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Exploitation of heterosis for quantitative and qualitative characters in castor (*Ricinus communis* L.)

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ABSTRACT

A study was conducted in Castor (*Ricinus communis* L.) at Castor-Mustard Research Station, Sardarkrushinagar Dantiwada Agricultural University, Sardarkrushinagar (Gujarat) to assess the extent of heterosis for ten characters including seed yield per plant. Six lines and Seven testers were crossed in line x tester mating design to develop 42 F_1 hybrids. The analysis of variance was found significant for all the character suggesting the presence of considerable amount of variability among the parents and hybrids for seed yield per plant, important yield components and oil content. A perusal of mean values revealed that the parent SKP 84 had the highest seed yield per plant, whereas among the all hybrids, SKP 84 x SKI 357, SKP 106 x SKI 342 and SKP 42 x SKI 357 registered the highest seed yield per plant. In the present study, extent of heterosis varied from cross to cross for all the traits. The cross JP 96 x SKI 350 recorded the highest heterosis for seed yield per plant (46.18%) over check variety GCH 7 Followed by JP 96 x SKI 342 (35.44%) and SKP 84 x SKI 350 (26.60 %), for 100 seed weight cross SKP 42 x SKI 349 (12.50%) recorded highest heterosis and cross SKP106 x SKI 357 (8.61 %) recorded highest oil content.

Key word: Castor, line x tester, heterosis, seed yield

Castor (*Ricinus communis L.*) with 2n=20 belongs to the family *Euphorbiaceae* and It is indigenous to eastern Africa and most probably originated in Ethiopia. The crop is grown as an important industrial non-edible oil seed crop. India is the world's principle producer of castor and rank first both in area and production. Castor productivity in India is more than world average and it ranks first among the major castor producing countries *viz.*, India, China, Brazil and Thailand. In India, castor crop occupies an area of about 1040 thousand ha with a production of 1733.00 thousand mt and the productivity being 1666 kg/ha (FAOSTAT, 2015). In India castor is being grown for oil under wide ranging environmental conditions.

Commercial exploitation of heterosis in castor is regarded as one of the major breakthrough in the field of castor improvement. Heterosis breeding is an important crop improvement method adopted in many crops all over the world. It is a quick and convenient way of combining desirable characters which has assumed greater significance in the production of F_1 hybrids. In castor, efforts were initiated to exploit heterosis since 1960s even before the identification of pistillate lines. The superiority of hybrids depends on their yield potential over the better released varieties and the extent of heterosis for seed yield and tolerance to biotic and abiotic stresses. Genetic basis of heterosis of seed yield is due to the factors other than heterosis and *per se* performance like the improved parental lines for spike density, more female ratio on spike, earliness, short stature, etc. The heterosis is mainly due to the highly female expression inherited from the dominant female nature of the S type pistillate line(Moshkin, 1986) and contributes to the raise in seed yield. Lack of inbreeding depression on selfing led to the initial slow pace and emphasis on heterosis breeding in castor. The aim of heterosis analysis is to find out best combination of crosses giving high degree of standard heterosis and characterization of hybrids for commercial exploitation.

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MATERIALS AND METHODS

The experimental material for the present investigation were generated by crossing 7 males (Tester) *viz*, SKI 342, SKI 344 , SKI 349 , SKI 350 , SKI 352 , SKI 357 and SH 41 with 6 females (Lines) *viz*, SKP 42, SKP 84 , SKP 106, SKP 121, SKP 122, and JP 96 Crossed during (*kharif - 2014*) in Line x Tester manner were collected from Castor-Mustard Research Station, S. D. Agricultural university. Sardarkrushinagar. The entries (Including parents and F_1 hybrids) were grown during rainy season (*kharif 2015*) at Castor - Mustard Research Station, S. D. Agricultural university. Sardarkrushinagar. Thirteen parents, their hybrids and two checks were raised in a randomized complete block design in two replications. Each genotype was sown in two rows of 6 m length with a spacing of 120 x 60 cm. Recommended agronomic practices were followed to grow a healthy crop. There were six Observations were recorded *viz*., Length of primary spike (cm), Seed yield (g/plant), 100- seed weight (g), effective spike per plant, Oil content (%), and Number of capsules. The data generated as per Line x Tester model of Kempthorne (1957) were subjected to analysis of variance as per the Line x Tester model given by Singh and Chaudhary (1977)

RESULTS AND DISCUSSION

The results obtained under the present investigation are presented in Table 1 to 2. The analysis of variance was found significant for all the character suggesting the presence of considerable amount of variability among parents and hybrids for seed yield per plant, important yield components and quality characters. The mean square for parents highly significantly for majority of the characters except 100-seed weight, and effective branches per plant revealed that the among parents being significant amount of genetically diversity which is desirable for the heterosis breeding. Mean squares due to hybrids were highly significant for all the characters. Mean square due to female vs. male were highly significant for all the character seed yield per plant, which are mainly yield attributing characters and significantly differ in male & female parents beneficial for high heterosis in hybrids. Mean square due to female was found highly significant for all the characters except 100 seed weight. Mean square due to male was found significant for oil content and seed yield. Comparison of mean squares due to parent vs. hybrids was found highly significant for almost all the characters except 100-seed weight (g) which indicates significant amount variability among parental lines & its hybrids.

In this study, out of forty two, nine hybrids manifested significant positive standard heterosis for seed yield. The cross JP-96 x SKI-350 recorded the highest heterosis (46.18%) over check variety GCH-7 followed by JP 96 x SKI 342 (35.44%) and SKP 84 x SKI 350 (26.60%), while hybrid SKP106 x SH 41 recorded highest relative heterosis (83.75%) and heterobeltiosis (62.53%). High amount of heterosis observed under the present study were agreed with those reported by Sapovadiya *et al*., (2015), Chaudhary *et al*., (2015), Patel *et al*., (2009), Kanwal (2002), Tank (2000), Mehta (1989) and Thakkar (1987) and for heterosis while for heterobeltiosis, Rabadia (1989).

For effective branches per plant, high value of relative

Table 1 Analysis of variance (mean square) for parents and hybrids for seed yield and its component characters

Source of variation	d.f	Length of Primary Spike (cm)	No. Capsule per plant (cm)	Seed yield(g / plant)	100 -seed weight (gm)	Oil Content (%)	Effective Branches/ plant
Replication	1	1292.77***	1748.02***	0.37	20.19	14.49***	4.94**
Parents	12	415.74***	325.73***	1.13***	9.76	21.81***	1.19
Female	5	708.66***	9.645	8.56*	43.65***	0.90	516.035***
Male	6	74.52	5..36	12.15*	5.99***	0.73	152.95
Female Vs. male	1	998.50***	63.15**	1.45	7.52**	5.37**	410.85*
Parents Vs. hybrid	1	296.92*	88.05**	5.44*	0.72	87.01***	374.13*
Hybrids	41	100.74**	16.37**	21.21**	13.50***	2.23***	148.70**
Error	54	49.90	74.12	0.30	8.97	1.00	0.65

* $P \leq 0.05$, ** $P \leq 0.01$.

Table 2 Estimates of per cent heterosis over mid parent (MP), better parent (BP) and check variety (GCH-7) for the characters under study

Sr. No.	Name of Crosses	Test Weight			Oil Content		
		MP	BP	SC	MP	BP	SC
1	SKP 42 x SKI 342	2.73	1.43	0.29	10.65 **	1.31	1.19
2	SKP 42 x SKI 344	2.64	1.94	0.79	10.77 **	0.62	2.28
3	SKP 42 x SKI 349	11.04	8.43	12.50**	9.36 **	-1.56	2.13
4	SKP 42 x SKI 350	0.19	-4.91	-5.97	20.92 **	12.95 **	8.02**
5	SKP 42 x SKI 352	5.3	-2.62	-3.71	14.14 **	3.5	5.62**
6	SKP 42 x SKI 357	-3.76	-4.25	-5.33	11.48 **	-0.67	5.45**
7	SKP 42 x SH 41	12.68	3.71	2.54	13.06 **	2.84	4.23*
8	SKP 84 x SKI 342	3.72	3.49	-0.25	6.6 **	6.16 **	6.93**
9	SKP 84 x SKI 344	-1.69	-2.49	-4.89	-0.01	-0.47	1.17
10	SKP 84 x SKI 349	3.08	-0.81	2.92	0.16	-1.3	2.40
11	SKP 84 x SKI 350	-0.89	-4.58	-8.44	-2.74	-5.19 **	-4.51*
12	SKP 84 x SKI 352	2.28	-4.09	-7.97	0.61	-0.06	2.00
13	SKP 84 x SKI 357	-2.78	-3.73	-5.78	-6.7 **	-9.09 **	-3.49
14	SKP 84 x SH 41	14.74	7.08	2.73	2.77	2.46	3.83
15	SKP106 x SKI 342	-2.36	-4.22	-7.68	-5.05 **	-8.62 **	-1.30
16	SKP106 x SKI 344	-8.66	-10.92	-13.11	-18.11 **	-20.52 **	-14.16**
17	SKP106 x SKI 349	-4.95	-10.02	-6.63	-9.4 **	-11.19 **	-4.08
18	SKP106 x SKI 350	-5.21	-7.21	-13.96	-0.3	-6 **	1.53
19	SKP106 x SKI 352	-6.05	-10.46	-16.98	-4.41 **	-7.04 **	0.40
20	SKP106 x SKI 357	-10.63	-12.99	-14.85	1.43	0.56	8.61**
21	SKP106 x SH 41	3.38	-1.95	-9.11	-3.35*	-6.33 **	1.17
22	SKP121 x SKI 342	1.14	-4.53	-8.00	-2.92	-5.02 **	-0.85
23	SKP121 x SKI 344	2.84	-3.47	-5.84	1.4	0.07	4.47*
24	SKP121 x SKI 349	4.48	-4.68	-1.08	2.32	2	6.47**
25	SKP121 x SKI 350	-5.75	-7.47	-17.84	-1.48	-5.61 **	-1.45
26	SKP121 x SKI 352	7.28	6.31	-9.04	-5.27**	-6.33 **	-2.21
27	SKP121 x SKI 357	-8.26	-14.03	-15.87	-5.21**	-6 **	-0.21
28	SKP121 x SH 41	4.79	3.3	-11.62	2.41	0.91	5.34
29	SKP122 x SKI 342	-12.72	-15.51	-18.57	-2.79	-4.05*	-4.17
30	SKP122 x SKI 344	-3.77	-7.39	-9.68	1.39	-0.79	0.85
31	SKP122 x SKI 349	-51.26**	-54.44**	-6.28	6.7**	3.38	7.25**
32	SKP122 x SKI 350	-12.46	-13.14	-21.64**	-10.62**	-11.37 **	-13.78**
33	SKP122 x SKI 352	-4.35	-7.64	-16.69	-4.07*	-6.32 **	-4.38*
34	SKP122 x SKI 357	-6.3	-9.97	-11.90	-1.55	-5.66 **	0.15
35	SKP 122 x SH 41	1.44	-2.53	-12.09	6.12**	4*	5.40**
36	JP 96 x SKI 342	3.65	-0.21	3.90	1.28	-0.41	2.91
37	JP 96 x SKI 344	-0.06	-3.23	0.76	-1.56	-2.36	0.91
38	JP 96 x SKI 349	4.95	4.77	9.11	0.93	0.73	4.49
39	JP 96 x SKI 350	-0.08	-7.44	-3.62	2.9	-0.93	2.38
40	JP 96 x SKI 352	-2.55	-11.96	-8.31	-4.71**	-5.3**	-2.13
41	JP 96 x SKI 357	-8.79	-11.54	-7.87	-3.11	-4.4*	1.49
42	JP 96 x SH 41	-4.09	-13.76	-10.19	-5.97**	-6.88**	-3.78*
	S.Em±	2.59	2.99	2.99	0.87	1.00	1.00

Cont.

Sr. No	Name of Crosses	Length of Primary Spike			No. of Capsules		
		MP	BP	SC	MP	BP	SC
1	SKP 42 x SKI 342	-10.5	-33.64**	-20.78**	12.8	-13.47	-16.59
2	SKP 42 x SKI 344	-11.6	-31.15**	-17.81	4.36	-12.5	-15.65
3	SKP 42 x SKI 349	17.98	-11.52	5.62	45.92**	11.69	7.67
4	SKP 42 x SKI 350	-24.32*	-47.25**	-37.03**	-12.13	-31.82*	-34.27**
5	SKP 42 x SKI 352	-27.17 **	-41.75**	-30.47**	-34.12**	-36.85*	-39.12**
6	SKP 42 x SKI 357	-27.78 *	-44.37**	-33.59**	-32.05*	-42.86**	-44.91**
7	SKP 42 x SH 41	-28.9 **	-41.88**	-30.63**	-17.71	-27.6	-30.20**
8	SKP 84 x SKI 342	-16.53	-38.06**	-26.25**	-24.05	-44.84**	-37.25**
9	SKP 84 x SKI 344	-26.77 *	-42.91**	-32.03**	-28.32*	-43.6**	-35.84**
10	SKP 84 x SKI 349	-25.7 *	-44.23**	-33.59**	-18.79	-41.13**	-33.02**
11	SKP 84 x SKI 350	-20.6	-44.62**	-34.06**	-20.9	-41.95**	-33.96**
12	SKP 84 x SKI 352	-28.85**	-43.04**	-32.19**	-40.25 **	-46.91**	-39.59**
13	SKP 84 x SKI 357	-27.83*	-44.36**	-33.75**	-22.93	-39.2**	-30.83**
14	SKP 84 x SH 41	-26.06*	-39.5**	-27.97**	-25.19	-38.51**	-30.05**
15	SKP106 x SKI 342	-2.06	-11.57	-36.72**	-3.94	-17.47	-40.85**
16	SKP106 x SKI 344	-14.03	-17.03	-40.63**	-20	-23.58	-45.23**
17	SKP106 x SKI 349	-3.57	-11.57	-36.72**	-0.38	-14.63	-38.81**
18	SKP106 x SKI 350	-2.77	-19.43	-42.34**	-14.54	-25.55	-46.64**
19	SKP106 x SKI 352	0.44	0.44	-28.13**	-9.29	-17.88	-27.39**
20	SKP106 x SKI 357	-9.3	-13.76	-38.28**	-18	-21.4	-43.66**
21	SKP106 x SH 41	-18.56	-20.82	-40.00**	-19.65	-20.51	-41.78**
22	SKP121 x SKI 342	-17.18	-23.86	-47.66**	-14.21	-23.82	-49.45**
23	SKP121 x SKI 344	-3.46	-5	-34.69**	-3.92	-4.72	-36.78**
24	SKP121 x SKI 349	-12.9	-18.64	-44.06**	-12.65	-22.64	-48.67**
25	SKP121 x SKI 350	-2.56	-17.95	-43.59**	-24.08	-31.6	-54.62**
26	SKP121 x SKI 352	5.12	3.06	-26.25**	-15.07	-25.66	-34.27**
27	SKP121 x SKI 357	-10.43	-13.18	-40.31**	-25.12	-25.47	-50.55**
28	SKP121 x SH 41	-11.78	-15.88	-36.25**	-15.25	-19.23	-40.85**
29	SKP122 x SKI 342	2.78	-4.88	-45.16**	-2.85	-11.85	-54.62**
30	SKP122 x SKI 344	10.27	-4.23	-36.25**	17.96	-3.12	-36.78**
31	SKP122 x SKI 349	-1.15	-9.95	-46.25**	-0.5	-9.48	-53.68**
32	SKP122 x SKI 350	-7.64	-9.55	-55.63**	-15.13	-24.12	-59.62**
33	SKP122 x SKI 352	-13.47	-27.07	-47.81**	-27.25	-46.37**	-52.58**
34	SKP122 x SKI 357	9.49	-3.63	-37.81**	13.95	-6.67	-38.65**
35	SKP 122 x SH 41	-11.76	-27.32	-44.84**	-17.93	-35.47	-52.74**
36	JP 96 x SKI 342	-1.24	-8.92	-37.81**	3.24	-9.95	-37.72**
37	JP 96 x SKI 344	16.34	14.87	-21.56**	10.83	7.69	-25.51**
38	JP 96 x SKI 349	6.72	0	-31.72**	21.2	5.43	-27.07**
39	JP 96 x SKI 350	22.49	3.43	-29.38**	7.93	-4.52	-33.96**
40	JP 96 x SKI 352	-13.52	-15.5	-39.53**	-28.6	-36.37*	-43.66**
41	JP 96 x SKI 357	28.24	24.71	-14.84	28.54	25.34	-13.30
42	JP 96 x SH 41	22.78	16.7	-11.56	27.47	23.93	-9.23
	S.Em±	6.12	7.06	7.06	7.45	8.60	8.60

Cont.

Sr. No.	Name of Crosses	No .of effective Spikes			Seed Yield		
		MP	BP	SC	MP	BP	SC
1	SKP 42 x SKI 342	52.54**	40.63**	-15.89**	54.57**	48.05*	25.89**
2	SKP 42 x SKI 344	42.61**	34.43*	-23.36**	-16.95	-21.33	-25.22**
3	SKP 42 x SKI 349	32.28**	15.07	-21.50**	19.3	8.43	-7.82
4	SKP 42 x SKI 350	35.94**	17.57	-18.69**	-5.71	-7.12	-18.61**
5	SKP 42 x SKI 352	52.14**	41.27**	-16.82**	22.66	8.34	20.20**
6	SKP 42 x SKI 357	25.86*	17.74	-31.78**	62.45	27.47	8.39
7	SKP 42 x SH 41	37.5**	18.92	-17.76**	21.34	-4.9	-19.14**
8	SKP 84 x SKI 342	55.36**	35.94**	-18.69**	-6.73	-6.73	-27.40**
9	SKP 84 x SKI 344	37.61**	22.95	-29.91**	2.63	-6.65	-11.28**
10	SKP 84 x SKI 349	25.62*	4.11	-28.97**	39.64	32.18	2.93
11	SKP 84 x SKI 350	54.1**	27.03*	-12.15	52.96**	44.42*	26.60**
12	SKP 84 x SKI 352	15.32	1.59	-40.19**	16.86	-0.56	10.30
13	SKP 84 x SKI 357	47.27**	30.65*	-24.30**	64.84**	33.66	4.09
14	SKP 84 x SH 41	42.62**	17.57	-18.69**	20.9	-2.08	-23.76**
15	SKP106 x SKI 342	25.4*	23.44	-26.17**	67.21*	50.99*	17.58**
16	SKP106 x SKI 344	23.58*	22.58	-28.97**	43.72*	19.3	13.41**
17	SKP106 x SKI 349	15.56	6.85	-27.10**	40.91	34.04	-6.79
18	SKP106 x SKI 350	8.82	0	-30.84**	26.81	8.8	-4.62
19	SKP106 x SKI 352	24.8*	23.81	-27.10**	29.07	1.04	12.08**
20	SKP106 x SKI 357	29.03*	29.03*	-25.23**	55.48*	37.71	-13.59**
21	SKP106 x SH 41	-4.41	-12.16	-39.25**	83.75**	62.53*	2.00
22	SKP121 x SKI 342	8.66	7.81	-35.51**	-7.31	-18.82	-15.90**
23	SKP121 x SKI 344	12.9	11.11	-34.58**	4.23	-0.07	3.55
24	SKP121 x SKI 349	22.06*	13.7	-22.43**	18.08	-1.34	2.22
25	SKP121 x SKI 350	6.57	-1.35	-31.78**	-4.31	-11.68	-8.48
26	SKP121 x SKI 352	14.29	14.29	-32.71**	1.04	-2.29	8.39
27	SKP121 x SKI 357	20	19.05	-29.91**	-18.76	-40.4*	-38.23**
28	SKP121 x SH 41	37.23**	27.03*	-12.15	45.99*	6.99	10.88
29	SKP122 x SKI 342	26.67*	18.75	-28.97**	47.33*	32.38	3.06
30	SKP122 x SKI 344	50.43 **	44.26**	-17.76**	14.13	-5.68	-10.35
31	SKP122 x SKI 349	36.43**	20.55	-17.76**	2.52	-2.99	-32.55**
32	SKP122 x SKI 350	50.77**	32.43**	-8.41	59.11**	35.88	19.09*
33	SKP122 x SKI 352	49.58**	41.27**	-16.82**	3.21	-19.53	-10.75
34	SKP122 x SKI 357	93.22**	83.87**	6.54	53.8*	36.89	-15.05**
35	SKP 122 x SH 41	52.31**	33.78**	-7.48	21.73	8.2	-32.86**
36	JP 96 x SKI 342	53.85**	51.52**	-6.54	34.43*	9.54	35.44**
37	JP 96 x SKI 344	43.31**	37.88**	-14.95	-16.53	-26.18	-8.70
38	JP 96 x SKI 349	26.62*	20.55	-17.76**	-2.63	-23.94	-5.95
39	JP 96 x SKI 350	30.71**	23.65*	-14.02	38.34**	18.2	46.18**
40	JP 96 x SKI 352	55.04**	51.52**	-6.54	-40.26**	-43.33**	-29.93**
41	JP 96 x SKI 357	40.62**	36.36**	-15.89**	-11.02	-38.09**	-23.45**
42	JP 96 x SH 41	32.86**	25.68*	-13.08	-5.74	-34.48*	-18.96**
	S.Em±	0.70	0.81	0.81	0.47	0.55	0.55

heterosis SKP122 x SKI 357 (93.22%), heterobeltiosis (83.87 %) and standard heterosis (6.54%) were recorded. Similar trend was noticed by Thakkar (1987) and Mehta *et al.,* (1989) for heterosis and Thakkar (1987) and Tank (2000) for heterobeltiosis. The highest value for relative heterosis JP 96 x SKI 357 (45.92%), for heterobeltiosis cross JP 96 x SKI 357 (25.34 %) and for economic heterosis cross JP 96 x SKI 357 (7.67%) were recorded for number of capsule per plant. The positive heterotic effects observed under the present study are in correspondence to those of Rabadia (1989) for both heterosis and heterobeltiosis. The heterosis was recorded for 100-seed weight over mid-parent SKP 84 x SH 41 (14.74 %), better parent SKP 42 x SKI 349 (8.43%) and standard check SKP 84 x SH 41 (12.50%) which was similar with those reported by Rabadia (1989), Mehta *et al.,* (1989) for both heterosis and heterobeltiosis,.

For quality character like oil content heterosis was recorded cross over mid-parent SKP 42 x SKI 350 (20.92%), better parent (12.95%), and for standard check SKP106 x SKI 357 (8.61%). The positive desirable heterosis for oil content was earlier noticed by Tank (2000), Kanwal (2002) for heterosis and, Thakkar (2002) and Patel *et al.* (1986) for heterobeltiosis. For length of primary spike highest value of relative heterosis JP 96 x SKI 357 (28.24 %), better parents (24.71%) and standard check SKP 42 x SKI 349 (5.62 %).

In case of heterosis over standard check, number of hybrids exhibited significant heterosis in desired direction for seed yield per plant (9 hybrids), oil content (10 hybrids), and 100 seed weight (1 hybrids). None of the hybrids exhibited significant heterosis in desirable direction for length of primary spike, number of capsules per plant, effective branches per plant. Based on mean performance and heterosis the parents SKP 106 and SKI 350 and the hybrids JP-96 x SKI-350 (46.18%), JP 96 x SKI 342 (35.44%) and SKP 84 x SKI 350 (26.60%), were found to be promising for the development of high yielding genotypes, Thus these results indicated that there will be huge possibilities for genetic improvement and heterosis breeding in castor.

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