirable heterosis over better parent and standard check variety GT 3. Out of these 10 cross combinations, only 2 cross combination AT 238 × AT 345 and AT 282 × GT 10 were found superior then GT 3 in respect of seed yield per plant, as it manifested significantly higher seed yield than GT 3, of which only AT 238 × AT 345 exhibited the significant standard heterosis over GT 3 across the environments for seed yield per plant along with significant sca effects. This cross combination manifested significant standard heterosis in desired direction for yield components like number of branches per plant, height to first capsule and biological yield per plant. As discussed earlier, this cross combination also noted the significant and desirable standard heterosis in E_1, E_2 and pooled over environments, but it had non-significant but desirable standard heterosis in E_4. The data presented in Table 2 also revealed that cross combinations AT 238 × AT 345, AT 282 × GT 10, AT 238 × GT 1 and AT 164 × AT 238 manifested the significant and desirable heterosis over standard check GT 3 for number of branches per plant, height to first capsule, number of capsules per plant, number of seeds per capsule, number of capsules per leaf axil, plant height and biological yield perplant. However, all the ten hybrids manifested desirable and significant standard heterosis for many of the yield components.

Overall, on pooled basis, AT 238 × AT 345 (11.69 %) was the best cross manifested significant and positive standard heterosis for seed yield per plant. This cross also manifested significant standard heterosis in desired direction for yield components like number of branches per plant, height to first capsule and biological yield per plant. Therefore, the cross AT 238 × AT 345 could be exploited further for yield advancement in sesame.

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Table 1. Estimates of per cent heterosis over better parent and standard check in individual environments as well as pooled over environments for seed yield per plant (g) in sesame

Sr. No.	Hybrids	E_1		E_2		E_3		E_4		Pooled	
		BP	SH	BP	SH	BP	SH	BP	SH	BP	SH
1	AT 164 x AT 238	76.29**	4.72	98.34**	18.45**	40.45**	-18.17**	65.01**	-3.86	83.30**	0.46
2	AT 164 x AT 255	26.72**	-26.17**	38.13**	-19.52**	8.73	-36.65**	15.88	-32.49**	33.08**	-28.59**
3	AT 164 x AT 282	16.14	-24.64**	10.21	-25.33**	2.76	-40.13**	17.30	-31.66**	16.03	-30.32**
4	AT 164 x AT 345	-14.96*	-25.57**	-18.53*	-28.87**	-28.40**	-42.47**	-17.82*	-32.54**	-19.78**	-32.25**
5	AT 164 x China	27.76**	-25.57**	27.00*	-26.00**	-3.23	-43.62**	26.12*	-26.52**	29.87**	-30.31**
6	AT 164 x Nesadi Selection	10.22	-35.79**	9.53	-36.18**	-1.45	-42.58**	7.17	-37.56**	15.68	-37.92**
7	AT 164 x GT 1	-17.24	**-51.78****	-21.27	**-54.13****	-40.15**	**-65.13****	-20.23	-53.52**	-18.13	**-56.07****
8	AT 164 x GT 10	-14.67*	-34.23**	-8.81	-30.02**	-29.27**	-58.79**	-19.75*	-44.12**	-16.72*	-41.69**
9	AT 238 x AT 255	-11.13	-47.21**	-9.79	-46.41**	-45.08**	-67.38**	-23.70*	**-54.68****	-15.77	-53.84**
10	AT 238 x AT 282	13.31	-26.47**	14.32	-22.54**	-26.40**	-56.28**	6.12	-36.96**	7.48	-35.45**
11	AT 238 x AT 345	31.95**	**15.48****	61.75**	**41.23****	7.82	-13.36*	25.05**	**2.66**	32.24**	**11.69***
12	AT 238 x China	24.61*	-25.98**	19.75	-28.87**	-8.41	-45.59**	10.75	-34.21**	21.25*	-33.55**
13	AT 238 x Nesadi Selection	14.46	-32.01**	13.92	-32.33**	-21.22*	-53.20**	3.48	-38.53**	11.46	-38.91**
14	AT 238 x GT 1	**90.70****	13.28*	**109.97****	24.73**	45.27**	-13.70*	**70.35****	1.19	**94.43****	6.56
15	AT 238 x GT 10	38.71**	6.92	37.31**	5.37	21.69*	-27.71**	31.30**	-8.57	34.48**	-5.84
16	AT 255 x AT 282	10.48	-28.31**	-2.11	-33.68**	-1.09	-47.25**	27.15*	-31.55**	8.09	-35.09**
17	AT 255 x AT 345	2.64	-10.17	8.11	-5.61	-21.93**	-37.27**	-4.47	-21.57**	-3.53	-18.52**
18	AT 255 x China	76.19**	-9.42	81.04**	-4.69	26.11*	-35.17**	57.26**	-19.15**	74.22**	-16.97**
19	AT 255 x Nesadi Selection	82.91**	-5.96	103.94**	4.85	**57.24****	-19.16**	67.39**	-13.94*	94.24**	-8.40
20	AT 255 x GT 1	54.49**	-15.52**	68.02**	-11.01	22.35*	-37.10**	59.26**	-18.12**	61.91**	-20.30**
21	AT 255 x GT 10	7.72	-16.97**	15.28	-11.53	16.62	-34.51**	17.58*	-18.13**	14.04	-20.15**

Table 1.Contd…

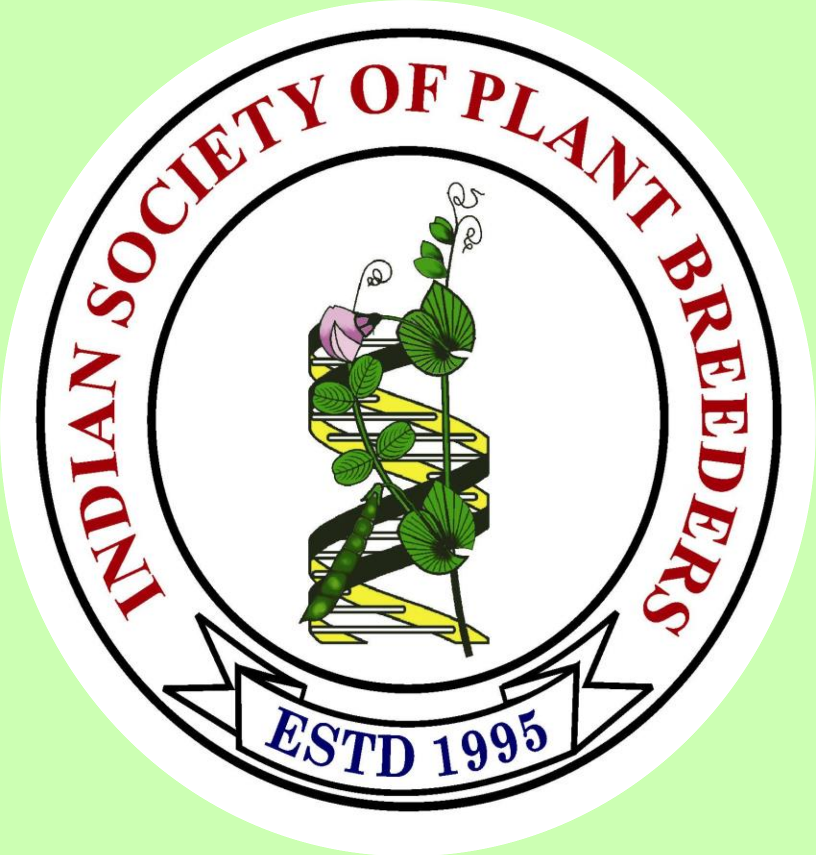
Sr. No.	Hybrids	E_1		E_2		E_3		E_4		Pooled	
		BP	SH	BP	SH	BP	SH	BP	SH	BP	SH
22	AT 282 x AT 345	-7.91	-19.40**	-10.25	-21.63**	-27.41**	-41.67**	-13.30	-28.83**	-14.47*	-27.76**
23	AT 282 x China	4.47	-32.21**	8.82	-29.38**	-26.33**	-52.19**	1.41	-34.19**	5.09	-36.89**
24	AT 282 x Nesadi Selection	13.03	-26.66**	8.95	-29.3**	-10.33	-41.82**	12.52	-26.99**	14.77	-31.07**
25	AT 282 x GT 1	20.05*	-22.10**	26.04*	-18.21**	-15.56	-45.21**	7.92	-29.97**	18.64	-28.75**
26	AT 282 x GT 10	48.98**	14.83*	65.03**	26.64**	36.68**	**-11.31***	44.34**	0.50	54.03**	7.85
27	AT 345 x China	10.88	-2.96	24.22**	8.71	-12.49	-23.42**	3.16	-9.72	10.47	-6.69
28	AT 345 x Nesadi Selection	**-25.16****	-34.50**	**-21.54****	-31.33**	**-56.57****	-61.99**	**-39.13****	-46.73**	**-33.16****	-43.54**
29	AT 345 x GT 1	-22.73**	-32.38**	-21.26**	-31.09**	-46.07**	-52.80**	-26.72**	-35.87**	-26.51**	-37.93**
30	AT 345 x GT 10	7.37	-6.04	20.35**	5.33	-18.08**	-28.31**	-7.36	-18.93**	4.38	-11.84*
31	China x Nesadi Selection	42.35**	-26.91**	33.38*	-31.52**	32.96**	-31.73**	53.55**	-21.16**	51.68**	-27.71**
32	China x GT 1	54.58**	-15.47**	74.25**	-7.71	16.02	-40.43**	51.99**	-21.96**	59.97**	-21.26**
33	China x GT 10	21.77**	-6.14	14.82	-11.89	35.81**	-23.74**	7.98	-24.82**	19.25*	-16.50**
34	Nesadi Selection x GT 1	56.21**	-14.58*	87.39**	-0.76	35.28**	-31.44**	57.07**	-20.39**	69.33**	-16.65**
35	Nesadi Selection x GT 10	-8.72	-29.64**	-12.69	-33.00**	-11.28	-50.18**	-6.13	-34.64**	-9.68	-36.76**
36	GT 1 x GT 10	-5.64	-27.27**	-3.83	-26.20**	1.57	-42.96**	5.34	-26.65**	-0.96	-30.65**
Range of heterosis		-25.16 to 90.70	-51.78 to 15.48	-21.54 to 109.97	-54.13 to 41.23	-56.57 to 57.24	-65.13 to -11.31	-39.13 to 70.35	-54.68 to 2.60	-33.16 to 94.43	-56.07 to 11.69
No. of crosses showing significant desirable heterosis		16	3	16	4	10	0	14	0	15	1
S.E.±		0.48		0.57		0.48		0.52		0.49	

Table 2. Performance of top ten high yielding hybrids for heterosis over better parent (BP) and standard check (GT 3), their inbreeding depression, SCA effects in F_1 and F_2 population for seed yield per plant and component traits showing significant and desirable heterosis over standard check and better parent in pooled analysis

Sr. No.	Hybrids	Seed yield per plant (g)	Heterosis Over		SCA effects	Component characters showing significant and desirable heterosis over	
			BP	GT 3		BP	GT 3
1	AT 238 x AT 345	9.35	32.24**	11.69*	2.36**	DM, HFC, LC, WC, BY	NB, HFC, BY
2	AT 282 x GT 10	9.03	54.03**	7.85	2.61**	BY	NB, NC, NS, BY
3	AT 238 x GT 1	8.92	94.43**	6.56	2.76**	PH, LC, BY	NCL, BY
4	AT 164 x AT 238	8.41	83.30**	0.46	2.57**	PH, NB, LC, WC, TW, BY	PH, NB, BY
5	AT 238 x GT 10	7.88	34.48**	-5.84	1.03**	-	PH, NB, NC, NS
6	AT 345 x China	7.81	10.47	-6.69	1.24**	WC, BY	PH,
7	AT 255 x Nesadi Selection	7.67	94.24**	-8.40	2.36**	BY, HI	DF, DM, NCL
8	AT 345 x GT 10	7.38	4.38	-11.84*	0.21	-	PH, NB, NC,
9	China x GT 10	6.99	19.25*	-16.50**	0.55**	-	PH, NS, BY
10	Nesadi Selection x GT 1	6.98	69.33**	-16.65**	1.66**	BY, HI	-

***, ** Indicate significance at P = 0.05 and P = 0.01 levels, respectively**

DF = Days to flowering, DM = Days to maturity, PH = Plant height (cm), NB = Number of branches per plant, NC = Number of capsules per plant, HFC = Height to first capsule (cm), LC = Length of capsule (cm), WC = Width of capsule (cm), NCL = Number of capsules per leaf axil, NS = Number of seeds per capsule, TW=1000 seed weight, BY = Biological yield per plant, HI = Harvest index



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