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Study of Heterosis for Seed Yield and its Component Traits in Castor [*Ricinus communis* L.]

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A B S T R A C T

The phenomenon of heterosis has provided the most important genetic tools in improving yield of crop plants. Identification of specific parental combination capable of producing the highest level of heterotic effects in F_1 has immense value for commercial exploitation of heterosis. The experimental material comprised of 3 diverse pistillate lines, 13 inbred lines and their resultant 39 cross combinations and one standard check GCH 7 was evaluated in a randomized complete block design with three replications. Among 39 hybrids, 20 hybrids exhibited significant positive heterobeltiosis for seed yield, of these best three heterotic hybrids in order were SKP 84 x ANDCI 8, SP 1 x SI 5 and SP 1 x DCS 100on the other hand three hybrids *viz.*, SP1 x SI 5, SKP 84 x ANDCI 8 and SKP 84 x SI 5 exhibited significant positive standard heterosis over GCH 7.

Introduction

Castor (*Ricinus communis* L., 2n=2X=20) resides one of the most important non-edible oilseed crops of India. Castor belongs to monospecific genus *Ricinus* of Euphorbiaceae family. Castor oil has great industrial utility along with it is used in pharmaceutical and cosmetics. Castor oil and cake are two major products obtained from castor seed. Castor oil is the source of sebacic acid, which is used in the manufacture of nylon and vinyl resins (Nagraj, 1996). In world, India ranks first in respect to area and production, contributing about 40 per cent of the global requirements. The other castor growing countries in the world were Brazil, China, Russia, Thailand, U.S.A. and a group of African countries. The area, production and productivity of castor in India during 2014-15 were 11.05 lakh ha, 17.33 lakh tonnes and 1568 kg/ha, respectively (Anonymous, 2015).

Nature and magnitude of heterosis is one of the important aspects for selection of the right parents for crosses and also help in identification of superior cross combinations that may produce desirable transgressive segregants in advanced generations. The choice of parents to be incorporated in hybridization programme is a crucial step for breeders, particularly if the aim is to improve the complex quantitative characters such as yield and its components. The use of parents of known superior genetic worth ensures much better success. It requires extensive and detailed genetic assessment of existing germplasm as well as newly developed promising genotype, which could be used in future breeding programme or could be directly released as a cultivar after thorough testing.

Materials and Methods

Experimental material of the study included 56 test entries comprising of three female lines (SP 1, VP 1 and SKP 84) and thirteen male parents (ANDCI 8, ANDCI 9DCS 100, DCS 9, JI 35, JI 384, JI 399, JI 402, JI 404, SI 4, SI 5, SI 6 and SI 9) and 39 resultant hybrids and one standard check hybrid GCH 7.

The crosses were made during *kharif* 2015-16 through Line x Tester mating design and evaluation was carried out during the year 2016-17 at Agricultural Research Station, Anand Agricultural University, Sansoli during *kharif* 2016-2017. Each entry was planted in a 6 meter long row with inter and intra row spacing of 120 x 60 cm. All the recommended agronomic and plant protection practices were uniformly applied throughout the crop growth period to raise a good crop.

The observations were recorded on five randomly selected plants for 12 characters in each replication for each genotype and the average value per plant was computed except for days to 50 per cent flowering and days to maturity of primary raceme. The observations of both these characters were recorded on population basis.

The replication wise mean values for all the characters were subjected to analysis of variance technique suggested by Snedecor and Cochran (1967) and reviewed by Panse and Sukhatme (1978) to determine significance differences among genotypes.

Results and Discussion

The analysis of variance was performed to test the differences among parents and hybrids for all the twelve characters and is presented in table 1. The results revealed that the mean squares due to genotypes were significant for all the characters under study. The mean squares due to genotypes were further partitioned into parents, hybrids and parents *vs.* hybrids. The parents and hybrids differed significantly for all the characters. This revealed the existence of considerable genetic variability among the parents and hybrids for all the characters under study.

The analysis of variance further revealed that hybrids differed highly significantly for all the characters. The mean squares due to parents *vs.* hybrids were significant for all the characters, which indicated that the performance of parents was different from that of hybrids, thereby supporting the possibility of heterotic effects for all the traits. The mean squares due to check *vs.* hybrids were significant for all the traits except plant height upto primary raceme.

Seed yield is the economic important trait and breeders attempt to evolve varieties/hybrids with high seed yield. The results revealed that heterosis over better parent ranged from -18.68 (VP 1 x JI 404) to 56.21 (SKP 84 x ANDCI 8) percent; while, standard heterosis over GCH 7 varied from -49.69 (VP 1 x JI 404) and 23.77 (SP 1 x SI 5) percent. As many as 20 hybrids registered significant positive heterobeltiosis. Only three hybrids *viz.*, SP 1 x SI 5 (23.77 %), SKP 84 x ANDCI 8 (19.74 %) and SKP 84 x SI 5 (17.71%) recorded significant and positive standard heterosis over GCH 7. As observed in the present investigation, several workers have also reported the presence of considerable degree of heterosis for seed yield in castor (Chaudhari and Patel, 2014; Chaudhari, 2007; Dave, 2015; Patel et al., 2010; Patel, 2013, 2014; Sasidharan, 2005; Thakker, 2002).

Table.1 Analysis of variance for yield and its components (Mean sum of squares)

Source	d. f.	DF	NN	PH	DM	LP	NCP
Replication	2	3.74	2.25	138.5	7.13	21.07	60.57
Genotypes	55	73.57**	9.01**	666.34**	226.12**	290.49**	476.68**
Parents	15	85.7**	8.36**	228.51**	172.12**	98.81**	238.65**
Females	2	165.44**	18.9**	140.65	240.33**	465.5**	232.75**
Males	12	65.94**	5.67**	48.34	114.47**	41.22	255.29**
Females vs Males	1	163.36**	19.56**	2566.27**	727.5**	56.62	50.73
Hybrids	38	64.82**	8.47**	539.52**	196.01**	300**	539.62**
Parents vs Hybrids	1	149.6**	10.41**	12446.42**	2191.4**	25035.5**	1531.34**
Check vs Hybrids	1	173.46**	41.29**	48.13	112.62**	398.59**	444.68**
Error	110	3.11	0.93	66.99	9.63	32.8	37.76
Source	**d. f.**	**NEB**	**TNB**	**SY**	**TW**	**SH**	**OC**
Replication	2	1.29	1.69	98	0.73	6.78	1.16
Genotypes	55	12.96**	11.61**	5296.67**	23.23**	34.4**	15.35**
Parents	15	12.22**	11.53**	1187.86**	17.29**	17.54**	15.66**
Females	2	25.41**	26.01**	346.57	28.18**	3.07	0.3
Males	12	6.23**	8.35**	1218.86**	16.91**	21.26**	17.75**
Females vs Males	1	57.68**	20.77**	2498.42*	0.14	1.85	21.36**
Hybrids	38	13.07**	10.93**	5705.31**	25.36**	34.65**	14.85**
Parents vs Hybrids	1	6.82*	14.82**	44152.75**	8.18*	260.37**	16.53**
Check vs Hybrids	1	23.87**	31.18**	8775.24**	42.77**	33.75**	31.96**
Error	110	1.16	1.92	441.76	2.02	4.81	0.49

*, ** significant at 5% and 1 % levels of probability, respectively.
DF = Days to 50 per cent flowering, NN = Number of nodes upto primary raceme, PH = Plant height upto primary raceme (cm), DM = Days to maturity of primary raceme, LP = Length of primary raceme (cm), NCP = Number of capsules on primary raceme, NEB = Number of effective branches per plant, TNB = Total number of branches per plant, SY = Seed yield per plant (g), TW = 100 seed weight (g) (Test weight), SH = Shelling out turn (%) and OC =Oil content (%)

Table.2 Promising hybrids for seed yield per plant with heterosisover standard check hybrid (GCH 7) and better parent (BP), their sca effects and component characters showing significant desired standard heterosis in castor

Sr. No	Hybrids	SY(g)	Heterosis over		sca effects	Significant and desirable heterosis over GCH 7 for component traits
			BP	SC		
1	SP 1 x SI 5	315.22	47.26**	23.77**	10.72	DF, NN, PH, DM, LP, NCP, NEB, TNB, TW and SH
2	SKP 84 x ANDCI 8	304.96	56.21**	19.74**	49.72**	DF, DM ,LP, NCP, TW and SH
3	SKP 84 x SI 5	299.79	40.06**	17.71**	-12.8	LP, NCP, TW and SH
S. E ±		12.13	17.30	17.30	8.31	

*, ** significant at 5% and 1 % levels of probability, respectively.
DF = Days to 50 per cent flowering, NN = Number of nodes upto primary raceme, PH = Plant height upto primary raceme (cm), DM = Days to maturity of primary raceme, LP = Length of primary raceme (cm), NCP = Number of capsules on primary raceme, NEB = Number of effective branches per plant, TNB = Total number of branches per plant, SY = Seed yield per plant (g), TW = 100 seed weight (g) (Test weight), SH = Shelling out turn (%) and OC =Oil content (%)

Table.3 Estimates of heterobeltiosis and standard heterosis for days to 50 per cent flowering, Number of nodes upto primary raceme and plant height upto primary raceme

Sr. No.	Hybrids	DF		NN		PH	
		BP	SH	BP	SH	BP	SH
1	SP 1 × ANDCI 8	0.00	-9.84**	-0.74	-16.67**	27.25*	-24.14**
2	SP 1 × ANDCI 9	-10.06**	-16.94**	-4.78	-20.06**	50.13**	-10.50
3	SP 1 × DCS 100	-7.10**	-14.21**	-5.51	-20.68**	46.92**	-12.41
4	SP 1 × DCS 9	-2.37	-9.84**	-6.25	-21.30**	12.21	-33.10**
5	SP 1 × JI 35	-5.36*	-13.11**	-5.15	-20.37**	50.90**	-10.04
6	SP 1 × JI 384	-8.28**	-15.30**	-14.71**	-28.40**	51.41**	-9.73
7	SP 1 × JI 399	1.18	-6.56**	1.10	-15.12**	53.86**	-8.28
8	SP 1 × JI 402	-1.18	-8.74**	-1.10	-16.98**	57.71**	-5.98
9	SP 1 × JI 404	-3.85	-31.69**	0.00	-32.72**	0.13	-40.31**
10	SP 1 × SI 4	2.40	-6.56**	-0.37	-16.36**	52.06**	-9.35
11	SP 1 × SI 5	1.18	-6.56**	1.84	-14.51**	33.29*	-20.54**
12	SP 1 × SI 6	-11.54**	-24.59**	-15.44**	-29.01**	35.60**	-19.16*
13	SP 1 × SI 9	-2.96	-10.38**	-9.56*	-24.07**	55.53**	-7.28
14	VP 1 × ANDCI 8	31.01**	-7.65**	36.62**	-10.19**	107.53**	-2.84
15	VP 1× ANDCI 9	25.58**	-11.48**	24.41**	-18.21**	111.13**	-1.15
16	VP 1× DCS 100	12.40**	-20.77**	15.49**	-24.07**	113.26**	0.61
17	VP 1× DCS 9	18.60**	-16.39**	25.82**	-17.28**	113.58**	0.00
18	VP 1× JI 35	11.63**	-21.31**	18.31**	-22.22**	108.35**	-2.45
19	VP 1× JI 384	-0.78	-30.05**	4.23	-31.48**	31.26	-38.54**
20	VP 1× JI 399	13.95**	-19.67**	23.94**	-18.52**	91.49**	-10.34
21	VP 1× JI 402	22.48**	-13.66**	21.60**	-20.06**	91.98**	-10.11
22	VP 1× JI 404	5.43	-25.68**	15.02**	-24.38**	87.23**	-12.34
23	VP 1× SI 4	24.81**	-12.02**	21.60**	-20.06**	88.05**	-11.95
24	VP 1× SI 5	31.78**	-7.10**	24.88**	-17.90**	98.36**	-7.13
25	VP 1× SI 6	26.36**	-10.93**	15.02**	-24.38**	102.13**	-5.36
26	VP 1× SI 9	3.88	-26.78**	9.39	-28.09**	108.84**	-2.22
27	SKP 84× ANDCI 8	3.64	-6.56**	8.63*	-6.79	86.34**	13.95
28	SKP 84× ANDCI 9	6.02*	-3.83	7.07	-6.48	88.97**	15.56*
29	SKP 84× DCS 100	2.41	-7.10**	2.12	-10.80**	54.76**	-5.36
30	SKP 84× DCS 9	3.61	-6.01*	4.24	-8.95*	64.91**	0.84
31	SKP 84× JI 35	-2.41	-11.48**	2.94	-13.58**	98.25**	21.23**
32	SKP 84× JI 384	-2.41	-11.48**	-8.48*	-20.06**	80.70**	10.50
33	SKP 84× JI 399	3.61	-6.01*	12.06**	-2.47	84.96**	13.10
34	SKP 84× JI 402	4.22	-5.46*	8.83*	-4.94	62.78**	-0.46
35	SKP 84× JI 404	16.15**	-17.49**	18.81**	-20.06**	62.16**	-0.84
36	SKP 84× SI 4	0.60	-8.74**	2.52	-12.04**	102.76**	23.98**
37	SKP 84× SI 5	8.43**	-1.64	10.60*	-3.40	117.42**	32.95**
38	SKP 84× SI 6	10.90**	-5.46*	9.16*	-8.02*	58.77**	-2.15
39	SKP 84× SI 9	6.63*	-3.28	5.65	-7.72*	81.58**	11.03
Range	Min	-11.54	-31.69	-15.44	-32.72	0.13	-40.31
	Max	31.78	-1.64	36.62	-2.47	117.42	32.95
S. E.±		1.45	1.45	0.79	0.79	6.73	6.73
No of significant crosses		20	36	21	34	36	10
Positive		15	0	17	0	36	4
Negative		5	36	4	34	0	6

*, ** Significant at P = 0.05 and P = 0.01 levels of probability, respectively.
BP and SH were better parent and standard check hybrid, respectively. DF = Days to 50 per cent flowering, NN = Number of nodes upto primary raceme and PH = Plant height upto primary raceme (cm)

Table.4 Estimates of heterobeltiosis and standard heterosis for day's maturity of primary raceme, Length of primary raceme and number of capsules on primary raceme

Sr. No.	Hybrids	DM		LP		NCP	
		BP	SH	BP	SH	BP	SH
1	SP 1 × ANDCI 8	18.81**	1.41	2.44	-10.63	5.76	-12.04*
2	SP 1 × ANDCI 9	13.53**	-3.10	-14.53*	-25.43**	-2.61	-19.00**
3	SP 1 × DCS 100	14.52**	-2.25	-0.72	-13.39*	6.38	-11.52*
4	SP 1 × DCS 9	18.48**	1.13	-6.95	-18.82**	4.77	-12.86*
5	SP 1 × JI 35	18.81**	1.41	0.45	-12.36*	1.44	-15.63**
6	SP 1 × JI 384	18.48**	1.13	-1.26	-13.86*	8.27	-9.95
7	SP 1 × JI 399	20.79**	3.10	3.79	-9.45	5.94	-11.89*
8	SP 1 × JI 402	5.94*	-9.58**	1.99	-11.02*	17.90**	-1.94
9	SP 1 × JI 404	2.95	-21.41**	-12.82*	-23.94**	1.53	-15.56**
10	SP 1 × SI 4	5.94*	-9.58**	13.27*	-1.18	11.36*	10.02
11	SP 1 × SI 5	4.95*	-10.42**	34.75**	17.56**	25.13**	30.74**
12	SP 1 × SI 6	-3.00	-18.03**	-14.44*	-25.35**	-5.76	-21.62**
13	SP 1 × SI 9	7.26**	-8.45**	-7.04	-18.90**	-1.98	-18.47**
14	VP 1 × ANDCI 8	29.18**	-6.48**	12.43	-7.40	10.21	-20.04**
15	VP 1× ANDCI 9	32.30**	-4.23*	6.08	-13.46*	9.54	-21.02**
16	VP 1× DCS 100	17.90**	-14.65**	7.93	-12.13*	6.00	-15.41**
17	VP 1× DCS 9	23.35**	-10.70**	14.39	-15.51**	15.33	-17.28**
18	VP 1× JI 35	16.73**	-15.49**	36.19**	1.34	20.02**	-7.63
19	VP 1× JI 384	17.90**	-14.65**	11.01	-17.40**	4.44	-22.51**
20	VP 1× JI 399	35.02**	-2.25	13.23	-19.13**	7.29	-16.31**
21	VP 1× JI 402	38.91**	0.56	2.87	-26.54**	-2.66	-23.41**
22	VP 1× JI 404	14.01**	-17.46**	-11.76	-35.04**	-15.91*	-37.55**
23	VP 1× SI 4	37.35**	-0.56	9.40	-11.10*	-13.85*	-14.88**
24	VP 1× SI 5	32.68**	-3.94	19.71**	-1.02	7.37	12.19*
25	VP 1× SI 6	31.13**	-5.07*	0.00	-26.06**	-6.79	-31.19**
26	VP 1× SI 9	21.79**	-11.83**	-8.11	-31.34**	-9.79	-33.13**
27	SKP 84× ANDCI 8	8.55**	-7.04**	38.15**	13.78*	43.88**	16.01**
28	SKP 84× ANDCI 9	10.53**	-5.35*	-1.83	-19.92**	2.13	-17.65**
29	SKP 84× DCS 100	15.13**	-1.41	0.87	-17.87**	2.23	-17.58**
30	SKP 84× DCS 9	14.80**	-1.69	17.21*	-12.05*	12.62	-9.20
31	SKP 84× JI 35	17.76**	0.85	17.52*	-11.81*	12.34	-9.42
32	SKP 84× JI 384	13.82**	-2.54	-0.84	-25.59**	-4.55	-23.04**
33	SKP 84× JI 399	16.78**	0.00	-3.04	-27.24**	-6.49	-24.61**
34	SKP 84× JI 402	18.09**	1.13	0.63	-24.49**	-12.52	-29.47**
35	SKP 84× JI 404	13.65**	-13.24**	16.58*	-12.52*	-9.00	-26.63**
36	SKP 84× SI 4	19.08**	1.97	22.48**	-0.47	10.45	9.12
37	SKP 84× SI 5	25.33**	7.32**	36.19**	12.60*	9.45	14.36*
38	SKP 84× SI 6	18.00**	-0.28	13.96	-14.49**	-15.12*	-31.56**
39	SKP 84× SI 9	13.49**	-2.82	11.86	-16.06**	-15.40*	-31.79**
Range	Min	-3.00	-21.41	-14.53	-35.04	-15.91	-37.55
	Max	38.91	7.32	38.15	17.56	43.88	30.74
S. E.±		2.55	2.55	4.71	4.71	5.05	5.05
No of significant crosses		37	19	13	32	9	32
Positive		37	1	10	3	5	4
Negative		0	18	3	29	4	28

*, ** Significant at P = 0.05 and P = 0.01 levels of probability, respectively.
BP and SH were better parent and standard check hybrid, respectively. DM = Days to maturity of primary raceme, LP = Length of primary raceme (cm) and NCP = Number of capsules on primary raceme

Table.5 Estimates of heterobeltiosis and standard heterosis for number of effective branches per Plant, total number of branches per plant and seed yield per plant

Sr. No.	Hybrids	NEB		TNB		SY	
		BP	SH	BP	SH	BP	SH
1	SP 1 × ANDCI 8	0.00	0.95	-5.45	-11.64	12.95	-13.42*
2	SP 1 × ANDCI 9	-13.68*	-12.86*	-11.67	-17.45**	13.69	-26.91**
3	SP 1 × DCS 100	-8.49	-7.62	-8.17	-14.18*	43.13**	-12.07
4	SP 1 × DCS 9	-22.17**	-21.43**	-16.73*	-22.18**	26.30*	-22.41**
5	SP 1 × JI 35	-16.04*	-15.24*	-5.06	-11.27	20.55*	-21.63**
6	SP 1 × JI 384	-28.77**	-28.10**	-20.62**	-25.82**	17.04	-28.10**
7	SP 1 × JI 399	-27.83**	-27.14**	-9.73	-15.64*	5.71	-27.81**
8	SP 1 × JI 402	-15.09*	-14.29*	-3.89	-10.18	22.69*	-23.25**
9	SP 1 × JI 404	-20.75**	-20.00**	-14.01*	-19.64**	23.04*	-23.87**
10	SP 1 × SI 4	-2.83	-1.90	3.50	-3.27	21.59*	-12.41
11	SP 1 × SI 5	20.28**	21.43**	24.43**	18.55**	47.26**	23.77**
12	SP 1 × SI 6	-31.13**	-30.48**	-27.24**	-32.00**	5.41	-34.5**
13	SP 1 × SI 9	-28.30**	-27.62**	-12.06	-17.82**	5.60	-31.46**
14	VP 1 × ANDCI 8	-19.25**	-28.10**	-5.60	-20.36**	2.97	-21.07**
15	VP 1× ANDCI 9	-5.84	-30.95**	-1.83	-22.18**	18.05	-24.11**
16	VP 1× DCS 100	3.92	-24.29**	-7.37	-26.91**	25.65*	-27.05**
17	VP 1× DCS 9	13.10	-21.90**	24.19**	-16.00**	29.61*	-28.04**
18	VP 1× JI 35	25.93**	-2.86	19.03*	-2.18	33.81**	-13.02
19	VP 1× JI 384	4.61	-24.29**	9.95	-15.64*	19.48	-29.60**
20	VP 1× JI 399	-23.17**	-40.00**	-12.56	-29.09**	-17.68	-43.78**
21	VP 1× JI 402	-11.72	-39.05**	7.77	-24.36**	-10.46	-43.99**
22	VP 1× JI 404	-26.90**	-49.52**	-10.26	-36.36**	-18.68	-49.69**
23	VP 1× SI 4	9.04	-13.81*	0.86	-14.91*	28.53**	-7.42
24	VP 1× SI 5	4.71	-4.76	-2.67	-7.27	32.45**	11.32
25	VP 1× SI 6	-11.72	-39.05**	5.91	-28.36**	-17.64	-48.83**
26	VP 1× SI 9	-6.21	-35.24**	10.75	-25.09**	-17.61	-46.53**
27	SKP 84× ANDCI 8	-1.32	6.67	-3.75	-6.55	56.21**	19.74**
28	SKP 84× ANDCI 9	-26.87**	-20.95**	-15.73*	-18.18**	8.52	-30.24**
29	SKP 84× DCS 100	-23.79**	-17.62**	-11.61	-14.18*	37.28**	-17.20*
30	SKP 84× DCS 9	-24.67**	-18.57**	-15.36*	-17.82**	34.54**	-18.85**
31	SKP 84× JI 35	-20.70**	-14.29*	-14.98*	-17.45**	41.6**	-7.96
32	SKP 84× JI 384	-37.00**	-31.90**	-22.47**	-24.73**	22.18*	-26.30**
33	SKP 84× JI 399	-25.55**	-19.52**	-11.61	-14.18*	7.94	-26.29**
34	SKP 84× JI 402	-43.17**	-38.57**	-29.96**	-32.00**	12.68	-29.52**
35	SKP 84× JI 404	-48.90**	-44.76**	-32.21**	-34.18**	10.73	-31.49**
36	SKP 84× SI 4	-19.82**	-13.33*	-9.74	-12.36*	18.58*	-14.58*
37	SKP 84× SI 5	-5.73	1.90	-1.12	-4.00	40.06**	17.71**
38	SKP 84× SI 6	-30.40**	-24.76**	-18.35**	-20.73**	25.77*	-21.85**
39	SKP 84× SI 9	-27.75**	-21.90**	-24.72**	-26.91**	14.01	-26.00**
Range	Min	-48.90	-49.52	-32.21	-36.36	-18.68	-49.69
	Max	25.93	21.43	24.43	18.55	56.21	23.77
S. E.±		0.88	0.88	1.13	1.13	17.30	17.30
No of significant crosses		25	32	15	31	20	33
Positive		2	1	3	1	20	3
Negative		23	31	12	30	0	30

*, ** Significant at P = 0.05 and P = 0.01 levels of probability, respectively. BP and SH were better parent and standard check hybrid, respectively.NEB = Number of effective branches per plant, TNB = Total number of branches per plant and SY = Seed yield per plant (g)

Table.6 Estimates of heterobeltiosis and standard heterosis for 100 seed weight, Shelling out turn and oil content

Sr. No.	Hybrids	TW		SH		OC	
		BP	SH	BP	SH	BP	SH
1	SP 1 × ANDCI 8	-1.51	-8.71*	-3.63	-3.13	-0.18	-1.55
2	SP 1 × ANDCI 9	-11.37**	-17.85**	2.08	-7.77**	-3.19**	-5.61**
3	SP 1 × DCS 100	-0.08	-7.39*	-0.43	-9.73**	-0.15	-2.64*
4	SP 1 × DCS 9	-4.41	-11.40**	0.59	-10.26**	-7.51**	-9.82**
5	SP 1 × JI 35	-1.24	-8.46*	2.54	-4.77	-2.30	-4.74**
6	SP 1 × JI 384	-10.93**	-17.44**	4.36	-6.91*	-1.33	-3.79**
7	SP 1 × JI 399	-0.85	-8.10*	-2.14	-12.70**	-12.17**	-14.37**
8	SP 1 × JI 402	-7.07*	-10.60**	0.84	-9.08**	-0.60	-3.08**
9	SP 1 × JI 404	-4.01	-9.70**	7.21*	-3.50	-6.31**	-8.65**
10	SP 1 × SI 4	7.01	-0.81	3.55	-5.83*	-3.86**	-6.26**
11	SP 1 × SI 5	7.82*	11.73**	12.96**	7.23*	-0.87	-1.61
12	SP 1 × SI 6	-7.87*	-14.61**	-1.95	-12.53**	-0.93	-3.41**
13	SP 1 × SI 9	-13.24**	-19.58**	-2.08	-12.65**	-11.77**	-13.98**
14	VP 1 × ANDCI 8	6.10	-8.80**	-1.72	-1.21	-0.97	-2.33*
15	VP 1× ANDCI 9	5.45	-15.89**	7.50*	-2.07	-5.37**	-8.37**
16	VP 1× DCS 100	-4.50	-19.47**	2.27	-6.85*	-2.81*	-5.89**
17	VP 1× DCS 9	-3.26	-19.71**	3.17	-6.02*	-7.03**	-9.99**
18	VP 1× JI 35	6.39	-5.34	-4.33	-11.16**	-1.65	-4.22**
19	VP 1× JI 384	-6.25	-18.29**	3.11	-6.08*	-10.43**	-13.28**
20	VP 1× JI 399	8.99*	-8.71*	-0.19	-9.08**	-5.01**	-8.03**
21	VP 1× JI 402	-11.46**	-14.82**	8.07*	-1.56	-2.18	-5.28**
22	VP 1× JI 404	-21.79**	-26.42**	-5.00	-13.47**	-5.29**	-8.30**
23	VP 1× SI 4	4.11	-10.75**	9.72**	-0.06	-7.72**	-10.65**
24	VP 1× SI 5	-11.31**	-8.10*	9.02**	3.48	-1.09	-1.82
25	VP 1× SI 6	-4.97	-25.58**	-2.18	-10.89**	-1.86	-4.50**
26	VP 1× SI 9	-12.08**	-24.06**	-3.83	-12.40**	-15.07**	-17.77**
27	SKP 84× ANDCI 8	18.10**	8.39*	6.18*	6.72*	0.59	-0.79
28	SKP 84× ANDCI 9	-11.48**	-18.76**	1.45	-8.34**	-2.29	-4.01**
29	SKP 84× DCS 100	-2.10	-10.15**	5.20	-4.63	-2.72*	-4.43**
30	SKP 84× DCS 9	-1.43	-9.54**	6.99*	-5.94*	-13.86**	-15.38**
31	SKP 84× JI 35	0.36	-7.89*	5.31	-2.20	-1.81	-3.54**
32	SKP 84× JI 384	3.51	-5.00	6.47*	-5.61	-8.63**	-10.24**
33	SKP 84× JI 399	-1.63	-9.72**	-1.51	-13.41**	-9.07**	-10.67**
34	SKP 84× JI 402	-7.20*	-10.73**	9.31**	-1.54	-3.32**	-5.02**
35	SKP 84× JI 404	-6.79	-12.31**	8.28**	-2.55	-1.54	-3.28**
36	SKP 84× SI 4	5.83	-2.87	7.63*	-2.12	-2.39*	-4.11**
37	SKP 84× SI 5	3.67	7.43*	12.10**	6.41*	-1.52	-2.25
38	SKP 84× SI 6	-12.82**	-19.99**	6.20	-6.64*	-1.29	-3.03**
39	SKP 84× SI 9	-7.91*	-15.48**	8.45*	-4.65	-13.78**	-15.30**
Range	Min	-21.79	-26.42	-5.00	-13.47	-15.07	-17.77
	Max	18.10	11.73	12.96	7.23	0.59	-0.79
S. E.±		1.16	1.16	1.79	1.79	0.57	0.57
No of significant crosses		16	35	14	24	21	34
Positive		3	3	14	3	0	0
Negative		13	32	0	21	21	34

*, ** Significant at P = 0.05 and P = 0.01 levels of probability, respectively.
BP and SH were better parent and standard check hybrid, respectively.
TW = 100 seed weight (g) (Test weight), SH = Shelling out turn (%) and OC =Oil content (%)

Whereas for days to 50 per cent flowering and days to maturity of primary raceme hybrid SP 1 x JI 404 found most promising.

Comparison of top three promising crosses on the basis of per se performance for seed yield per plant along with sca effect and percent heterosis over better parent and standard check GCH 7 in different traits (Table 2). On the basis of *per se* performance and heterosis the hybrids SP 1 x SI 5, SKP 84 x ANDCI 8 and SKP 84 x SI 5 were found the most promising and may be exploited in further breeding programme. Their superiority seems to have resulted from higher values of their yield contributing characters like length of primary raceme, number of capsules on primary raceme, number of effective branches per plant and 100-seed weight.

It can be concluded among 39 hybrids tested, three hybrids *viz*., SP 1 x SI 5, SKP 84 x ANDCI 8 and SKP 84 x SI 5 recorded significant and positive heterosis over GCH 7 for seed yield per plant (Tables 3-6). These hybrids also depicted significant and positive heterosis over their respective better parent. The high heterotic response in these hybrids resulted due to positive heterosis for yield contributing characters like length of primary raceme, number of capsules on primary raceme, effective number of branches per plant and 100 seed weight. The heterotic effect for seed yield per plant could be outcome of direct effect of these attributes, and could be outcome of indirect effects of other yield contributing attributes like number of effective branches per plant and number of capsules per plant. Therefore, heterotic effects for seed yield per plant could be a result of combinational heterosis.

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