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Karishma Kapadia
Agriculture Officer, Regional Cotton Research Station, Navsari Agricultural University, Bharuch, Gujarat, India

Chirag Solanki
Assistant professor, Department of Genetics and Plant Breeding, College of Agriculture, Madhav University, Abu Road, Sirohi, Rajasthan, India

Sneha Macwana
Professor & Head (I/c), Department of Genetics and Plant Breeding, Anand Agricultural University, Anand, Gujarat, India

Corresponding Author:
Karishma Kapadia
Agriculture Officer, Regional Cotton Research Station, Navsari Agricultural University, Bharuch, Gujarat, India

Exploitation of heterosis for seed yield and its contributing characters in sesame

Karishma Kapadia, Chirag Solanki and Sneha Macwana

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Abstract
A study was conducted to estimate the magnitude of heterosis for twelve quantitative characters including seed yield per plant in 28 hybrids of Sesame developed by half-diallel mating design. The analysis of variance revealed that the mean squares due to genotypes were highly significant for all the characters. Highly significant differences were also observed among the parents as well as hybrids for all the traits under study. It indicated that the experimental material used for investigation had adequate genetic variability for all the characters studied. The parents *vs.* hybrids comparison were significant for all the characters except test weight, indicating substantial amount of heterosis among hybrids. Heterosis was worked out over better parent and standard check, GT 2. On the basis of *per se* performance, standard heterosis over check GT 2, TMV 4 × GT 10, Rama × Kayamkulam 1 and AKT 101 × GT 5 were the best hybrids. These hybrids recorded the highest standard heterosis and desirable heterobeltiosis for seed yield per plant. While, on the basis of heterobeltiosis, AKT 101 × GT 5, AKT 101 × GT 10 and AKT 101 × GT 3 were the most promising hybrids for seed yield per plant.The heterosis for seed yield per plant was associated with the heterosis expressed by its component characters.

Keywords: Sesame, half-diallel, seed yield, heterosis, heterobeltiosis

Introduction

Sesame (*Sesamum indicum* L.) belonging to the genus Sesamum and family Pedaliaceae, is one of the most ancient oilseed crops in the world. 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 (Nupur *et al*., 2010) [9]. The crop is mostly grown in the tropical and subtropical regions of the world, with maximum concentration and production in Asia. India is the second largest producer of sesame in the world. In India, it is cultivated in an area of 18 lakh ha with production of 8.0 lakh tonnes and productivity of 451.50 kg/ha. However, the productivity of sesame is low in India (451.50 kg/ha) as compared to the world's average (535 kg/ha) (FAOSTAT, 2017-18) [4]. Cultivation in marginal lands, limited breeding efforts to develop high yielding cultivars with lack of resistance to biotic and abiotic stresses, is the major cause of low productivity in sesame. Heterosis breeding is one of the best methods to increase productivity in sesame. Different studies have indicated that exploitation of hybrid vigour is possible in sesame. Although it is a self-pollinated crop, cross pollination ranging from 5% to 50% is reported along with high level of heterosis for yield and its components by Dikshit and Swain (2000) [3], Patel *et al.* (2010) [11] and Vavdiya *et al.* (2013) [13]. Heterosis may be of limited use in autogamous crop like sesame as far as the development of hybrids is concerned, but the epipetalous nature of sesame makes it easier to emasculate and develop heterotic hybrids in sesame.

Materials and Methods

The experiment was conducted at Agronomy farm, B. A. College of Agriculture, Anand Agricultural University, Anand. The experimental material was developed during *summer* 2017, by crossing eight genotypes/varieties in all combinations excluding reciprocals (half-diallel mating design). The experimental material consisting of 36 genotypes comprising of 8 parents, namely, TMV 4, Rama, AKT 101, Kayamkulam 1, GT 10, GT 5, GT 3, GT 2 (standard check) and 28 hybrids was evaluated During *kharif* 2017 in a randomized block design with three replications. Each entry was planted in a single row of 3 m with a spacing of 45 x 15 cm. The standard agronomical practices and plant protection measures were followed to raise the good experimental crop. The observations were recorded on five randomly selected plants for each treatment in each replication and the average value per plot was computed except for days to 50 percent flowering and days to maturity, where the observations were recorded on plot basis.

Data were recorded for 12 characters *viz*., days to 50 percent flowering, days to maturity, plant height, number of primary branches per plant, number of capsules per plant, number of seeds per capsule, capsule length (cm), test weight (g), seed yield per plant (g), harvest index (%), oil content (%) and protein content (%). Oil content (%) and protein content (%) were determined from seed samples taken from each plot by Near Infrared Resonance (N.I.R).The performance of hybrids was evaluated on the basis of Heterosis expressed as percent, increase or decrease in the value of F_1 over better parent (Heterobeltiosis) and standard check, GT 2 (Standard heterosis).

Results and Discussion

Analysis of variance: The analysis of variance (Table 1) revealed highly significant differences among genotypes for all the characters suggesting the existence of substantial genetic variability. The mean squares due to parents as well as hybrids were highly significant for all the characters. Highly significant differences observed among the hybrids for all the characters may be due to better combination of genes derived from the diverse parents for maximization of hybrid vigour in respect of seed yield and its components. The mean squares due to parents *vs.* hybrids were significant for all the characters except test weight, thereby suggesting differences between parents and hybrids and possibility of heterotic effects for most of the characters.

The range of heterosis, number of crosses showing a desirable heterotic response and the best hybrids with the highest per se performance, heterobeltiosis and standard heterosis for all the studied characters are presented in Table 2 and Table 3, respectively.

The magnitude of heterosis varied from cross to cross for all the characters studied. For days to 50 percent flowering, the hybrids Kayamkulam 1 × GT 3 and GT 5 × GT 3 were the most promising as they exhibited highest heterosis in negative direction which is desirable for earliness. Thus it indicated that early maturity hybrids could be developed with the parental material in the present investigation. The results are in accordance with the findings of Karande *et al*. (2018) [6] and Virani *et al*. (2017) [14].

For Plant height, positive magnitude of heterosis is desirable, as it aids in higher vegetative growth thereby increasing the seed yield. Total 14 hybrids manifested significant positive standard heterosis over check GT 2 in desired direction. Karande *et al*. (2018) [6], Parimala *et al*. (2015) [10], Vavdiya *et al*. (2013) [13], Meena Kumari and Ganesamurthy (2017) [7], Virani *et al*. (2017) [14] also observed significant positive heterosis for plant height in sesame.

For number of primary branches per plant, total 3 and 18 hybrids significantly excelled the better parent and standard check, respectively. The highest standard heterosis was exerted by the hybrid AKT 101 × Kayamkulam 1, followed by Kayamkulam 1 × GT 10 and TMV 4 × GT 10. The heterosis for this character was previously reported by Vavdiya *et al*. (2013) [13] and Virani *et al*. (2017) [14].

Out of 28 hybrids, 19, 15 and 15 hybrids showed desirable heterosis for number of capsules per plant, number of seeds per capsule and length of capsule, respectively, in which heterosis ranged from -20.11 to 85.82, -22.16 to 42.50 and -30.15 to 26.91. These findings are in consonance with Vavdiya *et al*. (2013) [13]` and Virani *et al*. (2017) [14]. The Hybrid TMV 4 × GT 10 exhibited maximum heterosis (28.27 and 16.36) for Test Weight. TMV 4 × GT 10 also exhibited maximum standard heterosis for seed yield per plant. The results are in accordance with the findings of Vavdiya *et al*. (2013) [13], Monpara and Pawar (2016) [8], Patel *et al*. (2016) [12], Meena Kumari and Ganesamurthy (2017) [7] and Virani *et al*. (2017) [14].

For Harvest Index, total 7 and 9 hybrids exhibited positive heterosis. AKT 101 × GT 10 exhibited maximum heterosis for this character. Sesame being an oilseed crop, oil content is an important trait. Heterotic effects over better parental value varied from -11.45 to 4.24 percent. The standard heterosis ranged from-11.55 to 4.20 percent. The hybrids TMV 4 × AKT 101 and Rama × GT 5 exhibited maximum heterobeltiosis and standard heterosis, respectively. These findings are in consonance with those of Ansari *et al*. (2008) [2], Jatothu *et al*. (2013) [5], Vavdiya *et al*. (2013) [13], Monpara and Pawar (2016) [8], and Virani *et al*. (2017) [14]. The hybrid GT 10 × GT 5 expressed maximum positive HB and SH for protein content.

Seed yield is one of the most important objectives of any of the plant breeding programme. The estimation of heterotic effects for seed yield per plant over better parent ranged from -44.81% to 63.88%. Out of 20 significant hybrids, six hybrids showed significant positive heterosis. Highest significant positive heterosis was observed in AKT 101× GT 5, followed by AKT 101× GT 10 and AKT 101× GT 3. These hybrids also expressed desirable heterobeltiosis over several other yield contributing traits.

In case of Standard heterosis over check GT 2, 18 hybrids were significant, out of which, 16 hybrids demonstrated positive significant standard heterosis. The standard heterosis varied from -21.71 to 72.99 percent. The three hybrids TMV 4 × GT 10, Rama × Kayamkulam 1 and AKT 101 × GT 5 recorded higher significant positive standard heterosis for seed yield per plant. (Table 3) (Fig 1).

The high heterotic response for seed yield per plant in the top three hybrids resulted due to positive standard heterosis for yield contributing characters like number of primary branches per plant, number of capsules per plant, number of seeds per capsule and test weight. These hybrids expressed significant positive heterobeltiosis for at least three yield contributing traits.(Table 4).These findings are akin to the results of Anarase *et al*. (2015a) [1], Monpara and Pawar (2016) [8], Patel *et al*. (2016) [12], Meena Kumari and Ganesamurthy (2017) [7], Virani *et al*. (2017) [14] and Karande *et al*. (2018) [6].

The identification and utilization of most heterotic and useful crosses are very important in hybrid approach in order to make commercial cultivation of hybrids beneficial. Out of twenty eight hybrids tested three promising hybrids which out yielded check GT 2 were identified in respect of seed yield per plant. They are listed in Table 4 along with *per se* performance, heterobeltiosis, standard heterosis, as well as component traits showing significant desirable heterosis over better parent and standard check.

The best three hybrids on the basis of *per se* performance were TMV 4 × GT 10 (13.60 g), Rama × Kayamkulam 1 (12.92 g) and AKT 101× GT 5 (11.57 g). These hybrids exhibited highest heterosis for seed yield per plant and also possessed high desirable heterosis for various yield contributing characters like days to maturity, number of primary branches per plant number of capsules per plant, number of seeds per capsule, capsule length and test weight. These hybrids also exhibited desirable heterosis and heterobeltiosis for several yield contributing traits as depicted in the Table 4. It suggest the possibility of their direct cultivation. Furthermore, these hybrids may also be utilized in basic breeding programmes in getting transgressive segregants for desirable characters.

Table 1: Analysis of variance (mean squares) for various characters in sesame

Source of variation/ Characters	df	Days to 50 percent flowering	Days to maturity	Plant height	Number of primary branches per plant	Number of capsules per plant	Number of seeds per capsule
Replications	2	0.25	2.40	8.63	0.37	7.10	2.89
Genotypes	35	33.42**	86.19**	627.74**	14.47**	441.51**	161.54**
Parents	7	16.86**	72.52**	563.49**	27.12**	459.20**	67.30**
Hybrids	27	32.27**	67.39**	616.94**	10.33**	445.41**	191.04**
Parents *vs.* Hybrids	1	180.21**	689.45**	1369.26**	37.67**	212.62**	24.70*
Error	70	1.57	6.14	19.26	0.19	7.29	6.12

Source of variation/ Characters	df	Days to 50 percent flowering	Days to maturity	Plant height	Number of primary branches per plant	Number of capsules per plant	Number of seeds per capsule
Replications	2	0.002	0.15	0.10	2.75	0.29	0.56
Genotypes	35	0.4**	0.38**	11.67**	109.07**	11.09**	4.24**
Parents	7	0.32**	0.12**	17.65**	24.47**	8.31**	2.24**
Hybrids	27	0.44**	0.47**	10.51**	134.11**	11.76**	4.83**
Parents *vs.* Hybrids	1	0.05*	0.008	1.16*	25.01*	12.30**	2.29**
Error	70	0.009	0.04	0.29	4.05	0.33	0.13

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

Table 2: Range of heterobeltiosis (H1) and standard heterosis (H2) as well as number of crosses with specific heterotic effects for various traits in sesame

Sr. No	Characters	Range of heterosis (%)						No. of crosses with significant heterosis			
		Heterobeltiosis (H1) (%)			Standard heterosis (H2) (%)			H1 (%)		H2 (%)	
								+ve	-ve	+ve	-ve
1	Days to 50% flowering	-18.80	to	17.14	-9.52	to	23.81	7	16	16	7
2	Days to maturity	-17.98	to	13.45	-11.34	to	13.45	2	12	7	6
3	Plant height (cm)	-39.22	to	3.96	-21.17	to	33.72	0	21	14	7
4	No. of primary branches/plant	-68.96	to	28.10	-28.74	to	120.47	3	21	18	4
5	No. of capsules/plant	-46.27	to	49.48	-20.11	to	85.82	10	11	19	3
6	No. of seeds /capsule	-32.02	to	28.11	-22.16	to	42.50	10	10	15	4
7	Capsule length (cm)	-34.84	to	15.57	-30.15	to	26.91	7	11	15	9
8	Test weight (g)	-24.33	to	28.27	-24.26	to	16.36	5	11	4	11
9	Seed yield/plant (g)	-44.81	to	63.88	-21.71	to	72.99	6	14	16	2
10	Harvest Index (%)	-33.78	to	29.73	-28.32	to	45.89	7	8	9	6
11	Oil Content (%)	-11.45	to	4.24	-11.55	to	4.20	9	7	7	7
12	Protein Content (%)	-8.68	to	9.39	-5.82	to	15.74	6	14	15	3

Table 3: Best three crosses showing high heterotic vigour for yield and yield components.

Characters	Top Ranking Hybrids		
	Per se	**HB**	**SH**
Days to 50% flowering	Kayamkulam 1 × GT 3 & GT 5 × GT 3 (31.67)	Kayamkulam 1 × GT 3 & GT 5 × GT 3 (-18.80)	Kayamkulam 1 × GT 3 & GT 5 × GT 3 (-9.52)
	GT 3 × GT 2 & TMV 4 × GT 5 (32)	Rama × GT 3 (-17.09)	GT 3 × GT 2 & TMV 4 × GT 5(-8.57)
	TMV 4 × Kayamkulam 1 & Rama × GT 3 (32.33)	TMV 4 × GT 5 (-16.52)	TMV 4 × Kayamkulam 1 & Rama × GT 3 (-7.62)
Days to maturity	GT 5 × GT 3 (70.33)	TMV 4 × Kayamkulam 1 (-17.98)	GT 5 × GT 3 (-11.34)
	GT 3 × GT 2 (71.33)	TMV 4 × GT 5(-15.44)	GT 3 × GT 2 (-10.08)
	TMV 4 × GT 5 & TMV 4 × Kayamkulam 1 (73)	GT 5 × GT 3(-12.45)	TMV 4 × GT 5 & TMV 4 × Kayamkulam 1(-7.98)
Plant height (cm)	AKT 101 × Kayamkulam 1 (123.13)		AKT 101×Kayamkulam 1(33.72)
	TMV 4 × Rama (120.00)	----	TMV 4 × Rama (30.32)
	TMV 4 × Kayamkulam 1(118.67)		TMV 4 × Kayamkulam 1 (28.87)
No. of primary branches/plant	AKT 101 × Kayamkulam 1 (9.77)	GT 5 × GT 2 (28.10)	AKT 101×Kayamkulam 1(120.47)
	Kayamkulam 1 × GT 10 (9.67)	AKT 101 × GT 5 (23.00)	Kayamkulam 1 × GT 10 (118.36)
	TMV 4 × GT 10 (8.67)	AKT 101 × GT 2 (16.18)	TMV 4 × GT 10 (95.64)
No. of capsules/plant	TMV 4 × AKT 101 (76.51)	AKT 101 × GT 10 (49.48)	TMV 4 × AKT 101 (85.82)
	AKT 101 × GT 10 (73.65)	AKT 101 × GT 2 (16.66)	AKT 101 × GT 10 (78.88)
	Rama × Kayamkulam 1 (71.93)	AKT 101 × GT 5 (15.17)	Rama × Kayamkulam 1 (74.71)
No. of seeds /capsule	TMV 4 × GT 10 (68.82)	AKT 101 × GT 3 (28.11)	TMV 4 × GT 10 (42.50)
	TMV 4 × Rama (66.22)	AKT 101 × GT 5 (19.95)	TMV 4 × Rama (37.11)
	AKT 101 × GT 3 (61.44)	GT 5 × GT 3 (17.45)	AKT 101 × GT 3 (27.22)
Capsule length (cm)	GT 10 × GT 5 (2.88)	TMV 4 × GT 10 (15.57)	GT 10 × GT 5 (26.91)
	Rama × GT 5 (2.75)	Kayamkulam 1 × GT 3 (11.07)	Rama × GT 5 (21.18)
	Kayamkulam 1 × GT 3 (2.74)	GT 10 × GT 5 (10.93)	Kayamkulam 1 × GT 3 (21.03)
Test weight (g)	TMV 4 × GT 10 (4.22)	TMV 4 × GT 10 (28.27)	TMV 4 × GT 10 (16.36)
	GT 10 × GT 2 (4.18)	TMV 4 × GT 5 (19.60)	GT 10 × GT 2 (15.35)
	TMV 4 × GT 5 (4.15)	TMV 4 × AKT 101 (12.70)	TMV 4 × GT 5 (14.43)
Seed yield/plant (g)	TMV 4 × GT 10 (13.60)	AKT 101 × GT 5 (63.88)	TMV 4 × GT 10 (72.99)
	Rama × Kayamkulam 1 (12.92)	AKT 101 × GT 10 (56.69)	Rama × Kayamkulam 1 (64.42)
Harvest Index (%)	AKT 101 × GT 10 (45.91)	AKT 101 × GT 10 (29.73)	AKT 101 × GT 10 (45.89)
	TMV 4 × AKT 101 (45.35)	TMV 4 × AKT 101 (28.14)	TMV 4 × AKT 101 (44.11)
	AKT 101 × GT 5 (43.45)	TMV 4 × Kayamkulam 1 (26.87)	AKT 101 × GT 5 (38.08)
Oil Content (%)	TMV 4 × AKT 101 (49.73)	Rama × GT 5 (4.24)	TMV 4 × AKT 101 (4.20)
	TMV 4 × Kayamkulam 1 (49.59)	GT 10 × GT 2 (3.28)	TMV 4 × Kayamkulam 1 (3.92)
	TMV 4 × GT 10 (49.58)	AKT 101 × GT 10 (3.20)	TMV 4 × GT 10 (3.88)
Protein Content (%)	GT 10 × GT 5 (26.37)	GT 10 × GT 5 (9.39)	GT 10 × GT 5 (15.74)
	GT 5 × GT 3 (26.20)	TMV 4 × GT 2 (8.98)	GT 5 × GT 3 (15.01)
	AKT 101 × GT 5 (26.18)	GT 5 × GT 3 (8.70)	AKT 101 × GT 5 (14.93)

Standard Check – GT 2

Table 4: Comparison of top three promising hybrids on the basis of *per se* performance for seed yield per plant (g)

Sr. No.	Promising hybrids	Seed yield per plant (g)	Heterosis		Significant heterosis for component traits in desirable direction over	
			HB	SH	HB	SH
1	TMV 4 × GT 10	13.6	14.93**	72.99**	DFF, DM, SC, CL, TW, HI, OC	BP, CP, SC, CL, TW, HI, OC
2	Rama × Kayamkulam1	12.92	1.44	64.42**	DFF, DM, CP, SC, CL, TW	BP, CP, SC, CL, PC
3	AKT 101× GT 5	11.57	63.88**	47.20**	DFF, DM, BP, CP, SC, TW, HI, OC, PC	BP, CP, SC, CL, HI, PC

where,** indicates significant at 1% level of significance

DFF	=	Days to 50 percent flowering	CL	=	Capsule length (cm)
DM	=	Days to maturity	TW	=	Test weight (g)
BP	=	Number of primary branches per plant	HI	=	Harvest index (%)
CP	=	Number of capsules per plant	OC	=	Oil content (%)
SC	=	Number of seeds per capsule	PC	=	Protein content (%)

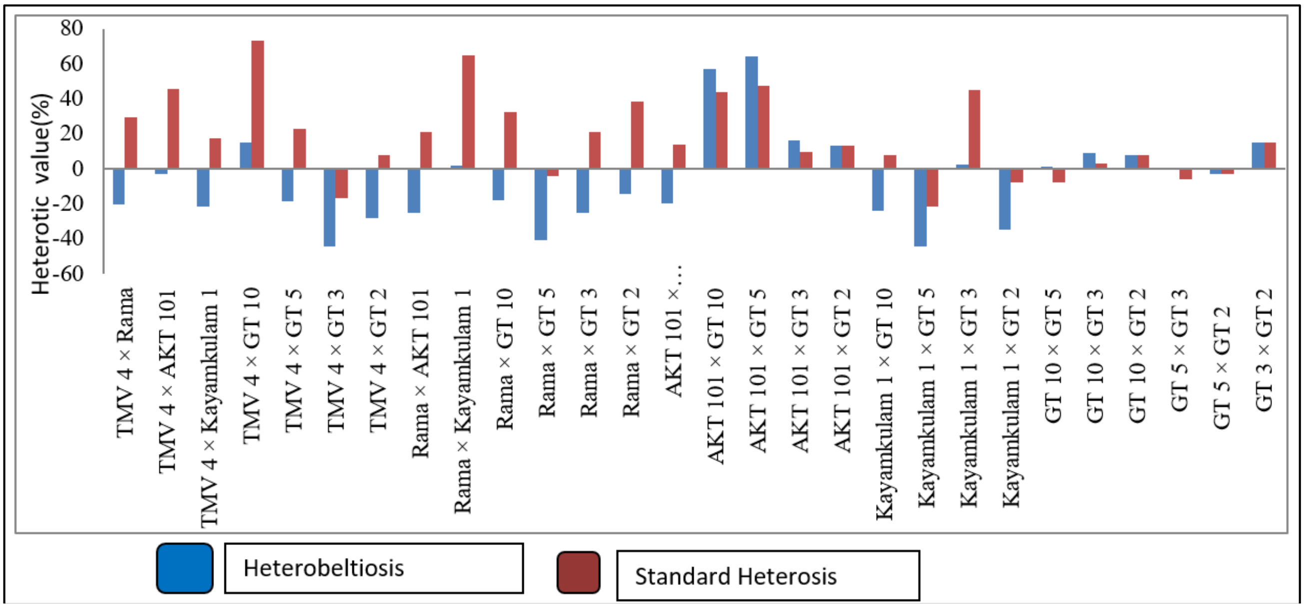

Fig 1: Heterobeltiosis and standard heterosis of hybrids for seed yield per plant

Conclusion

The study revealed significant genetic variability among sesame hybrids for various yield-contributing traits, including seed yield per plant, plant height, and capsule number. Analysis of variance demonstrated highly significant differences among genotypes, indicating substantial heterosis potential. The hybrids TMV 4 × GT 10, Rama × Kayamkulam 1, and AKT 101 × GT 5 showed the highest per se performance and desirable heterosis for seed yield and related traits. These hybrids exhibited significant positive heterobeltiosis and standard heterosis for yield components, suggesting their potential for direct cultivation and use in breeding programs for further genetic improvement of sesame.

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