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Studies on estimation of heterotic effects on seed yield and its component traits in castor (*Ricinus communis* L.)

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Abstract
Thirty castor (*Ricinus communis* L.) hybrids developed by crossing three pistillate lines and ten monoecious lines in line x tester mating design were evaluated along with parents for seed yield and component traits and the data was analyzed for heterosis. The analysis of variance showed that mean square due to parents, crosses and parents vs. crosses were found significant for all the characters, indicating the presence of sufficient amount of genetic diversity in the material. The hybrids viz., DPC-9 × Haritha, M-574 × SKI-215, DPC-9 × PCS-106 and DPC-9 × JC-12 were highly heterotic for seed yield and its contributing characters. Number of crosses exhibiting significant relative heterosis, heterobeltiosis and standard heterosis for seed yield were 29, 19 and 4, respectively. Number of effective spikes per plant, primary spike length, 100 seed weight and number of nodes were important yield contributing characters.

Keywords: castor, heterosis, heterobeltiosis, standard heterosis, seed yield

Introduction
Castor (*Ricinus communis* L., 2n = 2x = 20) is one of the most important non-edible oilseed crops widely cultivated in the arid and semi-arid regions of the world. It is cultivated to an extent of 8.3 lakh ha in India with an average productivity of 1713 kg/ha (Annual Report, 2017-18, IIOR-ICAR). India is the largest producer of castor seed with major area and production mainly contributed by Gujarat, Rajasthan, Telangana, Andhra Pradesh, Tamil Nadu, Orissa and Karnataka states. It is majorly cultivated as rainfed crop in South India and as irrigated crop in North Indian states. Castor seed contains oil to an extent of 47 to 55 per cent. It is a highly proclaimed oil as it contains the very unique ricinoleic acid and such exquisite chemical and physical properties are responsible for the widespread industrial applications of castor oil. It is a farmer friendly crop because of its low cultivation costs and lack of menace due to wild boars and birds.

Being a highly cross pollinated crop, exploitation of heterosis through hybrid breeding programmes has played a remarkable role in augmenting the productivity and thus production levels in castor. The development of pistillate mechanism has paved way for successful commercial exploitation of hybrid vigour. It is very important to identify best pistillate and monoecious lines and their best cross combinations in order to tap the heterotic component in castor. The present study aims at identifying the best cross compatible combinations through determining their extent of heterosis.

Materials and Methods
Three elite pistillate lines (DPC-9, M-574 and PPL-18) were crossed with ten diverse male parents (PCS-202, PCS-225, PCS-124, SKI215, PCS-223, JC-12, PCS-136, PCS-106, PCS-171 and DCS-78) during *Rabi*, 2016-17. The resultant thirty hybrids were evaluated along with their parents and standard check, PCH-111 in a randomized block design, replicated thrice at Regional Agricultural Research Station, Palem during *Kharif*, 2017-18. The site of experimentation falls under semi-arid climate and comes under the ambit of Southern Telangana Zone on $16^0 35^1$ latitude, $78^0 1^1$ longitude and altitude of 642 m above mean sea level. Each entry was sown in four rows with a row length of 6 m. Ten plants were randomly selected from each entry and replication on which observations were recorded on nine economically important traits viz., days to fifty per cent flowering, days to maturity, number of nodes up to primary spike, plant height (cm), primary spike length (cm), number of spikes per plant, 100 seed weight (g), seed yield per plant (g) and oil content (per cent). Days to fifty per cent flowering and days to maturity were recorded on plot basis. A standard package of

practices was followed for raising the crop. The analysis of variance for each trait was calculated as per Panse and Sukhatme (1978) [12]. The superiority of hybrids was estimated over better parents as heterobeltiosis and as standard heterosis over check PCH-111 according to the method of Fonseca and Patterson (1968) [3].

Results and Discussion

The results obtained under the present investigation are presented in Tables 1 to 5. The analysis of variance revealed that the mean square values due to genotypes, parents and crosses were significant indicating differences among themselves for all the characters studied (Table 1). Results revealed heterotic effects over mid parent (relative heterosis), better parent (heterobeltiosis) and over the check hybrid (standard heterosis) for various characters thus emphasizing that the magnitude and extent of various heterotic effects varied with cross combinations and characters. Number of hybrids showing heterosis in positive direction and range of heterosis exhibited in different cross combinations is reported in Table 3.

Top four hybrids with respect to mean seed yield along with their values of relative heterosis, heterobeltiosis and standard heterosis over check PCH-111 as well as for component traits are given in Tables 2 to 4. Number of crosses exhibiting significant relative heterosis, heterobeltiosis and standard heterosis for seed yield were 29, 19 and 4, respectively (Table 5). The results indicated that the crosses DPC-9 × Haritha, M-574 × SKI-215, DPC-9 × PCS-106 and DPC-9 × JC-12 were found to be the top four promising hybrids. Whitehouse *et al.* (1958) [22] and Grafius (1959) [6] previously suggested that there cannot be any gene system special for seed yield *per se*, as yield is an end product of multiplicative interaction of several yield components. The high yielding hybrids manifested significant and desirable heterosis over standard check PCH-111 for the important yield contributing characters viz., number of spikes per plant, primary spike length, 100 seed weight and number of nodes. This emphasizes that high degree of standard heterosis for seed yield per plant might be due to the desirable heterosis observed for their important component traits. In all top four hybrids one parent is the male line and other one is the pistillate line. Hence, these hybrids should be further evaluated before commercial use.

High association of heterosis between seed yield components and seed yield per plant in castor have also been earlier reported by Joshi *et al.* (2001) [9], Venkata Ramana *et al.* (2005) [20], Patel and Pathak (2006) [13], Chaudhuri *et al.* (2011), Singh *et al.* (2013) [18], Sapovadiya *et al.* (2015) [17] and Patel *et al.* (2016) [14].

Table 1: Analysis of variance for seed yield and yield components in castor

Source	df	Days to 50 per cent flowering	Days to maturity	No. of nodes up to primary spike	Plant height (cm)	Primary spike length (cm)	No. of spikes/ plant	100 Seed weight (g)	Seed yield/ plant (g)	Oil Content (%)
Replicates	2	0.30	2.43	0.03	1.83	0.60	0.14	0.78	158.30*	2.33
Genotypes	42	68.01**	23.68**	5.97**	422.96**	150.99**	1.45**	25.44**	889.78**	4.91**
Parents	12	12.79**	25.86**	8.06**	181.14**	35.39**	1.42**	19.42**	831.08**	2.06*
Parents (Line)	2	4.78	3.11	2.33**	49.67	5.79	0.52*	2.33	33.78	0.22
Parents (Testers)	9	15.99**	24.43**	9.43**	222.10**	38.61**	1.42**	17.17**	910.73**	2.67**
Parents (L vs T)	1	0.01	84.27**	7.20**	75.49*	65.58*	3.24**	73.88**	1708.89**	0.22
Parents vs Crosses	1	1371.95**	35.27**	3.73**	1873.37**	2246.73**	1.79**	89.08**	9315.83**	10.77**
Crosses	29	45.90**	22.38**	5.18**	473.00**	126.57**	1.44**	25.74**	623.51**	5.89**
Line Effect	2	101.48	1.23	11.69*	785.35	259.72	1.57	2.01	1296.21**	7.01*
Tester Effect	9	41.26	64.77**	8.76*	820.17*	88.46	3.31**	76.97**	1535.33**	14.72**
Line * Tester Eff.	18	42.05**	3.53	2.67**	264.71**	130.82**	0.50**	2.75*	92.85*	1.35
Error	84	2.72	2.64	0.38	16.44	11.71	0.16	1.53	45.81	0.89
Total	128	24.10	9.54	2.21	149.60	57.24	0.58	9.36	324.49	2.23

* Significant at 5% level, ** Significant at 1% level

Table 2: Heterosis for seed yield, days to 50% flowering and days to maturity in Castor

S. No.	Hybrid Name	Seed yield per plant (g)	Seed yield per plant (g)			Days to 50% flowering			Days to maturity		
			RH	HB	SH	RH	HB	SH	RH	HB	SH
1	DPC-9 × Haritha	148.3	48.33**	30.12**	23.96**	2.16	1.72	-4.84	1.58	-0.77	-1.15
2	M-574 × SKI-215	142.0	41.53**	23.84**	18.66**	14.75**	8.53**	12.9**	4.26**	0.00	3.46*
3	DPC-9 × PCS-106	131.7	28.87**	11.27*	10.03*	9.79**	7.5*	4.03	2.34	-1.13	0.77
4	DPC-9 × JC-12	130.7	29.16**	12.32*	9.19*	15.79**	8.33**	15.32**	5.93**	0.36	6.54**

* Significant at 5% level, ** Significant at 1% level

Table 3: Heterosis for number of nodes upto primary spike, plant height and primary spike length in Castor

S. No.	Hybrid Name	No. of nodes upto primary spike			Plant height			Primary spike length		
		RH	HB	SH	RH	HB	SH	RH	HB	SH
1	DPC-9 × Haritha	6.00	6.00	-0.63	32.64**	24.74**	0.62	26.77**	25.70**	-1.89
2	M-574 × SKI-215	-12.39**	-24.15**	-2.81	-5.24	-16.16**	-22.58**	-2.26	-8.42	-19.60**
3	DPC-9 × PCS-106	-10.31*	-15.59**	-10.31*	21.42**	13.89**	-7.61	7.70	0.52	-11.00*
4	DPC-9 × JC-12	-16.05**	-30.65**	-0.31	11.63**	-2.20	-7.61	10.40*	3.96	-9.68*

* Significant at 5% level, ** Significant at 1% level

Table 4: Heterosis for number of spike per plant, 100 seed weight and oil content in Castor

S. No.	Hybrid Name	No. of spikes per plant			100 seed weight			Oil content (%)		
		RH	HB	SH	RH	HB	SH	RH	HB	SH
1	DPC-9 × Haritha	12.41	-2.53	13.24	31.34**	27.54**	8.64*	6.75**	6.00**	4.89**
2	M-574 × SKI-215	3.03	-8.11	0.00	16.22**	8.86*	6.17	5.99**	5.61**	3.77*
3	DPC-9 × PCS-106	-9.02	-16.55*	-14.71*	10.83**	-1.14	7.41	1.80	0.35	0.77
4	DPC-9 × JC-12	23.21**	18.97*	1.47	16.13**	4.65	11.11**	4.86**	4.29*	1.75

* Significant at 5% level, ** Significant at 1% level

Table 5: Range of relative heterosis (RH), heterobeltiosis (HB) and standard heterosis (SH) and number of hybrids showing significant heterosis in desirable direction in Castor

S. No.	Character	Range for			No of hybrids significant for		
		RH	HB	SH	RH	HB	SH
1	Days to 50% flowering	2.16 to 51.69**	1.72 to 47.93**	-4.84** to 44.35**	0	0	0
2	Days to maturity	2.31 to 5.93**	-4.87 to 3.86*	-3.46* to 6.54**	0	3	3
3	No. of nodes upto primary spike	-16.05** to 46.15**	-30.65 to 39.71**	-13.75** to 48.44**	9	13	4
4	Plant height	-9.85* to 54.70**	-18.51** to 52.49**	-37.30** to 12.43**	1	4	17
5	Primary spike length	-2.26 to 55.96**	-8.42 to 52.35**	-21.83** to 15.07**	22	18	3
6	No. of spikes per plant	-33.65** to 23.21**	-39.13** to 18.97**	-48.53** to 13.24	1	1	0
7	100 seed weight	-6.38 to 34.88**	-14.29** to 33.85**	-18.52** to 14.81**	18	7	7
8	Seed yield per plant	8.54 to 48.33**	-1.43 to 30.12**	-25.63** to 23.96**	29	19	4
9	Oil content	-2.45 to 6.75**	-4.38** to 6.00**	-5.73** to 4.89**	8	4	2

* Significant at 5% level, ** Significant at 1% level

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