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Heterosis and per *se* performance studies in sesame (*Sesamum indicum* L.)

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Abstract
The set of 67 genotypes using 8 x 8 diallel mating design including reciprocals, eight genetically diverse parents and three checks were evaluated. The data were recorded for ten traits. The analysis of variance revealed highly significant differences due to genotypes for all the characters except 1000-seed weight. The parent *vs* hybrid sum of squares was significant for all the traits excluding plant height, number of branches per plant, length of capsule and 1000-seed weight indicating the presence of heterosis in the genotypes used. Based on mean values, the parents TBS-10, TBS-105, and TBS-7 recorded maximum seed yield per plant. TBS-10, TBS-3 and TBS-7 were top ranking for number of branches per plant and number of capsules per plant. These parental genotypes also expressed good performance for various yield components, *viz*., plant height, the number of capsules per plant, length of capsule, 1000-seed weight and oil content. The parent V-29 found better for earliness, length of capsule, number of seeds per capsule and oil content. While, hybrids including reciprocals TBS-7 x V-29, R-09 x V-29, TBS-10 x R-09, TBS-105 x R-09, TBS-105 x V-29, R-20 x TBS-105, TBS-10 x V-29, V-29 x TBS-12, TBS-10 x TBS-12 and TBS-7 x R-20 were the best for seed yield per plant. The total of 20 F_1 and 10 reciprocal F_1 crosses while 17 F_1 and 8 reciprocal F_1 crosses had revealed significant positive better and standard heterosis respectively for seed yield per plant. Among the crosses TBS-10 x R-09, TBS-105 x R-09, TBS-7 x R-20, TBS-7 x TBS-12 and TBS-7 x R-09 were top ranking crosses (F_1s and their reciprocals) manifested highly significant and desirable heterosis for seed yield and other component traits over better parent and standard check (AKT-101).

Keywords: heterobeltiosis, standard heterosis, reciprocals, sesame

Introduction
Sesame (*Sesamum indicum* L.) is one of the world's oldest oilseed crop grown across the globe. It is an important and ancient oil-yielding crop cultivated for its flavoursome, edible protein-rich seed and high-quality oil (Bhat *et al*., 1999) [1]. Sesame seed contains high oil content (46% - 50%) with 83% - 90% unsaturated fatty acids, 20-25% proteins and various minor nutrients such as vitamins and minerals, a large number of characteristic lignans (sesamin, sesamol and sesamolin) and tocopherols (Fukuda *et al*., 1985) [8]. Therefore, sesame seeds with high amounts of nutritional components are consumed as a traditional health food for their specific antihypertensive effect, anticarcinogenic, anti-inflammatory and antioxidative activity (Yakota *et al*., 2007).
Plant breeders are challenged with a parent selection during breeding of high yielding varieties. Although, plant breeders eliminates poor crosses in initial generations on the basis of their performance, but information on the genetic architecture of yield and attributing traits will help to find out the improved crosses more competently. Several researchers suggested diallel analysis is the one of the best method of understanding the genetic nature of biometric traits and to ascertain the prepotency of parents. Heterosis breeding provides information on probable gene action and helps in finding desirable genotypes. The objective of present study was to determine the magnitude of heterosis and *per se* performance for yield and its component traits.

Material and Method
The experimental material used in the present study comprised of 56 F_1 crosses made by using 8 x 8 diallel mating design including reciprocals. The 56 crosses were made during *kharif* 2019 at Oilseed Research Station, Latur. A set of 67 genotypes comprised of 56 hybrids, eight parents and three standard checks *viz*., AKT-101, JLT-408, GT-2 were grown in Randomized

Block Design (RBD) with two replications during summer 2020 at Oilseed Reseach Substation, Ambajogai. Each entry was sown in 3.0 m length in two rows with 45 × 15 cm spacing. The recommended agronomical practices and plant protection measures were adopted for raising a good crop. The observations were recorded on days to 50 per cent flowering and days to maturity, plant height, number of branches per plant, the number of capsules per plant, capsule length, the number of seeds per capsule, 1000 seed weight, seed yield per plant and oil content. The replication wise mean values of each entry for the 10 traits were analyzed using Randomized Block Design (RBD) as suggested by Panse and Sukhatme (1985) [12] and estimation of heterobeltiosis by Fonseca and Patterson (1968) [9] and economic heterosis by Meredith and Bridge (1972). The replicated mean data were analyzed statistically using the software WINDOSTAT version 8.1.

Results and Discussion

The analysis of variance from the mean data (Table 1) exhibited highly significant differences due to genotypes for all the traits, indicating parents and hybrids possessed a sufficiently high genetic variability. Further partitioning of mean sum of squares due to parents were significant for all the traits except days to 50 per cent flowering, days to maturity, number of capsules per plant, capsule length and seed yield per plant. The significant differences among parents suggested greater diversity in the parental lines. In case of hybrids, significant differences were observed for all the traits excluding days to 50 per cent flowering and number of seeds per capsule indicating varying performance of crosses. The mean sum of squares due to parents vs hybrids were also significant for all the characters except plant height, number of branches per plant, capsule length 1000-seed weight and oil content, indicated sufficient amount of heterosis was reflected in crosses for most of the yield contributing traits.

Based on the mean performance the parent TBS-10 was top ranking for seed yield per plant (g). This parent also expressed good performance for yield contributing traits *viz*., number of branches per plant, number of capsules per plant, length of capsule, number of seeds per capsule and 1000-seed weight. The parent V-29 found better for earliness, length of capsule, number of seeds per capsule and oil content (Table 2). None of the hybrids found superior for all the traits based on mean values. The hybrids including reciprocals TBS-7 x V-29, R-09 x V-29, TBS-10 x R-09, TBS-105 x R-09, TBS-105 x V-29, R-20 x TBS-105, TBS-10 x V-29, V-29 x TBS-12, TBS-10 x TBS-12 and TBS-7 x R-20 were the best for seed yield per plant (Table 2).

The estimated heterosis over better parent and standard variety for ten traits in F_1 and reciprocal F_1 crosses is presented in Table 3. The better parent and standard heterosis for days to 50 per cent flowering ranged from -6.82 to 17.07 and -10.99 to 5.49 respectively. The crosses TBS-3 x R-20 and TBS-3 x V-29 revealed significant negative heterosis over standard check (AKT-101). The highest standard heterosis for earliness was also reported by Choudhary *et al.* 2018.

Earliness character is important in breeding for early maturing varieties in sesame for better adaptation to climate change (Paroda, 2013) [14]. A suitable breeding methodology and the selection of superior parents are the prerequisite for the development of early maturing and high yielding varieties. The better parent and standard heterosis for days to maturity ranged from -19.24 to 20.18 and -5.86 to 48.35 respectively. The reciprocal cross R-09 x TBS-105 displayed significant negative heterosis over better parent. Similar reciprocal effects were also previously reported by Brindha and Sivasubramanian 1992 and Daba *et al.* 2019 for days to maturity.

Regarding plant height heterobeltiosis and standard heterosis ranged from -46.81 to 25.87 and -37.13 to 26.96 in F_1 crosses and reciprocals respectively. Among the reciprocal crosses, V-29 x TBS-12 revealed significant positive better parent and standard heterosis respectively. Dela and Sharma 2019 [6] and Chauhan *et al.* 2019 [4] also reported significant positive heterobeltiosis and standard heterosis in sesame.

In case of number of branches per plant, heterobeltiosis and standard heterosis ranged from -21.14 to 29.99 and -8.59 to 58.5 in F_1 crosses and reciprocals respectively. Sumathi and Murlidharan (2008) [20] reported that number of branches per plant have high association with grain yield in sesame. The cross R-09 x R-20 displayed significant positive heterobeltiosis for the number of branches per plant. Among the crosses 15 F_1s and 16 reciprocal F_1s displayed significant positive standard heterosis over check GT-2. In the present study some of the crosses revealed negative and significant better parent heterosis indicating genes with negative effects were dominant for this trait. Parimala *et al.* 2013 [13] and Nayak *et al.* 2017 [11] also reported both negative and positive significant heterosis for this trait.

Regarding number of capsule per plant better parent and standard heterosis ranged from -16.24 to 149.03 and -25.25 to 123.51 respectively in F_1 crosses and reciprocals (Table 3). The total of 15 and 12 (F_1 and reciprocal $F_{1)}$ crosses and 10 and 6 (F_1 and reciprocal $F_{1)}$ revealed positive and significant better parent and standard heterosis respectively. The cross TBS-10 x R-09 (149.03%) and V-29 x R-20 (88.57%) displayed highest heterobeltiosis in F_1 and reciprocal F_1 respectively. The highest standard heterosis was observed in cross TBS-10 x R-09 (123.51%) and V-29 x R-20 (53.21%) in F_1 and reciprocal F_1 respectively. Significant positive heterosis and heterobeltiosis in sesame were also reported by Shobha Rani *et al.* 2015 [9], Patel *et al.* 2016 [15], and Chaudhari *et al.* 2017 [3].

In case of capsule length one reciprocal cross V-29 x TBS-12 revealed significant positive better parent and standard heterosis respectively. It ranged from -19.24 to 20.18 and -5.86 to 48.35 for better parent and standard heterosis in F_1 and reciprocal F_1 respectively. Six F_1 crosses and 3 reciprocal F_1s displayed significant positive standard heterosis over check GT-2. Prajapati *et al.* 2010 [16] and Kumar *et al.* 2015 [10] reported similar results.

Number of seeds per capsule ranged from -19.08 to 29.00 and -21.76 to 26.68 in F_1s and reciprocals. The reciprocal cross R-09 x TBS-105 showed significant positive better parent heterosis. Similarly, reciprocal cross V-29 x TBS-12 showed significant standard heterosis. Similar results were also obtained by Dela and Sharma 2019 [6] and Chauhan *et al.* 2019 [4] in sesame.

1000-seed weight ranged from -40.99 to 4.55 and -30.62 to 33.33 for better parent and standard heterosis respectively. Four crosses *viz*., TBS-7 x TBS-12, TBS-7 x TBS-105, TBS-10 x R-09 and TBS_10 x R-20 displayed significant positive standard heterosis for this trait (Imran *et al.* 2017, Nayak *et al.* 2017 and Choudhary *et al.* 2018) [11].

Regarding seed yield per plant it ranged from -17.96 to 152.16 per cent and -32.15 to 109.4 per cent for better parent and standard heterosis respectively in F_1s and reciprocals. The total of 20 and 17 F_1 crosses and 10 and 8 reciprocal F_1 exhibited significant better parent and standard heterosis respectively. Chaudhari *et al.* 2015 [2] and Das *et al.* 2013 noted desirable heterosis for seed yield and other yield contributing traits. The best promising crosses for better parent and standard heterosis were TBS-10 x R-09, TBS-105 x R-09, TBS-7 x R-20, TBS-7 x TBS-12 and TBS-7 x R-09. Georgieve *et al.* 2011 and Parimala *et al.* 2013 [13] also reported significant positive heterosis over mid parent and better parent for this trait. The highest heterobeltios for seed yield per plant was observed for the cross R-09 x V-29 (152.16%) followed by number of capsule per plant in cross TBS-10 x R-09 (149.03%).

The single economic trait in sesame is oil content. None of the hybrids showed significant positive better parent and standard heterosis.

Table 1: Mean squares for parents and F_1s for different characters

Source of variation	D.f.	Days to 50% flowering	Days to maturity	Plant height (cm)	No of branches/ plant	Number of capsules/plant	Length of capsule (cm)	Number of seeds/capsule	1000 seed weight (g)	Seed yield/ plant (g)	Oil content (%)
Replication	1	0	38.15	11.77	0.19	34.93	0.001	7.70	0.01	0.19	0.19
Genotypes	66	7.84*	30.94**	848.86**	0.33**	705.7**	0.14**	82.98*	0.43	38.50**	45.60**
Parents (P)	7	2.53	19.26	688.3**	0.26*	23.99	0.06	59.48*	0.69**	1.27	62.91**
Hybrids (F_1)	55	6.58	30.95**	904.49**	0.27**	752.3**	0.14**	68.77	0.40**	37.22**	44.74**
P *vs* F_1	1	95.81**	69.47*	46.03	0.02	4306.5*	0	443.39**	0.21	398.1**	13.28
Error	66	5.18	13.5	108.12	0.09	28.40	0.07	46.52	2.92	2.92	21.32

*, ** Significant at 5% and 1% level respectively.

Table 2: Mean performance of the parents and their F_1s including reciprocal hybrids for ten traits in sesame

Sr. No.	Parents/hybrids	Days to 50% flowering	Days to maturity	Plant height (cm)	No of branches per plant	No of capsules per plant	Length of capsule (cm)	No of seeds per capsule	1000 seed weight (gm)	Seed yield per plant (gm)	Oil content (%)
	Parents										
1	TBS-3	42.00	88.50	114.83	3.82	57.00	2.96	63.17	4.19	9.72	38.08
2	TBS-7	41.50	88.00	117.71	3.74	59.50	2.99	62.17	4.61	10.86	42.86
3	TBS-10	41.50	87.50	113.96	3.75	59.17	3.30	62.34	4.29	11.07	36.57
4	TBS-12	40.50	87.50	113.53	3.50	52.00	3.03	56.25	4.30	9.88	48.05
5	TBS-105	42.00	92.00	120.11	3.17	52.50	3.00	55.84	4.77	10.91	48.02
6	R-09	44.00	94.75	133.02	3.34	59.84	2.92	58.17	3.86	9.94	40.04
7	R-20	40.50	85.00	72.66	2.74	52.17	2.86	68.34	2.97	9.88	34.12
8	V-29	41.00	87.00	93.52	3.50	54.17	3.37	71.00	3.55	8.68	47.98
	Parental mean	41.63	88.78	109.92	3.45	55.79	3.05	62.16	4.07	10.12	41.97
	Hybrids										
9	TBS-3 x TBS-7	43.00	87.50	95.47	3.74	63.17	3.16	66.67	3.95	14.02	37.37
10	TBS-3 x TBS-10	43.50	87.50	114.96	3.17	60.67	3.10	70.00	4.32	11.33	38.81
11	TBS-3 x TBS-12	41.50	87.00	128.57	3.17	62.17	2.90	73.17	4.12	14.86	41.51
12	TBS-3 x TBS-105	43.00	86.00	130.91	3.50	76.50	2.79	69.50	4.30	18.15	36.97
13	TBS-3 x R-09	42.50	88.00	126.50	3.17	63.84	3.07	61.83	4.17	16.92	34.16
14	TBS-3 x R-20	40.50	86.00	129.82	3.50	61.17	3.29	64.34	3.88	12.74	37.26
15	TBS-3 x V-29	40.50	85.00	115.91	3.50	58.28	3.50	65.01	3.54	12.18	45.17
16	TBS-7 x TBS-10	42.00	86.00	126.87	3.17	71.12	3.02	71.34	4.16	18.31	36.98
17	TBS-7 x TBS-12	42.50	87.50	132.50	3.17	89.42	3.02	69.89	4.75	19.83	46.92
18	TBS-7 x TBS-105	43.50	88.50	114.00	4.25	105.34	3.32	71.50	4.92	18.85	39.96
19	TBS-7 x R-09	45.50	88.50	128.48	3.34	73.00	3.36	73.50	3.71	18.71	38.94
20	TBS-7 x R-20	45.50	88.50	126.50	3.17	76.00	3.39	71.17	4.39	19.88	34.43
21	TBS-7 x V-29	44.00	87.00	121.33	3.74	93.34	3.29	71.84	3.66	25.17	45.57
22	TBS-10 x TBS-12	44.50	92.00	114.44	3.82	107.67	3.30	73.01	4.06	19.94	39.79
23	TBS-10 x TBS-105	42.50	94.50	123.65	3.50	80.16	3.19	68.67	3.98	17.76	38.70
24	TBS-10 x R-09	44.50	94.00	98.17	3.75	149.01	3.37	75.17	4.48	24.12	41.90
25	TBS-10 x R-20	43.50	91.50	125.01	3.17	72.67	3.29	68.22	4.46	17.59	38.24
26	TBS-10 x V-29	43.50	87.50	120.39	3.75	91.00	3.29	73.57	4.13	20.33	44.02
27	TBS-12 x TBS-105	44.50	92.50	89.34	3.75	63.00	3.13	58.50	4.29	12.94	40.93
28	TBS-12 x R-09	45.50	92.50	132.92	3.34	54.51	2.57	65.50	3.86	19.13	45.09
29	TBS-12 x R-20	44.00	86.00	123.06	2.82	53.67	3.12	60.00	4.07	12.83	43.22
30	TBS-12 x V-29	47.00	86.00	83.34	3.01	54.00	2.76	74.67	4.12	9.78	44.85
31	TBS-105 x R-09	45.50	94.00	100.84	4.00	67.50	2.97	66.33	3.96	22.84	47.29
32	TBS-105 x R-20	47.50	88.50	122.24	2.50	60.17	3.09	70.50	4.16	10.62	38.16

33	TBS-105 x V-29	45.50	91.50	128.61	3.17	100.50	3.20	65.50	4.25	22.56	50.04
34	R-09 x R-20	44.50	97.50	133.48	4.34	68.00	2.57	68.67	3.76	15.36	44.04
35	R-09 x V-29	46.00	97.50	118.17	3.82	135.34	2.77	58.50	3.49	25.07	38.99
36	R-20 x V-29	45.50	87.00	91.00	3.90	88.67	3.16	75.00	2.97	14.95	41.99
37	TBS-7 x TBS-3	43.50	90.50	73.50	3.17	49.84	2.80	68.67	4.38	11.89	37.81
38	TBS-10 x TBS-3	44.50	90.50	78.09	3.67	50.14	2.92	59.17	4.25	10.16	31.92

Sr. No.	Parents/hybrids	Days to 50% flowering	Days to maturity	Plant height (cm)	No of branches per plant	No of capsules per plant	Length of capsule (cm)	No of seeds per capsule	1000 seed weight (gm)	Seed yield per plant (gm)	Oil content (%)
39	TBS-12 x TBS-3	43.00	88.50	107.49	3.17	59.81	2.94	59.01	4.16	9.93	31.07
40	TBS-105 x TBS-3	43.50	93.50	87.92	3.50	59.31	3.22	68.48	3.88	9.94	38.09
41	R-09 x TBS-3	43.50	94.00	70.76	3.33	55.14	3.03	61.59	4.28	11.60	41.93
42	R-20 x TBS-3	44.00	92.00	109.86	3.74	84.81	3.15	71.07	4.05	12.86	45.62
43	V-29 x TBS-3	44.50	92.50	122.10	3.67	77.64	2.92	57.45	4.18	12.59	35.07
44	TBS-10 x TBS-7	45.50	92.50	123.10	4.17	64.14	3.26	67.79	4.27	13.22	41.12
45	TBS-12 x TBS-7	43.50	93.50	104.98	3.33	81.31	2.98	62.97	4.40	18.27	34.92
46	TBS-105 x TBS-7	44.00	97.00	120.28	3.74	67.47	3.03	67.45	4.31	13.15	39.81
47	R-09 x TBS-7	46.50	97.50	122.08	3.92	74.14	2.81	70.21	3.99	17.49	43.03
48	R-20 x TBS-7	44.00	97.00	117.67	3.17	70.65	2.92	57.45	3.43	17.04	42.98
49	V-29 x TBS-7	43.50	94.50	114.77	3.33	58.98	2.84	65.04	3.82	12.66	35.69
50	TBS-12 x TBS-10	47.50	92.00	101.76	3.83	67.64	2.77	67.97	3.25	13.81	52.29
51	TBS-105 x TBS-10	46.50	94.50	73.92	3.50	80.48	3.41	66.76	3.96	14.05	42.32
52	R-09 x TBS-10	45.00	98.00	75.26	3.75	65.81	2.67	62.80	4.21	17.55	40.12
53	R-20 x TBS-10	45.50	98.50	74.26	3.17	51.97	3.22	74.00	3.47	10.01	37.08
54	V-29 x TBS-10	47.50	98.00	72.59	3.83	62.81	3.09	67.45	3.74	10.20	33.04
55	TBS-105 x TBS-12	44.50	91.50	124.45	3.75	69.98	2.64	51.77	2.82	9.94	43.17
56	R-09 x TBS-12	45.50	93.50	127.68	3.84	73.98	2.98	65.21	3.81	13.82	41.78
57	R-20 x TBS-12	43.50	90.50	77.42	3.83	70.64	2.77	66.93	3.94	10.32	42.82
58	V-29 x TBS-12	43.50	86.50	142.89	3.58	79.64	4.05	83.82	3.45	20.18	46.78
59	R-09 x TBS-105	42.50	86.00	128.74	3.17	71.56	2.71	75.03	4.00	15.65	41.82

Sr. No.	Parents/hybrids	Days to 50% flowering	Days to maturity	Plant height (cm)	No of branches per plant	No of capsules per plant	Length of capsule (cm)	No of seeds per capsule	1000 seed weight (gm)	Seed yield per plant (gm)	Oil content (%)
60	R-20 x TBS-105	42.50	88.50	84.42	3.17	79.14	2.90	67.79	3.88	20.45	48.00
61	V-29 x TBS-105	41.50	87.00	71.76	3.75	61.14	2.90	74.86	3.27	11.88	34.84
62	R-20 x R-09	41.00	90.50	88.59	3.00	56.64	3.37	65.04	3.94	15.32	44.04
63	V-29 x R-09	48.00	95.50	73.76	2.92	59.81	2.79	75.72	2.56	8.16	47.85
64	V-29 x R-20	48.00	87.00	87.26	3.17	102.14	3.24	72.96	3.16	16.33	49.16
	Hybrid mean	44.24	91.01	108.10	3.49	73.33	3.06	67.79	3.94	15.45	40.99
	C.V.	5.17	4.05	9.64	8.97	7.54	9.24	10.23	9.56	11.70	11.23
	S.E.	1.61	2.59	7.35	0.22	3.77	0.20	4.82	0.27	1.21	3.21
	C.D. 5%	4.54	7.32	20.76	0.62	10.64	0.56	13.62	0.75	3.41	9.07

Table 3: Heterosis over better parent and best check in 28 F_1s and their reciprocals F_1 crosses for ten traits in sesame.

Crosses	Days to 50% flowering				Days to maturity			
	Heterobeltiosis		Standard heterosis		Heterobeltiosis		Standard heterosis	
	Cross	REC	Cross	REC	Cross	REC	Cross	REC
TBS-3 x TBS-7	2.38	3.57	-5.49	-4.4	-1.13	2.26	1.16	4.62
TBS-3 x TBS-10	3.57	5.95	-4.4	-2.2	-1.13	2.26	1.16	4.62
TBS-3 x TBS-12	-1.19	2.38	-8.79	-5.49	-1.69	0	0.58	2.31
TBS-3 x TBS-105	2.38	3.57	-5.49	-4.4	-6.52	1.63	-0.58	8.09
TBS-3 x R-09	-3.41	-1.14	-6.59	-4.4	-7.12	-0.79	1.73	8.67
TBS-3 x R-20	-3.57	4.76	-10.99*	-3.3	-2.82	3.95	-0.58	6.36
TBS-3 x V-29	-3.57	5.95	-10.99*	-2.2	-3.95	4.52	-1.73	6.94
TBS-7 x TBS-10	1.2	9.64	-7.69	0	-2.27	5.11	-0.58	6.94
TBS-7 x TBS-12	2.41	4.82	-6.59	-4.4	-0.57	6.25	1.16	8.09
TBS-7 x TBS-105	3.57	4.76	-4.4	-3.3	-3.8	5.43	2.31	12.14**
TBS-7 x R-09	3.41	5.68	0	2.2	-6.6	2.9	2.31	12.72**
TBS-7 x R-20	9.64	6.02	0	-3.3	0.57	10.23*	2.31	12.14**
TBS-7 x V-29	6.02	4.82	-3.3	-4.4	-1.14	7.39	0.58	9.25*
TBS-10 x TBS-12	7.23	14.46*	-2.2	4.4	5.14	5.14	6.36	6.36
TBS-10 x TBS-105	1.19	10.71	-6.59	2.2	2.72	2.72	9.25*	9.25*
TBS-10 x R-09	1.14	2.27	-2.2	-1.1	-0.79	3.43	8.67	13.29**
TBS-10 x R-20	4.82	9.64	-4.4	0	4.57	12.57**	5.78	13.87**
TBS-10 x V-29	4.82	14.46*	-4.4	4.4	0	12**	1.16	13.29**

TBS-12 x TBS-105	5.95	5.95	-2.2	-2.2	0.54	-0.54	6.94	5.78
TBS-12 x R-09	3.41	3.41	0	0	-2.37	-1.32	6.94	8.09
TBS-12 x R-20	8.64	7.41	-3.3	-4.4	-1.71	3.43	-0.58	4.62
TBS-12 x V-29	14.63*	6.1	3.3	-4.4	-1.71	-1.14	-0.58	0
TBS-105 x R-09	3.41	-3.41	0	-6.59	-0.79	-9.23*	8.67	-0.58
TBS-105 x R-20	13.1*	1.19	4.4	-6.59	-3.8	-3.8	2.31	2.31
TBS-105 x V-29	8.33	-1.19	0	-8.79	-0.54	-5.43	5.78	0.58
R-09 x R-20	1.14	-6.82	-2.2	-9.89	2.9	-4.49	12.72**	4.62
R-09 x V-29	4.55	9.09	1.1	5.49	2.9	0.79	12.72**	10.4*
R-20 x V-29	10.98	17.07**	0	5.49	0	0	0.58	0.58

Crosses	Plant height				Number of branches per plant			
	Heterobeltiosis		Standard heterosis		Heterobeltiosis		Standard heterosis	
	Cross	REC	Cross	REC	Cross	REC	Cross	REC
TBS-3 x TBS-7	-18.89 *	-37.56 **	-15.18	-34.7**	-2.1	-17.04*	36.56	15.72
TBS-3 x TBS-10	0.12	-32.00 **	2.14	-30.62**	-16.91	-3.8	15.9	34.19**
TBS-3 x TBS-12	11.97	-6.39	14.23	-4.5	-16.91	-17.04*	15.9	15.72
TBS-3 x TBS-105	9	-26.80 **	16.31	-21.88*	-8.26	-8.39	27.97*	27.79*
TBS-3 x R-09	-4.9	-46.81 **	12.39	-37.13**	-17.04 *	-12.71	15.72	21.76
TBS-3 x R-20	13.06	-4.32	15.34	-2.39	-8.26	-2.1	27.97*	36.56**
TBS-3 x V-29	0.94	6.33	2.99	8.48	-8.26	-3.93	27.97*	34**
TBS-7 x TBS-10	7.78	4.58	12.72	9.37	-15.6	11.07	15.72	52.29**
TBS-7 x TBS-12	12.56	-10.81	17.72	-6.73	-15.26	-10.84	15.72	21.76
TBS-7 x TBS-105	-5.09	0.14	1.28	6.86	13.79	0	55.39**	36.56**
TBS-7 x R-09	-3.41	-8.23	14.15	8.46	-10.71	4.82	21.94	43.14**
TBS-7 x R-20	7.47	-0.03	12.39	4.55	-15.26	-2.1	15.72	15.72
TBS-7 x V-29	3.08	-2.5	7.8	1.97	0	-10.84	36.56**	21.76
TBS-10 x TBS-12	0.42	-10.71	1.67	-9.59	1.73	2.13	39.49**	40.04**
TBS-10 x TBS-105	2.95	-38.45**	9.86	-34.32**	-6.67	-6.67	27.97*	27.97*
TBS-10 x R-09	-26.20 **	-43.43**	-12.78	-33.14**	0	-0.13	37.11**	36.93**
TBS-10 x R-20	9.69	-34.84 **	11.07	-34.02**	-15.47	-15.6	15.9	15.72
TBS-10 x V-29	5.64	-36.31 **	6.97	-35.51**	0	2.13	37.11**	40.04**
TBS-12 x TBS-105	-25.62 **	3.61	-20.63*	10.57	7.14	7.14	37.11**	37.11**
TBS-12 x R-09	-0.08	-4.02	18.09	13.44	-4.71	9.57	21.94	40.22**
TBS-12 x R-20	8.39	-31.80 **	9.33	-31.21**	-19.57 *	9.43	2.93	40.04**
TBS-12 x V-29	-26.59 **	25.87 **	-25.96*	26.96**	-14.14	2.29	9.87	30.9**
TBS-105 x R-09	-24.20 **	-3.22	-10.41	14.38	19.79 *	-5.1	46.07**	15.72
TBS-105 x R-20	1.77	-29.71 **	8.61	-24.99**	-21.14 *	-0.16	-8.59	15.72
TBS-105 x V-29	7.08	-40.26 **	14.26	-36.25**	-9.57	7	15.72	36.93**
R-09 x R-20	0.35	-33.40 **	18.6	-21.29*	29.99 **	-10.04	58.5**	9.69
R-09 x V-29	-11.17	-44.55 **	4.99	-34.47**	9	-16.71	39.49**	6.58
R-20 x V-29	-2.69	-6.7	-19.15*	-22.47*	11.43	-9.57	42.6**	15.72

Crosses	Number of capsules per plant				Length of capsule			
	Heterobeltiosis		Standard heterosis		Heterobeltiosis		Standard heterosis	
	Cross	REC	Cross	REC	Cross	REC	Cross	REC
TBS-3 x TBS-7	6.16	-16.24	-5.25	-25.25**	5.7	-6.2	15.57	2.56
TBS-3 x TBS-10	2.53	-15.26	0	-24.79**	-6.06	-11.67	13.55	6.78
TBS-3 x TBS-12	9.06	4.93	-6.75	-10.28	-4.29	-2.97	6.23	7.69
TBS-3 x TBS-105	34.21 **	4.05	14.75	-11.03	-7.17	7.17	2.01	17.77
TBS-3 x R-09	6.69	-7.85	-4.25	-17.29*	3.89	2.37	12.45	10.81
TBS-3 x R-20	7.32	48.78**	-8.24	27.21**	11.17	6.6	20.33	15.38
TBS-3 x V-29	2.25	36.21**	-12.58	16.46	3.86	-13.5	28.21**	6.78
TBS-7 x TBS-10	19.52 *	7.8	6.68	-3.79	-8.64	-1.21	10.44	19.41
TBS-7 x TBS-12	50.28 **	36.66**	34.13**	21.97**	-0.5	-1.65	10.44	9.16
TBS-7 x TBS-105	77.03 **	13.39	58.01**	1.21	10.5	0.83	21.43*	10.81
TBS-7 x R-09	22.00 *	23.90**	9.5	11.21	12.4	-5.86	22.89*	2.93
TBS-7 x R-20	27.73 **	18.73*	14	5.97	13.4	-2.35	23.99*	6.78
TBS-7 x V-29	56.87 **	-0.88	40.01**	-11.54	-2.52	-15.88	20.33	3.85
TBS-10 x TBS-12	81.97 **	14.31	61.51**	1.46	0	-16.06	20.88*	1.47
TBS-10 x TBS-105	35.47 **	36.01**	20.24**	20.72*	-3.48	3.33	16.67	24.91*
TBS-10 x R-09	149.03 **	9.98	123.51**	-1.29	2.12	-19.24*	23.44*	-2.38
TBS-10 x R-20	22.81 *	-12.17	9	-22.04*	-0.45	-2.58	20.33	17.77
TBS-10 x V-29	53.79 **	6.14	36.5**	-5.79	-2.52	-8.31	20.33	13.19
TBS-12 x TBS-105	19.99	33.29**	-5.51	4.97	3.3	-12.87	14.65	-3.3
TBS-12 x R-09	-8.91	23.63**	-18.24*	10.97	-15.18	-1.65	-5.86	9.16
TBS-12 x R-20	2.89	35.42**	-19.49*	5.96	2.81	-8.58	14.1	1.47

TBS-12 x V-29	-0.3	47.03**	-19*	19.46*	-18.25 *	20.18 *	0.92	48.35**
TBS-105 x R-09	12.81	19.59*	1.25	7.34	-1.17	-9.83	8.61	-0.92
TBS-105 x R-20	14.6	50.74**	-9.75	18.71*	2.83	-3.33	13	6.23
TBS-105 x V-29	85.54 **	12.88	50.75**	-8.29	-5.04	-13.95	17.22	6.23
R-09 x R-20	13.65	-5.34	2	-15.04	-11.84	15.61	-5.86	23.44*
R-09 x V-29	126.18 **	-0.05	103.01**	-10.29	-17.80 *	-17.21*	1.47	2.2
R-20 x V-29	63.70 **	88.57**	33.01**	53.21**	-6.38	-3.86	15.57	18.68

Crosses	Number of seeds per capsule				1000-seed weight			
	Heterobeltiosis		Standard heterosis		Heterobeltiosis		Standard heterosis	
	Cross	REC	Cross	REC	Cross	REC	Cross	REC
TBS-3 x TBS-7	5.55	8.72	0.76	3.79	-14.32	-4.99	7.05	18.7
TBS-3 x TBS-10	10.82	-6.32	5.8	-10.57	0.82	-0.82	17.07	15.18
TBS-3 x TBS-12	15.84	-6.59	10.59	-10.82	-4.3	-3.37	11.52	12.6
TBS-3 x TBS-105	10.03	8.41	5.04	3.5	-9.85	-18.76*	16.53	5.01
TBS-3 x R-09	-2.11	-2.49	-6.55	-6.91	-0.48	2.03	13.01	15.85
TBS-3 x R-20	-5.85	4	-2.77	7.41	-7.52	-3.34	5.01	9.76
TBS-3 x V-29	-8.44	-19.08	-1.75	-13.17	-15.51	-0.36	-4.07	13.14
TBS-7 x TBS-10	14.44	8.75	7.81	2.46	-9.76	-7.38	12.74	15.72
TBS-7 x TBS-12	12.42	1.29	5.62	-4.84	2.93	-4.56	28.59**	19.24
TBS-7 x TBS-105	15.02	8.49	8.06	1.93	3.14	-9.75	33.33**	16.67
TBS-7 x R-09	18.23	12.93	11.09	6.11	-19.52 *	-13.56	0.54	7.99
TBS-7 x R-20	4.15	-15.93	7.56	-13.17	-4.77	-25.60**	18.97	-7.05
TBS-7 x V-29	1.18	-8.39	8.57	-1.7	-20.61 *	-17.14*	-0.81	3.52
TBS-10 x TBS-12	17.12	9.03	10.34	2.72	-5.58	-24.42**	10.03	-11.92
TBS-10 x TBS-105	10.15	7.09	3.78	0.89	-16.67 *	-17.09*	7.72	7.18
TBS-10 x R-09	20.58	0.74	13.6	-5.09	4.55	-1.75	21.41*	14.09
TBS-10 x R-20	-0.17	8.28	3.11	11.83	4.08	-19.14*	20.87*	-6.1
TBS-10 x V-29	3.62	-5	11.19	1.94	-3.62	-12.72	11.92	1.36
TBS-12 x TBS-105	4	-7.97	-11.58	-21.76*	-10.06	-40.99**	16.26	-23.71*
TBS-12 x R-09	12.61	12.1	-1.01	-1.45	-10.23	-11.4	4.61	3.25
TBS-12 x R-20	-12.2	-2.06	-9.33	1.16	-5.47	-8.49	10.16	6.64
TBS-12 x V-29	5.16	18.05	12.85	26.68*	-4.3	-19.77*	11.52	-6.5
TBS-105 x R-09	14.04	29.00*	0.25	13.4	-16.98 *	-16.25*	7.32	8.27
TBS-105 x R-20	3.17	-0.8	6.55	2.46	-12.89	-18.66*	12.6	5.15
TBS-105 x V-29	-7.75	5.43	-1.01	13.13	-10.9	-31.55**	15.18	-11.52
R-09 x R-20	0.48	-4.83	3.78	-1.71	-2.46	2.2	1.9	6.78
R-09 x V-29	-17.61	6.64	-11.58	14.43	-9.47	-33.59**	-5.42	-30.62*
R-20 x V-29	5.63	2.76	13.35	10.27	-16.48	-10.99	-19.65	-14.36

Crosses	Seed yield per plant				Oil content			
	Heterobeltiosis		Standard heterosis		Heterobeltiosis		Standard heterosis	
	Cross	REC	Cross	REC	Cross	REC	Cross	REC
TBS-3 x TBS-7	29.1	9.44	16.64	-1.12	-12.81	-11.79	-14.42	-13.42
TBS-3 x TBS-10	2.35	-8.18	-5.78	-15.47	1.93	-16.17	-11.12	-26.9*
TBS-3 x TBS-12	50.43**	0.56	23.59	-17.39	-13.61	-35.33**	-4.95	-28.84**
TBS-3 x TBS-105	66.36**	-8.94	51.00**	-17.35	-23.01*	-20.6*	-15.33	-12.77
TBS-3 x R-09	70.17**	16.65	40.72**	-3.54	-14.69	4.72	-21.77*	-3.97
TBS-3 x R-20	29.01	30.18	5.99	6.95	-2.15	19.82	-14.68	4.48
TBS-3 x V-29	25.26	29.48	1.29	4.7	-5.86	-26.91**	3.44	-19.7
TBS-7 x TBS-10	65.48**	19.43	52.33**	9.94	-13.73	-4.07	-15.32	-5.84
TBS-7 x TBS-12	82.60**	68.19**	64.98**	51.96**	-2.35	-27.33**	7.44	-20.04
TBS-7 x TBS-105	72.73**	20.49	56.78**	9.36	-16.78	-17.11	-8.49	-8.84
TBS-7 x R-09	72.28**	61.05**	55.66**	45.51**	-9.16	0.4	-10.83	-1.45
TBS-7 x R-20	83.06**	56.91**	65.39**	41.76**	-19.68	0.28	-21.16	-1.57
TBS-7 x V-29	131.77**	16.53	109.4**	5.28	-5.01	-25.61**	4.36	-18.26
TBS-10 x TBS-12	80.21**	24.81	65.89**	14.89	-17.19	8.83*	-8.89	19.74
TBS-10 x TBS-105	60.51**	26.93	47.75**	16.85	-19.42	-11.87	-11.38	-3.08
TBS-10 x R-09	117.98**	58.56**	100.67**	45.97**	4.65	0.19	-4.04	-8.13
TBS-10 x R-20	58.97**	-9.58	46.34**	-16.76	4.58	1.41	-12.42	-15.08
TBS-10 x V-29	83.69**	-7.82	69.09**	-15.14	-8.24	-31.13**	0.81	-24.33*
TBS-12 x TBS-105	18.61	-8.89	7.65	-17.3	-14.81	-10.15	-6.26	-1.13
TBS-12 x R-09	92.45**	39.03*	59.15**	14.98	-6.16	-13.04	3.25	-4.32
TBS-12 x R-20	29.87	4.46	6.7	-14.18	-10.05	-10.89	-1.03	-1.95
TBS-12 x V-29	-0.96	104.30**	-18.64	67.85**	-6.66	-2.64	2.7	7.12
TBS-105 x R-09	109.30**	43.45**	89.98**	30.2*	-1.53	-12.92	8.29	-4.24
TBS-105 x R-20	-2.7	87.40**	-11.69	70.09**	-20.54*	-0.04	-12.62	9.93

TBS-105 x V-29	106.74**	8.85	87.65**	-1.21	4.2	-27.46**	14.59	-20.22
R-09 x R-20	54.48**	54.07**	27.75	27.41	9.98	9.98	0.85	0.85
R-09 x V-29	152.16**	-17.96	108.53**	-32.15*	-18.74	-0.26	-10.72	9.58
R-20 x V-29	51.39**	65.32**	24.38	35.82*	-12.48	2.47	-3.84	12.58

Conclusion

It can be concluded from present study that F_1 hybrids and reciprocals TBS-10 x R-09, TBS-105 x R-09, TBS-7 x R-20, TBS-7 x TBS-12 and TBS-7 x R-09 were the top ranking out of 20 manifested highly significant and desirable heterosis for seed yield and other component traits over better parent and standard check (AKT-101). The hybrid TBS-105 x R-09 showed desirable heterosis for component traits like number of branches per plant, number of capsules per plant and number of seeds per capsule, TBS-7 x R-20 and TBS-7 x TBS-12 for number of capsule per plant. Heterosis and *per se* performance indicated that F_1 hybrids TBS-7 x V-29, R-09 x V-29, TBS-10 x R-09, TBS-105 x R-09, TBS-105 x V-29, R-20 x TBS-105, TBS-10 x V-29, V-29 x TBS-12, TBS-10 x TBS-12 and TBS-7 x R-20 were found promising for commercial exploitation. The selected crosses for each trait have high potential to be used for recombination breeding to develop high yielding pure lines. The different extent of heterosis showed by some crosses of F_1 and their reciprocal F_1 for most of the characters indicated the presence of maternal inheritance suggested importance of considering female parents in the respective crosses and characters to maximize the exploitable heterosis in hybrids.

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