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Heterosis for seed yield and its components in castor (*Ricinus communis* 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. Experimental material consisting of 95 entries comprised of four pistillate lines (used as females) and eighteen inbred lines (used as males) and their 72 hybrids developed through line x tester mating design along with standard check hybrid (GCH 9) were evaluated in a randomized block design with three replications. Perusal of mean data revealed that among females, SKP 84 and JP 96 and among males, SKI 392, SKI 215 and SKI 405 exhibited higher per se performance for seed yield per plant and its contributing traits. Three crosses viz., JP 96 × SKI 392, JP 96 × SKI 215 and SKP 84 × JI 244 appeared to be the most suitable crosses for exploitation in practical plant breeding programme in castor, as they recorded 41.34 per cent, 25.89 per cent and 45.99 per cent significantly the higher heterosis over their respective better parent; and 52.45 per cent (429.00 g), 29.38 per cent (364.07 g) and 27.77 per cent (359.53 g) significantly the higher heterosis over standard check GCH 9 (281.40 g). These cross combinations also possessed high per se performance for one or more yield contributing traits.

Keywords: castor, heterosis, heterobeltiosis, standard heterosis

Introduction
Castor (*Ricinus communis* L.) is one of the most important non-edible oilseed crops in the world. It is generally distributed in the tropical, sub-tropical and warm temperate zones (Weiss, 2000) [35]. It is a species of flowering plant in the spurge family, Euphorbiaceae. It belong to a monotypic genus, *Ricinus* and subtribe, Ricininae. Castor is believed to have originated in Egypt, Ethiopian region of tropical East Africa and India. Subsequently it spread to China, Brazil, Thailand, Argentina, U.S.A. etc. (Anjani, 2012) [1]. It is a cross pollinated crop with a chromosomes number, 2n = 20. Castor is a monoecious plant and its inflorescence is known as raceme or spike. In the raceme, 30-50% upper portion contains female flowers and 50-70% lower portion possess male flowers. *Ricinus communis* has been reported to be a secondary balanced polyploidy with basic chromosome number x=5. The haploid studies indicated that the species has arisen as tetraploid from a diploid progenitors 2n=10. The wild species in the castor includes *Ricinus perciens*, *Ricinus chinesis and Ricinus maxicanus* (Kulkarni, 1959) [13]. Castor is a sexually polymorphic species with different sex forms viz., monoecious, pistillate and pistillate with interspersed staminate flowers (Ramachandram and Rangarao, 1988 and Lavanya, 2002) [29, 14].
The phenomenon of heterosis has proved to be the most important genetic tool in enhancing the yield of self as well as cross pollinated species in general and castor in particular. With the availability of cent per cent pistillate lines in castor, exploitation of heterosis or hybrid vigour on commercial scale has become commercially feasible and economical (Gopani *et al.*, 1968) [9]. In Gujarat, real breakthrough in castor production has come with the development and release of hybrids for commercial cultivation. Still, there is potential to further increase in yield level of castor through genetic improvement.

Materials and Methods
Experimental material consisting of 95 entries comprised of four pistillate lines (JP 96, JP 106, SKP 84 and VP 1, used as testers/females) and Eighteen inbred lines (JI 244, JI 390, JI 398, JI 424, JI 426, JI 436, JI 437, SKI 215, SKI 327, SKI 343, SKI 392, SKI 397, SKI 405, RG 3041, RG 3073, JC 24, PCS 124 and 500-2 used as lines/males) and their 72 hybrids developed through line x tester mating design along with standard check hybrid (GCH 9) were evaluated in a randomized block design with three replications. The materials were evaluated during *kharif* 2016-17 at the Main Oilseeds Research station, Junagadh Agricultural University, Junagadh.

Five competitive plants per each entry in each replication were randomly selected before flowering and tagged for the purpose of recording the observations of different characters *viz*., plant height up to primary raceme (cm), number of nodes up to primary raceme, length of primary raceme (cm), effective length of primary raceme (cm), number of effective branches per plant, number of capsules on primary raceme, shelling out turn (%), 100-seed weight (g), seed yield per plant (g) and oil content (%). Days to flowering of primary raceme and days to maturity of primary raceme were recorded on plot basis. The analysis of variance for experimental design was performed to test the significance of difference among the genotypes for all the characters as per the method suggested by Panse and Sukhatme (1985) [22]. 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 GCH 9 and it was estimated as per the formula given by Meredith and Bridge (1972) [20] 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 twelve characters studied and is presented in Table 1. The results revealed that the mean squares due to genotypes were highly significant for all the characters. The mean squares due to genotypes were further partitioned into mean squares due to parents, hybrids and parents *vs.* hybrids. The analysis of variance revealed that the mean squares due to parents and hybrids differed significantly for all the characters except oil content in case of hybrids. The mean squares due to parents vs. hybrids were also significant for all the characters. Which indicated that the performance of parents as a group was different than that of crosses as a group, thereby supporting the presence of mean heterosis for all the traits studied.

Considering *per se* performance of hybrids, eleven hybrids yielded higher than GCH 9 for seed yield per plant, of which three hybrids JP 96 × SKI 392 (429.00 g), JP 96 × SKI 215 (364.07 g) and SKP 84 × JI 244 (359.53 g) yielded significantly higher than GCH 9 (281.40 g). Ten superior cross combinations for seed yield per plant placed in based on *per se* performance. Among them, three cross combinations JP 96 × SKI 392, JP 96 × SKI 215 and SKP 84 × JI 244 had high *per se* performance along with significant heterobeltiosis and standard heterosis for seed yield per plant. These crosses also manifested the significant positive standard heterosis over GCH 9 for important yield contributing traits like JP 96 × SKI 392 manifested the significant standard heterosis for days to flowering of primary raceme, days to maturity of primary raceme, length of primary raceme, effective length of primary raceme, number of capsules on primary raceme, number of effective branches per plant, 100-seed weight and shelling out turn; JP 96 × SKI 215 for length of primary raceme, effective length of primary raceme, number of capsules on primary raceme, number of effective branches per plant, 100-seed weight and shelling out turn; and SKP 84 × JI 244 for days to flowering of primary raceme, days to maturity of primary raceme, effective length of primary raceme, number of capsules on primary raceme, 100-seed weight and shelling out turn (Table 2). This emphasized that high degree of heterosis for seed yield might be attributed to the heterosis observed for these component characters. Similar findings have been reported by Sridhar *et al*. (2009) [33], Sodavadiya (2010) [32], Sapovadiya *et al.* (2015) [30], Makani *et al.* (2015) [18] and Patted *et al*. (2016) [27], Chaudhari *et al.* (2017) [4].

In the present study, heterosis over better parent (heterobeltiosis) and over standard check, GCH 9 (standard heterosis) was estimated. Several crosses exhibited conspicuous level of heterobeltiosis and standard heterosis for different characters are presented in Table 3A to 3C. Range of heterosis as well as number of crosses exhibited significance positive as well as negative heterobeltiosis and standard heterosis are presented in Table 4.

The magnitude of standard heterosis in the positive direction was high for number of capsules on primary raceme and 100-seed weight; medium for length of primary raceme, effective length of primary raceme, number of effective branches per plant, shelling out turn and seed yield per plant and low for oil content. Similarly, the magnitude of standard heterosis in the negative direction was medium for characters, viz., days to flowering of primary raceme, plant height up to primary raceme and number of nodes up to the primary raceme and low for days to maturity of primary raceme. The magnitude of heterobeltiosis in the positive direction was high for number of capsules on primary raceme and seed yield per plant; medium for length of primary raceme, effective length of primary raceme, number of effective branches per plant, shelling out turn and 100-seed weight and low for oil content. Similarly, the magnitude of heterobeltiosis in the negative direction was high for plant height up to primary raceme and medium for days to flowering of primary raceme, days to maturity of primary raceme and number of nodes up to the primary raceme (Table 4).

With respect to the performance of hybrids for seed yield per plant, it was observed that 29 hybrids over better parent and 11 hybrids over standard check (GCH 9) exhibited significant and positive heterosis (Table.4). The range of heterosis over better parent was from -44.56 to 115.85 %, while over standard check, it ranged from -61.90 to 52.45 %. The cross JP 96 × SKI 392 depicted significantly the highest and positive heterobeltiosis (41.34 %), standard heterosis (52.45 %) as well as the highest seed yield per plant (429 g). JP 96 × SKI 215 and SKP 84 × JI 244 were the next best crosses exhibiting significant and positive heterobeltiosis (25.89 % and 45.99 %, respectively), standard heterosis (29.38 % and 27.77 %, respectively) and *per se* performance (364.07 g and 359.53 g, respectively). In such cases, expression of heterotic response over better and standard parents indicated the real superiority of hybrids from the commercial point of view. High heterosis for seed yield in castor has also been reported Patel and Pathak, (2006) [24], Sridhar *et al.*, (2009) [33], Barad *et al.*, (2009) [2], Chaudhari *et al.*, (2011) [5], Chaudhari and Patel, (2014) [3], Makani et *al.*, (2015) [18], Sapovadiya *et al.*, (2015) [30], and Patted *et al.*, (2016) [27].

With regard to days to first flowering of primary raceme (Table 4), 52 crosses exhibited heterobeltiosis in desired (negative) direction and 54 crosses were found significantly earlier over standard check. The cross VP 1 x JI 398 was found earliest among the crosses over standard check followed by VP 1 x JI-390, VP 1 x JC 24 and VP 1 x SKI 343, while VP 1 x SKI 392, VP 1 x JI-390 and VP 1 x JC 24 were found the earliest over batter parent. Significant and desirable (negative) heterosis for days to 50 % flowering was also reported by Thakker *et al.* (2005) [34], Golakia *et al.* (2008) [8], Monapara *et al.* (2010) [21], Sodavadiya *et al.* (2010) [32], Chaudhari *et al.* (2011) [5], Rajani *et al.* (2015) [28] and Patel *et al.* (2015) [26].

For days to maturity of primary raceme, out of 72 hybrids, 47 and 49 hybrids showed significant and negative heterosis over better parent and standard check, respectively. The cross combination JP 96 x JI 424 recorded the highest desirable heterosis over standard check followed by VP 1 x RG 3073 and JP 96 x JI-436, while JP 96 x JI 424 followed by VP 1 x RG 3073 and JP 96 x 500-2 were found the earliest over better parent. Significant and negative heterosis for days to maturity has also been reported by Monapara *et al.* (2010) [21], Sodavadiya *et al.* (2010) [32], Chaudhari *et al.* (2011) [5], Rajani *et al.* (2015) [28], Sapovadiya *et al.* (2015) [30] and Patel *et al.* (2015) [26].

In case of plant height, dwarfness is considered as desirable attribute in castor. Out of 72 hybrids, 50 and 16 hybrids exhibited significant and negative heterobeltiosis and standard heterosis, respectively. In this context, three best crosses *viz*., VP 1 x RG 3073, JP 106 x RG 3073 and VP 1 x JI 424 depicted significant and negative standard heterosis, while cross combinations JP 106 x RG 3073, VP 1 x SKI 392 and VP 1 x JC 24 depicted desired heterobeltiosis for this trait. Significant and negative heterosis for plant height has been also reported by Joshi *et al.* (2001) [12], Golakia *et al.* (2004) [7], Patel and Pathak (2006) [24], Rajani *et al.* (2015) [28], Sapovadiya *et al.* (2015) [30] and Patel *et al.* (2015) [26].

Minimum number of nodes is being desirable in castor. Fourty seven crosses showed significant and desirable (negative) heterobeltiosis for this trait, while significant and desirable (negative) standard heterosis was observed in 23 cross combinations (Table 4). Three cross combinations *viz.*, JP 96 x JI 390, JP 96 x JI 424 and VP 1 x JC 24 recorded significantly higher and desirable magnitude for standard heterosis and were the best standard heterotic hybrids for number of nodes up to primary raceme, while cross combinations JP 96 x JI 390, JP 96 x JI 424 and JP 106 x JI 424 depicted desired heterobeltiosis for this trait. The results confirmed the results of those reported Manivel *et al.* (1999) [19], Joshi *et al.* (2001) [12], Thakkar *et al.* (2005) [34], Barad *et al.* (2009) [2] and Rajani *et al.* (2015) [28], Jalu *et al.* (2017) [11] for this trait.

The number of cross combinations that exceeded over better parent and standard check for length of primary raceme were five and 39 respectively (Table 4). The highest estimates of heterobeltiosis and standard heterosis were reported by the cross SKP 84 x SKI 392. The crosses JP 106 x JI 436, JP 96 x SKI 392, JP 106 x JI 398 and JP 106 x SKI 392 were the other best cross combinations with respect to standard heterosis for length of primary raceme. Similarly, for effective length of primary raceme, 11 hybrids exhibited significant and positive heterosis over better parent, whereas 48 hybrids exhibited significant and positive heterosis over standard check. Similar to length of primary raceme, cross SKP 84 x SKI 392 exhibited significantly the maximum and positive standard heterosis as well as heterobeltiosis for this trait. JP 106 x JI 436, JP 96 x SKI 392, JP 106 x SKI 392 and JP 106 x JI 398 were the other standard heterotic cross combination showing significant and positive heterosis over GCH 9 for effective length of main raceme. Similar findings for length of primary raceme and effective length of primary raceme have also been reported Manivel *et al.* (1999) [19], Golakia *et al.* (2004) [7], Sridhar *et al.* (2009) [33], Singh *et al.*, (2013) [31] and Patted *et al.* (2016) [27].

Two and six cross combinations exhibited significant and positive heterosis over better parent and standard hybrid, respectively for number of effective branches per plant (Table 4). The cross JP 106 × JI 390 exhibited significantly the highest and positive standard heterosis for number of effective branches per plant followed by JP 106 x SKI 215, JP 96 x 500-2, JP 96 x RG 3073 and JP 106 x JI 426. The highest estimate of heterobeltiosis (41.53 %) was recorded by JP 106 × JI 390. Positive estimation of heterosis for this trait was also reported by Joshi *et al.* (2001) [12], Lavanya and Chandramohan (2003) [15], Patel and Pathak (2006) [24] and Patted *et al.* (2016) [27].

Number of capsules on primary raceme is a major factor governing the seed yield in castor. The number of cross combinations which exceeded better and standard parental values for number of capsules on primary raceme was 26 and 39 crosses, respectively (Table 4). The present findings indicated that this character has wide genetic base in the population and still better results could be achieved by isolating desirable cross combinations with different parentage. The cross combination SKP 84 × JI 436 exhibited significantly the highest and positive standard heterosis followed by JP 106 x SKI 215, JP 106 x SKI 343, SKP 84 x JI 244 and JP 106 x JI 244. The top performing hybrid SKP 84 × JI 436 for number of capsules on primary raceme (144.8) also recorded significant and positive heterobeltiosis (73.48 %) and standard heterosis (79.65%) for this trait. High magnitude of desirable heterosis for this trait was also reported by Patel (1994), Manivel *et al.* (1999) [19], Joshi *et al.* (2001) [12], Sridhar *et al.* (2009) [33] and Patted *et al.* (2016) [27].

In case of shelling out turn, 26 hybrids showed significant and positive heterosis over better parent and eleven hybrids exhibited significant and positive heterosis over standard check (Table 4). Out of eleven standard heterotic crosses, JP 106 x JI 390, JP 96 × JI 398 and SKP 84 x SKI 405 registered significantly the maximum and positive standard heterosis for shelling out turn. The cross combination JP 96 x JI 398 exhibited significantly the highest and positive magnitude of heterobeltiosis followed by VP 1 x JI 424 and VP 1 x SKI 343. Positive estimation of heterosis for this trait was also reported by Lavanya *et al.* (2006) [16], Barad *et al.* (2009) [2] and Patel *et al.* (2010) [23] in castor.

For 100-seed weight, nine crosses expressed significant and positive heterobeltiosis, while 55 crosses exhibited significant and positive standard heterosis (Table 4). The cross combination JP 96 × JI 244 exhibited significantly the maximum heterobeltiosis and standard heterosis for test weight. SKP 106 x JI 398, SKP 84 x JI 390, JP 96 x SKI 343 and SKP 84 x JI 244 were the next four superior crosses for test weight as they displayed significant and positive standard heterosis. Significant estimates of heterosis for l00-seed weight have been also reported by Joshi *et al.* (2001) [12], Lavanya and Chandramohan (2003) [15], Golakia *et al.* (2004) [7], Sridhar *et al.* (2009) [33], Patel *et al.* (2010) [23] and Chaudhari and Patel (2014) [3].

For oil content, out of 72 crosses, none of hybrids manifested significant and desirable (positive) heterosis over better parent and standard check but the crosses JP 96 x SKI 397, SKP 84 x JI 437 and SKP 84 x JC 24 showed positive heterobeltiosis and JP 106 x 500-2, SKP 84 x 500-2 and VP 1 x 500-2 recorded positive standard heterosis for oil content. Similar findings have also been reported by Patel *et al.* (1991) [25], Maheshwari (2007) [17] and Rajani *et al.* (2015) [28] for this trait.

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

Sources	D.F.	Days to flowering of primary raceme	Days to maturity of primary raceme	Plant height up to primary raceme (cm)	Number of nodes up to primary raceme	Length of primary raceme (cm)	Effective length of primary raceme (cm)
Replications	2	49.64 **	55.10 *	106.63**	3.43*	56.17*	91.84**
Genotypes	93	150.22 **	512.11 **	946.35**	12.69**	368.32**	349.74**
Parents (P)	21	99.24 **	515.82 **	1266.93**	15.35**	425.82**	393.14**
Hybrids (H)	71	147.82 **	487.92**	846.82**	11.56**	337.08**	322.01**
Parents *vs* Hybrids	1	1391.36 **	2151.66 **	1280.37**	37.70**	1379.22**	1406.87**
Error	186	6.01	15.07	13.26	5.63	16.82	10.41

Table 1: Contd…

Sources	d.f.	Number of effective branches per plant	Number of capsules on primary raceme	Shelling out turn (%)	100-seed Weight (g)	Seed yield per plant (g)	Oil content (%)
Replications	2	2.19*	231.26**	79.84**	49.97**	644.84*	3.75**
Genotypes	93	6.01**	1049.79**	101.36**	58.32**	12844.79**	0.80*
Parents (P)	21	4.94**	746.11**	117.53**	69.76**	7115.13**	1.58**
Hybrids (H)	71	6.04**	1106.93**	93.24**	54.19**	13489.60**	0.54
Parents *vs* Hybrids	1	26.30**	3369.46**	338.91**	111.26**	87385.69**	2.58*
Error	186	0.66	41.02	2.07	0.99	189.89	0.58

** Significant at 1 per cent levels of significance

Table 2: The best performing hybrids for seed yield per plant along with heterobeltiosis (H_1), standard heterosis (H_2), sca effect and standard heterosis for component characters in castor.

S. No	Hybrids	Seed yield per plant (g)	Heterosis (%)		Significant desirable standard heterosis for component traits
			H_1	H_2	
1	JP 96 × SKI 392	429.00	41.34**	52.45**	DF, DM, LR, ELR, EB, CR, ST, SW
2	JP 96 × SKI 215	364.07	25.89**	29.38**	LR, ELR, EB, CR, ST, SW
3	SKP 84 × JI 244	359.53	45.99**	27.77**	DF, DM, ELR, CR, ST, SW
4	JP 106 × SKI 215	352.47	21.88**	25.25**	LR, ELR, EB, CR, ST
5	JP 106 × SKI 405	334.67	41.01**	18.93**	DF, DM, LR, ELR, CR, SW
6	SKP 84 × SKI 392	333.40	9.84**	18.48**	LR, ELR, CR, ST, SW
7	JP 106 × SKI 327	324.07	115.85**	15.16**	DM, LR, ELR, CR
8	SKP 84 × 500-2	323.20	31.24**	14.85**	DF, LR, ELR, ST, SW
9	JP 96 × JC-24	318.53	54.98**	13.20**	DF, NR, SW
10	JP 96 × SKI 397	317.53	53.55**	12.84**	DF, DM, LR, ELR, CR, SW
	GCH 9	281.40	-	-	-

*, ** Significant at 5 per cent and 1 per cent levels of significance, respectively
DF= Days to flowering of primary raceme, DM= Days to maturity of primary raceme, NR= Number of nodes up to primary raceme, LR= Length of primary raceme, ELR= Effective length of primary raceme, CR= Number of capsules on primary raceme, EB= Number of effective branches per plant, SW= 100-seed weight, ST= Shelling out

Table 3A: Per cent heterobeltiosis (H_1) and standard heterosis (H_2) for days to flowering of primary raceme, days to maturity of primary raceme, plant height up to primary raceme and number of nodes up to primary raceme in castor

Sr. No.	Hybrids	Days to flowering of primary raceme		Days to maturity of primary raceme		Plant height up to primary raceme (cm)		Number of nodes up to primary raceme	
		H_1 (%)	H_2 (%)	H_1 (%)	H_2 (%)	H_1 (%)	H_2 (%)	H_1 (%)	H_2 (%)
1.	JP-96 × JI 244	-17.20**	-24.51**	-14.15**	-14.36**	-10.39**	29.60**	-7.25	-4.12
2.	JP-96 × JI 390	-15.87**	-22.06**	-18.68**	-16.30**	-22.00**	12.82*	-32.97**	-30.71**
3.	JP-96 × JI 398	-16.32**	-22.06**	-5.12*	-5.35*	-13.30**	25.41**	-16.30**	-13.48**
4.	JP-96 × JI 424	-17.20**	-24.51**	-24.39**	-24.57**	-45.04**	-20.51**	-32.97**	-30.71**
5.	JP-96 × JI 426	8.60*	-0.98	-6.34**	-6.57**	3.71	50.00**	-4.32	-0.37
6.	JP-96 × JI 436	-11.83**	-19.61**	-19.51**	-19.71**	-35.05**	-6.06	-13.77**	-10.86**
7.	JP-96 × JI 437	3.13	-2.94	-16.83**	-17.03**	-7.74*	33.45**	-2.90	0.37
8.	JP-96 × SKI 215	5.64	0.98	-0.23	5.35*	-6.61	43.24**	-7.94*	8.61*
9.	JP-96 × SKI 327	-17.06**	-14.22**	-19.81**	-16.30**	-9.99**	30.19**	-9.76*	-3.00
10.	JP-96 × SKI 343	-0.52	-5.39	-13.41**	-13.63**	15.39**	66.90**	-2.90	0.37
11.	JP-96 × SKI 392	-11.27**	-7.35*	-19.58**	-17.03**	-24.45**	48.72**	-8.22*	4.49
12.	JP-96 × SKI 397	1.61	-7.35*	-11.83**	-7.54**	-17.00**	20.05**	-7.50	-3.00
13.	JP-96 × SKI 405	-4.06	-7.35*	6.34**	6.08**	-23.93**	10.02	-3.81	4.12
14.	JP-96 × RG-3041	-6.16*	-2.94	-15.61**	-15.82**	-28.52**	44.29**	-12.11**	5.99
15.	JP-96 × RG-3073	1.06	-6.37*	0.48	1.46	-34.41**	-5.13	-5.07	-1.87
16.	JP-96 × JC-24	-4.08	-7.84*	0.95	3.41	-11.94**	33.22**	-18.48**	-15.73**
17.	JP-96 × PCS-124	-16.91**	-15.69**	-20.32**	-16.06**	-35.37**	-6.53	-7.97*	-4.87
18.	JP-96 × 500-2	-6.40*	-6.86*	-21.55**	-18.49**	-6.93	34.62**	-2.90	0.37
19.	JP-106 × JI 244	-6.47*	-7.84*	0.46	5.35*	-11.12*	11.77*	-3.85	3.00
20.	JP-106× JI 390	-6.97*	-8.33**	-6.50**	-1.95	-6.12	18.07**	-7.34	-0.75
21	JP-106× JI 398	-1.49	0.00	-8.58**	-4.14	-31.14**	-13.40*	-16.78**	-10.86**
22	JP-106× JI 424	-18.91**	-20.10**	-0.93	3.89	-19.09**	1.75	-30.42**	-25.47**
23	JP-106× JI 426	-2.49	-3.92	0.46	5.35*	30.88**	74.36**	-15.38**	-9.36*
24	JP-106× JI 436	-1.99	-3.43	0.00	4.87*	3.15	29.72**	-10.49**	-4.12

25	JP-106× JI 437	0.00	-1.47	2.55	7.54**	-12.93**	12.24*	-3.85	3.00
26	JP-106× SKI 215	-1.00	-2.45	3.46	9.25**	7.22*	64.45**	-14.92**	0.37
27	JP-106× SKI 327	-7.58*	-4.41	-9.28**	-4.87*	8.25	36.13**	-4.88	2.25
28	JP-106× SKI 343	-18.91**	-20.10**	-13.46**	-9.25**	-10.57*	12.47*	-7.69*	-1.12
29	JP-106× SKI 392	-3.76	0.49	0.46	5.35*	-35.35**	27.27**	-5.59	7.49
30	JP-106× SKI 397	-7.96*	-9.31**	-20.19**	-16.30**	-0.93	24.59**	-27.97**	-22.85**
31	JP-106× SKI 405	-9.95**	-11.27**	-20.19**	-16.30**	-4.94	32.40**	-1.38	6.74
32	JP-106× RG-3041	-6.64*	-3.43	0.93	5.84**	-10.45**	80.77**	-16.15**	1.12
33	JP-106× RG-3073	-5.57	-6.86*	-12.99**	-8.76**	-54.22**	-42.42**	-9.44*	-3.00
34	JP-106× JC-24	-6.47*	-7.84*	0.46	5.35*	-19.11**	22.38**	-4.55	2.25
35	JP-106× PCS-124	-20.29**	-19.12**	-20.09**	-15.82**	-34.63**	-9.56	-4.55	2.25
36	JP-106 × 500-2	-6.40*	-6.86*	-16.24**	-12.17**	-15.66**	6.06	-8.74*	-2.25
37	SKP-84 × JI 244	-8.74**	-7.84*	-15.38**	-11.68**	5.51	15.97**	-18.99**	-4.12
38	SKP-84 × JI 390	-20.39**	-19.61**	-1.40	2.92	34.29**	58.86**	-14.24**	1.50
39	SKP-84 × JI 398	-15.05**	-14.22**	-8.39**	-4.38*	7.24	12.24*	-13.92**	1.87
40	SKP-84 × JI 424	-22.82**	-22.06**	-18.88**	-15.33**	-13.39*	-19.35**	-13.92**	1.87
41	SKP-84 × JI 426	-20.87**	-20.10**	-18.88**	-15.33**	-0.26	32.87**	-12.66**	3.37
42	SKP-84 × JI 436	-16.50**	-15.69**	-19.35**	-15.82**	13.77*	5.94	-26.58**	-13.11**
43	SKP-84 × JI 437	-18.93**	-18.14**	-17.25**	-13.63**	9.95*	41.72**	-14.87**	0.75

Table 3A: Contd…

S. No	Hybrids	Days to flowering of primary raceme		Days to maturity of primary raceme		Plant height up to primary raceme (cm)		Number of nodes up to primary raceme	
		H_1 (%)	H_2 (%)	H_1 (%)	H_2 (%)	H_1 (%)	H_2 (%)	H_1 (%)	H_2 (%)
44	SKP-84 × SKI 215	-4.85	-3.92	-3.69	1.70	7.45*	64.80**	-7.28*	9.74*
45	SKP-84 × SKI 327	-8.53**	-5.39	0.47	4.87*	45.19**	35.55**	-4.75	12.73**
46	SKP-84 × SKI 343	-22.33**	-21.57**	-19.11**	-15.57**	-18.07**	-9.09	-29.43**	-16.48**
47	SKP-84 × SKI 392	-4.69	-0.49	2.56	7.06**	-25.87**	45.92**	-7.59*	9.36*
48	SKP-84 × SKI 397	-13.59**	-12.75**	-10.44**	-6.08**	0.10	22.14**	-21.52**	-7.12
49	SKP-84 × SKI 405	-21.84**	-21.08**	-18.18**	-14.60**	-11.05**	23.89**	-12.03**	4.12
50	SKP-84 × RG-3041	-6.64*	-3.43	-18.88**	-15.33**	-27.83**	45.69**	0.93	21.72**
51	SKP-84 × RG-3073	-18.93**	-18.14**	-1.17	3.16	-13.89*	-19.81**	-13.29**	2.62
52	SKP-84 × JC-24	-18.93**	-18.14**	-16.78**	-13.14**	-15.87**	27.27**	-18.35**	-3.37
53	SKP-84 × PCS-124	-2.90	-1.47	-6.47**	-1.46	-26.58**	1.57	-13.13**	2.81
54	SKP-84 × 500-2	-7.28*	-6.37*	0.23	4.62*	-0.47	22.84**	-13.61**	2.25
55	VP-1 × JI 244	-8.07*	-27.45**	2.62	-14.11**	-29.37**	-22.38**	-22.91**	-20.60**
56	VP-1 × JI 390	-25.93**	-31.37**	-20.80**	-18.49**	-21.67**	-7.34	-23.11**	-23.97**
57	VP-1 × JI 398	-26.84**	-31.86**	0.56	-13.38**	-25.72**	-22.26**	-21.34**	-25.47**
58	VP-1 × JI 424	-9.43*	-29.41**	5.93*	-13.14**	-33.16**	-41.03**	-20.73**	-26.97**
59	VP-1 × JI 426	-19.44**	-28.92**	-9.40**	-15.57**	-38.15**	-17.60**	-21.58**	-18.35**
60	VP-1 × JI 436	-11.45**	-27.94**	2.68	-16.06**	-16.94**	-30.30**	2.01	-23.97**
61	VP-1 × JI 437	-0.52	-6.37*	-3.46	-18.49**	-37.61**	-19.58**	-14.45**	-15.73**
62	VP-1 × SKI 215	-23.59**	-26.96**	-9.22**	-4.14	-39.82**	-7.69	-22.54**	-8.61*
63	VP-1 × SKI 327	-27.01**	-24.51**	-18.41**	-14.84**	0.37	-6.29	-8.01*	-1.12
64	VP-1 × SKI 343	-27.32**	-30.88**	-2.93	-19.46**	-23.00**	-14.57**	-7.42	-11.24**
65	VP-1 × SKI 392	-33.80**	-30.88**	-19.58**	-17.03**	-51.39**	-4.31	-21.71**	-10.86**
66	VP-1 × SKI 397	-17.71**	-29.41**	-20.19**	-16.30**	-37.63**	-23.89**	-19.29**	-15.36**
67.	VP-1 × SKI 405	-21.83**	-24.51**	-11.08**	-12.17**	-15.56**	17.60**	-6.92	0.75
68.	VP-1 × RG-3041	-31.28**	-28.92**	-16.59**	-16.79**	-42.73**	15.62**	-10.25**	8.24*
69.	VP-1 × RG-3073	-25.40**	-30.88**	-22.65**	-21.90**	-43.96**	-59.44**	-14.01**	-17.23**
70.	VP-1 × JC-24	-28.57**	-31.37**	-17.10**	-15.09**	-49.08**	-22.96**	5.51	0.37
71.	VP-1 × PCS-124	-27.05**	-25.98**	-11.78**	-7.06**	-39.01**	-15.62**	0.00	-1.12
72.	VP-1 × 500-2	-22.66**	-23.04**	-18.74**	-15.57**	-18.79**	0.23	27.15**	5.24
		-33.80	-31.86	-24.39	-24.57	-54.22	-59.44	-32.97	-30.71
		to	to	to	to	to	to	to	to
		8.60	0.98	6.34	9.25	45.19	80.77	27.15	27.72
Mean Heterosis		-12.49	-14.64	-10.00	-8.56	-15.60	13.34	-11.74	-4.46
S.Em ±		2.10	2.10	3.03	3.03	3.10	3.10	0.73	0.73

*, ** Significant at 5 per cent and 1 per cent levels of significance, respectively

Table 3B: Per cent heterobeltiosis (H_1) and standard heterosis (H_2) for length of primary raceme, effective length of primary raceme, number of effective branches per plant and number of capsules on primary raceme in castor

S. No.	Hybrids	Length of primary raceme (cm)		Effective length of primary raceme (cm)		Number of effective branches per plant		Number of capsules on primary raceme	
		H_1 (%)	H_2 (%)	H_1 (%)	H_2 (%)	H_1 (%)	H_2 (%)	H_1 (%)	H_2 (%)
1.	JP-96 × JI 244	-42.35**	-15.68**	-45.39**	-17.82**	-11.11	1.99	-1.99	5.79
2.	JP-96 × JI 390	-38.46**	-9.98	-39.51**	-8.97	-17.36*	-5.18	-49.10**	-37.14**
3.	JP-96 × JI 398	-17.84**	20.18**	-21.78**	17.70**	-11.46	1.59	18.90**	17.62**
4.	JP-96 × JI 424	-47.60**	-23.36**	-47.14**	-20.45**	-22.57**	-11.16	-7.53	-8.52
5.	JP-96 × JI 426	-28.04**	5.26	-29.17**	6.58	-21.71**	-5.18	-8.17	-6.12
6.	JP-96 × JI 436	-23.99**	11.18	-22.58**	16.51**	-14.58*	-1.99	9.36	8.19
7.	JP-96 × JI 437	-20.91**	15.68**	-20.75**	19.26**	-37.50**	-28.29**	-20.16**	0.25
8.	JP-96 × SKI 215	-5.62	38.05**	-8.90**	37.08**	-12.35*	18.73*	31.69**	30.27**
9.	JP-96 × SKI 327	-12.97**	27.30**	-11.76**	32.78**	-19.44**	-7.57	-6.19	-7.20
10.	JP-96 × SKI 343	-18.97**	18.53**	-12.24**	32.06**	-10.76	2.39	-11.14*	4.88

11.	JP-96 × SKI 392	-0.82	45.07**	-0.32	50.00**	-0.69	13.94	9.62	8.44
12.	JP-96 × SKI 397	-6.90	36.18**	-7.23*	39.59**	-15.70*	-1.59	13.08*	22.99**
13.	JP-96 × SKI 405	-17.47**	20.72**	-17.57**	24.04**	-11.11	1.99	14.09*	29.28**
14.	JP-96 × RG-3041	-10.04*	31.58**	-9.78**	35.77**	-5.90	7.97	1.80	26.14**
15.	JP-96 × RG-3073	-25.86**	8.44	-25.12**	12.68*	-3.63	27.09**	3.76	2.65
16.	JP-96 × JC-24	-25.79**	8.55	-27.19**	9.57	-7.99	5.58	-42.47**	-43.09**
17.	JP-96 × PCS-124	-29.54**	3.07	-31.16**	3.59	-10.42	2.79	-5.35	-6.37
18.	JP-96 × 500-2	-15.67**	23.36**	-18.20**	23.09**	9.80	33.86**	-32.36**	-33.09**
19.	JP-106 × JI 244	-1.66	29.93**	-1.34	32.18**	-5.11	3.59	27.79**	38.46**
20.	JP-106× JI 390	-5.23	25.22**	-4.11	28.47**	44.53**	57.77**	-32.69**	-16.87*
21	JP-106× JI 398	6.05	42.32**	7.97*	45.81**	-15.33*	-7.57	0.38	8.77
22	JP-106× JI 424	-22.24**	2.74	-25.62**	-0.36	-3.65	5.18	-25.04**	-18.78**
23	JP-106× JI 426	-9.88*	19.08**	-9.82**	20.81**	1.97	23.51**	-17.48**	-10.59
24	JP-106× JI 436	11.87**	47.81**	13.13**	51.56**	-11.68	-3.59	26.79**	37.39**
25	JP-106× JI 437	-5.39	25.00**	4.91	40.55**	-17.54*	-6.37	-13.37*	8.77
26	JP-106× SKI 215	-0.50	31.47**	1.07	35.41**	4.12	41.04**	45.88**	58.06**
27	JP-106× SKI 327	-5.98	24.23**	-2.86	30.14**	-12.04	-3.98	10.31	19.52**
28	JP-106× SKI 343	-7.22	22.59**	-5.45	26.67**	-38.69**	-33.07**	20.39**	42.10**
29	JP-106× SKI 392	6.22	40.35**	9.91**	47.25**	-6.57	1.99	18.70**	28.62**
30	JP-106× SKI 397	-5.64	24.67**	-2.23	30.98**	-19.11**	-5.58	23.88**	34.74**
31	JP-106× SKI 405	2.90	35.96**	2.14	36.84**	-1.82	7.17	20.58**	36.64**
32	JP-106× RG-3041	-5.81	24.45**	-3.75	28.95**	-10.58	-2.39	-11.42*	9.76
33	JP-106× RG-3073	-31.37**	-9.32	-29.82**	-5.98	-52.57**	-37.45**	-31.60**	-25.89**
34	JP-106× JC-24	-5.89	24.34**	-1.34	32.18**	-21.90**	-14.74	1.22	9.68
35	JP-106× PCS-124	-29.79**	-7.24	-24.91**	0.60	-12.41	-4.38	-34.58**	-29.11**
36	JP-106 × 500-2	-19.50**	6.36	-21.34**	5.38	-21.24**	-3.98	-9.24	-1.65
37	SKP-84 × JI 244	-5.61	10.75	-0.10	14.11**	-27.46**	-29.48**	28.28**	38.46**
38	SKP-84 × JI 390	2.06	19.74**	4.40	19.26**	2.08	-2.39	-14.53**	5.54
39	SKP-84 × JI 398	-6.54	25.44**	-1.95	32.42**	4.82	-4.78	-2.24	1.24
40	SKP-84 × JI 424	-25.23**	-12.28*	-26.49**	-16.03**	-17.54*	-25.10**	-0.40	3.14
41	SKP-84 × JI 426	3.36	21.27**	2.92	18.06**	-21.05**	-4.38	1.68	5.29

Table 3B: Contd…

	Hybrids	Length of primary raceme (cm)		Effective length of primary raceme (cm)		Number of effective branches per plant		Number of capsules on primary raceme	
		H_1 (%)	H_2 (%)	H_1 (%)	H_2 (%)	H_1 (%)	H_2 (%)	H_1 (%)	H_2 (%)
42	SKP-84 × JI 436	3.74	21.71**	-4.77	15.85**	-4.20	-9.16	73.48**	79.65**
43	SKP-84 × JI 437	-9.44	6.25	-10.26*	2.51	-11.93	0.00	-27.14**	-8.52
44	SKP-84 × SKI 215	6.64	25.11**	14.20**	34.69**	-25.59**	0.80	0.40	3.97
45	SKP-84 × SKI 327	6.07	24.45**	16.75**	33.37**	-12.65	-14.74	23.56**	27.96**
46	SKP-84 × SKI 343	-10.90*	10.20	-8.72*	16.39**	5.70	-3.98	-19.13**	-4.55
47	SKP-84 × SKI 392	32.15**	55.04**	31.16**	56.58**	-7.00	-4.78	26.76**	31.27**
48	SKP-84 × SKI 397	6.36	24.78**	14.87**	31.22**	-17.06*	-3.19	26.39**	37.47**
49	SKP-84 × SKI 405	-8.97	6.80	-7.75	5.38	4.17	-0.40	-9.64	2.40
50	SKP-84 × RG-3041	4.16	29.06**	2.10	33.85**	19.30*	8.37	10.28	36.64**
51	SKP-84 × RG-3073	-7.20	8.88	-2.62	11.24*	-24.17**	0.00	8.07	11.91
52	SKP-84 × JC-24	-7.38	8.66	-3.04	10.77*	-6.92	-3.59	-12.78*	-9.68
53	SKP-84 × PCS-124	-12.57*	2.58	-9.84*	2.99	-12.09	-4.38	-0.56	2.98
54	SKP-84 × 500-2	4.49	22.59**	8.69*	24.16**	-16.67**	1.59	5.03	8.77
55	VP-1 × JI 244	14.06*	17.43**	9.10*	16.87**	-35.25**	-37.05**	5.51	23.49**
56	VP-1 × JI 390	-12.95**	0.22	-12.61**	-0.48	-30.83**	-33.86**	6.36	31.35**
57	VP-1 × JI 398	-17.57**	10.64	-12.13**	18.66**	-20.85*	-25.90**	15.27**	34.90**
58	VP-1 × JI 424	-8.35	-8.55	-6.09	0.60	-5.96	-11.95	-5.44	10.67
59	VP-1 × JI 426	-14.80**	-8.44	-13.45**	-0.72	-29.93**	-15.14	4.03	21.75**
60	VP-1 × JI 436	-6.76	5.92	-13.27**	5.50	-8.82	-13.55	11.24*	30.19**
61.	VP-1 × JI 437	-3.19	-3.40	-14.68**	-8.61	-32.98**	-23.90**	-51.05**	-38.54**
62.	VP-1 × SKI 215	13.97**	23.46**	7.91	27.27**	-35.88**	-13.15	-16.33**	-2.07
63.	VP-1 × SKI 327	7.58	7.35	9.99*	17.82**	-13.47	-15.54*	5.51	23.49**
64.	VP-1 × SKI 343	-5.41	17.00**	-7.32	18.18**	-8.94	-14.74	-1.05	16.79*
65.	VP-1 × SKI 392	20.08**	38.38**	15.63**	38.04**	-27.24**	-25.50**	15.27**	34.90**
66.	VP-1 × SKI 397	1.32	1.10	-3.41	3.47	-47.10**	-38.25**	-12.86*	1.99
67.	VP-1 × SKI 405	-9.78	-9.98	-9.77*	-3.35	-2.50	-6.77	-9.12	6.37
68.	VP-1 × RG-3041	0.97	25.11**	3.01	35.05**	3.40	-3.19	-12.62*	8.27
69.	VP-1 × RG-3073	-23.19**	-23.36**	-28.87**	-23.80**	-42.90**	-24.70**	-53.64**	-45.74**
70.	VP-1 × JC-24	-23.30**	-23.46**	-26.19**	-20.93**	-12.31	-9.16	-38.87**	-28.45**
71.	VP-1 × PCS-124	-11.40*	-8.00	-10.33*	-3.95	-5.13	3.19	-19.22**	-5.46
72.	VP-1 × 500-2	8.24	8.00	9.10*	16.87**	-24.84**	-8.37	-0.71	16.21*
Range		-47.60 to 32.15	-23.46 to 55.04	-47.14 to 31.16	-23.80 to 56.58	-52.57 to 44.53	-38.25 to 57.77	53.64 to 73.48	-45.74 to 79.65
Mean Heterosis		-8.51	14.64	-7.95	17.83	-13.52	-4.76	-1.41	9.14
S.Em ±		3.45	3.45	2.72	2.72	0.64	0.64	5.32	5.32

*, ** Significant at 5 per cent and 1 per cent levels of significance, respectively

Table 3C: Per cent heterobeltiosis (H_1) and standard heterosis (H_2) for shelling out turn, 100 seed weight, seed yield per plant and oil content in castor

S. No	Hybrids	Shelling out turn (%)		100 seed weight (g)		Seed yield per plant (g)		Oil content (%)	
		H_1 (%)	H_2 (%)	H_1 (%)	H_2 (%)	H_1 (%)	H_2 (%)	H_1 (%)	H_2 (%)
1.	JP-96 × JI 244	-7.94**	1.03	24.76**	67.95**	23.74**	-9.62*	-0.66	-0.67
2.	JP-96 × JI 390	-5.80**	8.21**	-8.82**	19.23**	1.91	-25.56**	-0.06	-0.70
3.	JP-96 × JI 398	22.28**	21.03**	-9.40**	35.90**	16.15**	-15.16**	-0.16	-0.80
4.	JP-96 × JI 424	11.46**	9.74**	-19.13**	19.23**	-15.67**	-38.40**	-1.07	-1.69
5.	JP-96 × JI 426	-1.90	5.64**	-9.35**	24.36**	10.89	-15.07**	0.09	0.65
6.	JP-96 × JI 436	-3.65*	-5.13**	-6.36**	32.05**	-14.99*	-37.91**	-0.74	-1.37
7.	JP-96 × JI 437	-9.91**	-2.05	-16.67**	8.97**	-9.99	-34.26**	-0.04	-0.68
8.	JP-96 × SKI 215	-2.74	9.23**	0.98	32.05**	25.89**	29.38**	-0.57	-0.33
9.	JP-96 × SKI 327	7.81**	6.15**	-21.57**	2.56	19.30**	-12.86**	-0.46	0.03
10.	JP-96 × SKI 343	-0.52	-2.05	9.80**	43.59**	-22.12**	-43.12**	-0.55	-1.18
11.	JP-96 × SKI 392	5.21**	3.59*	-8.82**	19.23**	41.34**	52.45**	-0.63	-1.26
12.	JP-96 × SKI 397	-5.73**	-7.18**	-10.78**	16.67**	53.55**	12.84**	1.30	0.66
13.	JP-96 × SKI 405	3.41*	8.72**	-20.59**	3.85	25.11**	5.52	0.83	0.23
14.	JP-96 × RG-3041	-10.95**	-4.10*	-16.67**	8.97**	20.50**	-11.99**	0.61	-0.03
15.	JP-96 × RG-3073	-5.73**	-7.18**	-16.67**	8.97**	4.51	-23.67**	-0.09	-0.72
16.	JP-96 × JC-24	-9.87**	3.08	-10.78**	16.67**	54.98**	13.20**	-0.44	-1.07
17.	JP-96 × PCS-124	-16.27**	-10.26**	-14.71**	11.54**	-2.21	-22.27**	-1.43	-0.77
18.	JP-96 × 500-2	-11.11**	-1.54	-21.85**	19.23**	40.29**	2.46	-0.50	0.44
19.	JP-106 × JI 244	-11.68**	-3.08	4.76*	41.03**	18.42*	-33.43**	0.42	0.82
20.	JP-106× JI 390	6.70**	22.56**	6.67**	23.08**	110.66**	12.39**	0.48	0.88
21.	JP-106× JI 398	2.07	1.03	-18.80**	21.79**	21.18**	-16.11**	-0.17	0.23
22.	JP-106× JI 424	15.47**	7.18**	-26.09**	8.97**	58.88**	-15.23**	-1.31	-0.92
23.	JP-106× JI 426	-2.86	4.62*	-13.08**	19.23**	5.10	-19.50**	-0.44	0.13
24.	JP-106× JI 436	9.77**	-2.05	-7.27**	30.77**	40.72**	-24.92**	-0.94	-0.55
25.	JP-106× JI 437	-4.25*	4.10*	-18.89**	-6.41*	6.13	-36.86**	-0.89	-0.49
26.	JP-106× SKI 215	-3.65*	8.21**	-22.55**	1.28	21.88**	25.25**	-0.43	-0.03
27.	JP-106× SKI 327	10.98**	-1.54	-10.00**	3.85	115.85**	15.16**	-0.42	0.07
28.	JP-106× SKI 343	13.87**	1.03	5.56*	21.79**	46.85**	-21.65**	-0.71	-0.32
29.	JP-106× SKI 392	-15.00**	-21.54**	-3.13	19.23**	-10.52**	-3.48	0.17	0.57
30.	JP-106× SKI 397	15.38**	7.69**	-8.42**	11.54**	-16.22**	-38.43**	0.07	0.47
31.	JP-106× SKI 405	-3.90*	1.03	-4.44	10.26**	41.01**	18.93**	-0.38	0.02
32.	JP-106× RG-3041	-24.76**	-18.97**	15.56**	33.33**	-21.91**	-49.16**	-0.29	0.11
33.	JP-106× RG-3073	6.77**	5.13**	-10.53**	8.97**	-16.12**	-39.71**	-0.56	-0.17
34.	JP-106× JC-24	-16.14**	-4.10*	3.33	19.23**	30.19**	-18.98**	0.32	0.72
35.	JP-106× PCS-124	-11.48**	-5.13**	3.33	19.23**	28.73**	2.32	0.01	0.68
36.	JP-106 × 500-2	-6.48**	3.59*	-26.89**	11.54**	68.52**	-10.09*	0.80	1.76
37.	SKP-84 × JI 244	3.74*	13.85**	4.76*	41.03**	45.99**	27.77**	0.08	0.07
38.	SKP-84 × JI 390	-2.68	11.79**	20.62**	50.00**	-22.36**	-32.05**	0.87	-0.85
39.	SKP-84 × JI 398	10.88**	9.74**	5.13**	57.69**	4.41	-8.62*	0.32	-1.39
40.	SKP-84 × JI 424	17.89**	14.87**	-13.91**	26.92**	8.39	-5.14	0.21	-1.13
41.	SKP-84 × JI 426	-7.14**	0.00	-13.08**	19.23**	-10.15*	-21.37**	-0.84	-0.28
42.	SKP-84 × JI 436	2.63	0.00	-12.73**	23.08**	-7.74	-19.26**	0.25	-1.46

Table 3C: Contd…

	Hybrids	Shelling out turn (%)		100 seed weight (g)		Seed yield per plant (g)		Oil content (%)	
		H_1 (%)	H_2 (%)	H_1 (%)	H_2 (%)	H_1 (%)	H_2 (%)	H_1 (%)	H_2 (%)
43	SKP-84 × JI 437	7.55**	16.92**	6.19**	32.05**	-2.95	-15.07**	1.20	-0.18
44	SKP-84 × SKI 215	-1.37	10.77**	-4.90*	24.36**	12.98**	16.11**	-0.44	-0.20
45	SKP-84 × SKI 327	10.53**	7.69**	-30.93**	-14.10**	-10.42*	-21.61**	-2.94*	-2.45
46	SKP-84 × SKI 343	16.32**	13.33**	-10.31**	11.54**	11.07*	-2.80	0.06	-0.94
47	SKP-84 × SKI 392	14.21**	11.28**	-10.31**	11.54**	9.84*	18.48**	0.46	-0.26
48	SKP-84 × SKI 397	16.84**	13.85**	-7.22**	15.38**	14.46**	0.17	0.26	-1.44
49	SKP-84 × SKI 405	11.71**	17.44**	-10.31**	11.54**	4.87	-8.22	-0.20	-0.80
50	SKP-84 × RG-3041	4.29*	12.31**	-4.12	19.23**	-4.85	-16.73**	1.06	-0.03
51	SKP-84 × RG-3073	17.71**	15.90**	-10.31**	11.54**	-33.13**	-41.48**	0.10	-1.60
52	SKP-84 × JC-24	-1.35	12.82**	-6.19**	16.67**	-10.21*	-21.42**	1.12	-0.60
53	SKP-84 × PCS-124	-6.70**	0.00	-16.49**	3.85	15.51**	1.09	0.13	0.80
54	SKP-84 × 500-2	1.39	12.31**	-12.61**	33.33**	31.24**	14.85**	0.09	1.04
55	VP-1 × JI 244	-2.34	7.18**	-20.95**	6.41*	7.09	-32.03**	-0.96	-0.22
56	VP-1 × JI 390	-6.25**	7.69**	-12.77**	5.13	-9.56	-42.60**	-1.64	-0.90
57	VP-1 × JI 398	7.77**	6.67**	-22.22**	16.67**	-31.79**	-52.78**	-2.00	-1.26
58	VP-1 × JI 424	21.55**	12.82**	-27.83**	6.41*	-18.70**	-48.40**	-2.17	-1.43
59	VP-1 × JI 426	-1.90	5.64**	-28.04**	-1.28	-4.64	-26.96**	-1.95	-1.21
60	VP-1 × JI 436	-2.87	-13.33**	-20.00**	12.82**	-27.85**	-54.21**	-2.70*	-1.96
61.	VP-1 × JI 437	-11.32**	-3.59*	-26.60**	-11.54**	-39.98**	-61.90**	-2.08	-1.34
62.	VP-1 × SKI 215	-1.37	10.77**	-20.59**	3.85	-42.32**	-40.72**	-1.80	-1.06

63.	VP-1 × SKI 327	15.52**	3.08	-23.40**	-7.69**	3.12	-34.55**	-0.19	0.57
64.	VP-1 × SKI 343	21.26**	8.21**	-9.57**	8.97**	0.26	-36.37**	-2.14	-1.40
65.	VP-1 × SKI 392	19.44**	10.26**	-13.54**	6.41*	-15.33**	-8.67*	-2.59*	-1.85
66.	VP-1 × SKI 397	10.44**	3.08	-23.16**	-6.41*	-10.09	-33.93**	-0.50	0.25
67.	VP-1 × SKI 405	2.44	7.69**	-32.98**	-19.23**	-1.83	-17.20**	-0.48	0.28
68.	VP-1 × RG-3041	-11.90**	-5.13**	-1.06	19.23**	1.06	-34.21**	-2.63*	-1.90
69.	VP-1 × RG-3073	-3.65*	-5.13**	-23.16**	-6.41*	-44.56**	-60.15**	-2.06	-1.32
70.	VP-1 × JC-24	0.00	14.36**	-7.45**	11.54**	-11.20	-43.64**	-1.82	-1.07
71.	VP-1 × PCS-124	-6.22**	0.51	-31.91**	-17.95**	-22.38**	-38.31**	-1.36	-0.61
72.	VP-1 × 500-2	-0.93	9.74**	-39.50**	-7.69**	-25.49**	-52.71*	-0.10	0.84
Range		-24.76 to 22.28	-21.54 to 22.56	-39.55 to 24.76	-19.23 to 67.95	44.56 to 115.85	- 61.90 to 52.45	-2.94 to 1.3	-2.45 to 1.7
Mean Heterosis		1.45	4.47	-11.37	15.33	8.21	-17.08	-0.50	-0.45
S.Em ±		1.15	1.15	0.74	0.74	11.92	11.92	0.62	0.62

*, ** Significant at 5 per cent and 1 per cent levels of significance, respectively

Table 4: Range of heterobeltiosis (H_1) and standard heterosis (H_2) along with number of crosses showing significant heterosis for various characters in castor

S. No.	Characters	Range of heterosis (%)		Number of crosses showing significant heterosis			
		H_1 (%)	H_2 (%)	H_1 (%)		H_2 (%)	
				+Ve	-Ve	+Ve	-Ve
1	Days to flowering of primary raceme	-33.80 to 8.60	-31.86 to 0.98	1	52	0	54
2	Days to maturity of primary raceme	-24.39 to 6.34	-24.57 to 9.25	2	47	12	49
3	Plant height up to primary raceme (cm)	-52.45 to 45.19	-59.44 to 80.77	8	50	39	16
4	Number of nodes up to primary raceme	-32.97 to 27.15	-30.71 to 27.42	0	47	5	23
5	Length of primary raceme (cm)	-47.60 to 32.15	-23.46 to 55.04	5	29	39	5
6	Effective length of primary raceme (cm)	-47.14 to 31.16	-23.80 to 56.58	11	35	48	4
7	Number of effective branches per plant	-57.52 to 44.53	-38.25 to 57.77	2	37	6	15
8	Number of capsules on primary raceme	-53.64 to 73.48	-45.74 to 79.65	18	22	28	10
9	Shelling out turn (%)	-24.76 to 22.88	-21.54 to 22.56	26	26	39	11
10	100-seed weight (g)	-39.55 to 24.76	-19.23 to 67.95	9	54	55	8
11	Seed yield per plant (g)	-44.56 to 115.85	-61.90 to 52.45	29	22	11	51
12	Oil content (%)	-2.94 to 1.30	-2.45 to 1.76	0	4	0	0

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. Three crosses viz., JP 96 × SKI 392, JP 96 × SKI 215 and SKP 84 × JI 244 appeared to be the most suitable crosses for exploitation in practical plant breeding programme in castor, as they recorded 41.34 per cent, 25.89 per cent and 45.99 per cent significantly the higher heterosis over their respective better parent; and 52.45 per cent (429.00 g), 29.38 per cent (364.07 g) and 27.77 per cent (359.53 g) significantly the higher heterosis over standard check GCH 9 (281.40 g).

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