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HETEROSIS AND COMBINING ABILITY FOR YIELD AND YIELD COMPONENT CHARACTERS OF NEWLY DEVELOPED CASTOR (*RICINUS COMMUNIS* L.) HYBRID

M. RAMESH*, C. LAVANYA[2], M. SUJATHA[1], A. SIVASANKAR[1], J. ARUNA KUMARI,[1] AND H. P. MEENA[2]
[1]Department of Genetics and Plant Breeding,
College of Agriculture, ANGRAU, Rajendranagar, Hyderabad, Andhra Pradesh - 500 030
[2]Department of Plant Breeding, Directorate of Oilseeds Research, Rajendranagar, Hyderabad – 500 030
e-mail: rameshmalothu1@gmail.com

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***Corresponding author**

ABSTRACT
The estimates of the components of genetic variation were worked out by Kempthorne method from a Line x Tester analysis in castor for fourteen plant type related traits. The analysis for combining ability revealed significant mean sum of squares of both general combining ability (GCA) and specific combining ability (SCA) for all the characters which indicated the presence of both additive and non-additive gene actions. The ratio of GCA variance and SCA variance ratio revealed the predominance of non-additive gene action for all the traits except plant height up to primary spike, no. of nodes up to primary spike, no. of capsules/primary spike and total spike length of secondary. JP-87 was good general combiner for most of the characters including seed yield. The line DCS-106 was also a good general combiner for early flowering, days to maturity and number of capsules on secondary spike. Cross JP-87 × RG-1740/A was a good specific combiner for seed yield per plant and for other yield component. The hybrid DPC-9 × RG-156 with good specific combining ability for days to maturity can be used for yield improvement in castor. In general for yield and other yield attributing traits the promising hybrids with high heterosis were JP-87 × RG-1740/A, JP-87 × DCS-106, DPC-17 × RG-156, DPC-17 × DCS-106 and DPC-17 × DCS-107 were on par with the check. These cross combinations could be utilized for further use in breeding programme for improvement in yield of castor.

INTRODUCTION

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 principal producer of castor and ranks 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 734.9 thousand ha with a production of 1009.0 thousand tones and the productivity being 1372.9 kg/ha (Ministry of Agriculture, Government of India, 2009-10). In India, castor is being grown for oil under wide ranging environmental conditions.

Combining ability is a powerful tool to select good combiners and thus selecting the appropriate parental lines for hybridisation programme. In addition, the information on nature of gene action will be helpful to develop efficient crop improvement programme. General combining ability is due to additive and additive x additive gene action and is fixable in nature while specific combining ability is due to non-additive gene action which may be due to dominance or epistasis or both and is non-fixable. The presence of non-additive genetic variance is the primary justification for initiating the hybrid breeding programme (Cockerham, 1961). 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 abiotic and biotic stresses. Heterosis observed in castor is not as substantially as high as in other cross-pollinated crops due to its inherent ability to self-pollinate, especially in the primary spike. Genetic basis of heterosis of seed yield is due to the factors other than heterosis *per se* like the improved parental lines for spike density, highly female spikes, 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 the best combination of crosses giving high degree of useful heterosis and characterization of hybrids for commercial exploitation.

MATERIALS AND METHODS

The experimental material for the present investigation were generated by crossing 5 males (Lines) namely DCS-106, DCS-107, RG-156, DCS-119 and RG-1740/A with 3 females (Testers) namely DPC-9, DPC-17 and JP-87 crossed during (*Rabi*-2010) in a Line × Tester manner were collected from Directorate of Oilseeds Research, Rajendranagar, Hyderabad and from other countries. The entries (including parents and F_1 hybrids) were grown during rainy season (*kharif*) 2011 at Directorate of Oilseeds Research, Rajendranagar, Hyderabad. Eight 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 4.5 m length with a spacing of 90 × 45 cm. Recommended agronomic practices were followed to grow a healthy crop. Observations were recorded on the plant height up to primary raceme (cm), number of nodes up to primary raceme, total length of main spike (cm), effective length of main spike (cm), effective spikes per plant (No), number of capsules on main spike, 100-seed weight (g), seed yield (g/plant) and oil content (%).The data recorded on the material generated as per Line × Tester model of Kempthorne (1957) were subjected to analysis of variance as per the Line × Tester model given by Singh and Chaudhary (1977).

RESULTS AND DISCUSSION

In the present study mean sum of squares due to GCA and SCA (Table 1) were highly significant for all the fourteen characters studied. It suggests thereby the operation of both additive and non additive components of gene action. However the ratio of *GCA* and *SCA* variances (σ^2gca/σ^2sca) was found more than unity for number of nodes up to primary spike (1.48), plant height up to primary spike (582.97), number of capsules/ primary spike (1.98) and total spike length of secondary (1.48), indicating the predominance of additive genetic components of variation (Table 2). Similar results for effective spike length were reported by Ramesh *et al*. (2000); Kavani *et al*. (2001); Ramu *et al*. (2002) and Thakker *et al*. (2005) and for 100-seed weight by Tank *et al*. (2003) were well documented.

While for other ten traits the GCA/SCA ratio was less than unity suggesting the importance of non-additive gene action for these traits (Table 2). For seed yield both additive and non-additive gene actions were important. The predominance of *gca* effects over *sca* effects in the present study indicated the role of additive or non-dominant gene action especially for total spike length of primary, effective spike length of primary and 100-seed weight. Dominant gene action for seed yield was reported by several researchers like Ramu *et al*. (2002); Lavanya and Chandramohan (2003); Tank *et al*. (2003); Solanki *et al*. (2004); Thakker *et al*. (2005); Venkataramana *et al*. (2005) and Solanki (2006). But non-additive gene action was found to be more important than additive gene action.

The parent JP-87 was found to be good general combiner for seed yield and several other traits like days to 50 per cent flowering, days to maturity, number of nodes up to main spike, plant height up to primary spike and number of capsules on primary spike (Table 3). While, the line DCS-106 was also found good general combiner for early flowering, days to maturity and number of capsules on secondary spike. DCS-107 was found good combiner for days to 50 per cent flowering, maturity and plant height up to primary spike. Days to maturity are an important trait in castor for that DPC-17 was found promising. While the DCS-119 was found good combiner for plant height, total spike length of secondary, number of capsules on secondary. The present study identified that JP-87 and DCS-106 are the good general combiners for seed yield and several other yield components and thus can be directly exploited in heterosis breeding.

The sca effect of fifteen crosses is presented in Table 3. BGD JP-87 × RG-1740/A was the best cross among all crosses for seed yield per plant and for other yield component traits like days to maturity, effective spike length of primary and number of capsules on secondary spike. As it showed highest *sca* effects for seed yield per plant and harvest index, which are important traits in deciding the potential yield of a genotype. The cross

Table 1: Analysis of variance (mean squares) for combining ability for yield and yield components of 14 characters in 23 genotypes of castor

S. No		Degrees of freedom	50% flowering	Days to maturity	No. of nodes up to primary spike	Plant height up to primary spike(cm)	Primary spike			Secondary spike			No. of effective spikes/ plant	100-Seed weight	Final seed yield (g)	Oil content (%)
							Total spike length	Effective spike length	No of capsules/ plant	Total spike length	Effective spike length	No of capsules/ plant				
1	Replication	1	3.13	2.63	6.58	165.30	121.63	1.533	110.82	14.92	3.342	2.92	0.03	5.49	194.54	6.50
2	Treatments	22	12.43**	19.40**	13.08**	1506.32**	73.33*	80.30	769.75**	17.49	15.31	1149.83**	0.41	76.41**	1411.39**	7.00
3	Parents	7	6.42**	32.91**	21.58**	1472.81**	109.83*	133.71*	727.93*	12.73	23.44	976.01**	0.45	102.38	971.65	7.33
4	Parents Vs Crosses	1	1.27	5.67*	12.58*	780.00*	6.09	5.79	1496.97*	3.87	22.42	2288.20**	0.34	193.18**	7552.35**	14.78
5	Crosses	14	16.22**	13.62**	8.87**	1574.95**	59.88	58.92	738.71	20.84	10.75	1155.43**	0.40	55.10**	1192.63*	6.283
6	Lines	2	43.90*	31.60	25.04*	8996.90**	77.76	32.36	1341.17	17.96	5.26	2514.25	0.84	30.77	3051.64	4.741
7	Testers	4	16.13	16.36	9.24	693.42*	27.54	58.50	1135.64	36.04	9.40	1458.20	0.77	78.10	844.09	10.37
8	Line x Testers	8	9.35**	7.76**	4.64	160.24	71.59	65.77	389.63	13.96	12.79	664.33**	0.11	49.68**	902.14	4.62
9	Error	22	0.85	1.17	2.91	164.45	33.34	41.64	267.00	14.23	14.38	170.64	0.28	7.14	514.81	5.19

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

DPC-9 × RG-156 was the best cross for days to maturity while the cross JP-87 × DCS-106 also recorded significant *sca* effects for days to 50 per cent flowering. Similar results of significant *sca* effects for yield contributing characters were also reported by Solanki and Joshi (2000); Kanwal *et al.* (2006) and Bard *et al.* (2009); Chandresh (2009).

In the present investigation, the best five hybrids based on the mean seed yield per plant *viz.*, JP-87 × RG-1740/A (147 g), JP-87 × DCS-106 (134.7g), DPC-17 × RG-156 (118.6g), DPC-17 ×DCS-106 (111.6g) and DPC-17 × DCS-107 (107 g) along with the standard heterosis over DCH-177 were compared for their sca effects and gca effects of corresponding parents (Table 4). Among the best five hybrids, one hybrid JP-87 × RG-1740/A (50.08), was significantly superior to the standard check DCH-177 for seed yield per plant. Other four hybrids JP-87 × DCS-106 (37.52), DPC-17 × RG-156 (20.98), DPC-17 × DCS-

Table 2. Estimation of general and specific combing ability variances and degrees of dominance for 14 characters in castor

S. No	Character	σ^2gca	σ^2sca	σ^2gca / σ^2sca	Degrees of dominance
1	Day to 50% flowering	3.64	4.25	0.85	0.76
2	Day to Maturity	2.85	3.29	0.86	0.76
3	No of nodes up to primary spike	1.87	1.26	1.48	0.57
4	Plant height up to primary spike	585.08	-2.08	582.97	0.04
5	Total spike length of primary	2.41	19.12	0.12	1.99
6	Effective spike length of primary	0.47	12.06	0.03	3.56
7	No. of Capsules / primary spike	121.42	61.31	1.98	0.50
8	Total spike length of secondary	1.59	-0.13	1.46	0.20
9	Effective spike length of secondary	-0.88	-0.79	-1.67	0.67
10	No of Capsules / secondary spike	226.98	246.84	0.91	0.73
11	No of effective spikes / plant	0.06	-0.08	-0.01	0.80
12	Seed yield / plant (g)	179.13	193.66	0.92	0.73
13	100 – Seed weight	5.91	21.26	0.27	1.34
14	Oil Content (%)	0.29	-0.28	-0.27	0.69

Table 3: General combining and specific combining ability effects of different parents and hybrids in Castor

Parents	50% flowering	Days to maturity	No. of nodes up to primary spike	Plant height up to primary spike (cm)	Primary Spike			Secondary Spike			No. of effective spikes/ plant	100 Seed weight (g)	Seed yield / plant (g)	Oil content (%)
					Total spike length	Effective spike length	No. of capsules	Total spike length	Effective spike length	No. of capsules				
Lines														
DCS-106	-2.23**	0.96*	-0.82	-5.80	1.54	3.14	10.69	-0.94	-0.02	18.83**	0.44	0.11	14.60	1.77
DCS-107	1.43**	1.63**	0.80	13.13*	-0.59	2.61	8.72	-2.88	-1.65	-17.46**	-0.09	0.16	2.50	-1.28
RG-156	1.76**	0.63	1.74*	7.96	-2.66	-2.48	-7.57	0.52	-0.65	-12.83*	-0.39	5.11**	3.47	0.92
DCS - 119	-0.23	-0.70	-1.26	-13.80*	-1.02	-3.95	-20.74**	3.78*	1.61	12.13*	0.30	-0.08	-18.03	-0.31
RG-1740 / A	-0.73	-2.53**	-0.46	-1.50	2.74	0.68	8.89	-0.48	0.71	-0.66	-0.26	-5.08**	-2.51	-1.09
SEi±	0.37	0.44	0.59	5.23	0.76	2.63	6.67	1.54	1.54	5.33	0.21	1.09	9.26	0.93
Testers														
DPC-9	-2.30**	-2.00**	-1.52**	-28.89**	-2.90	-2.04	-11.86*	-1.14	-0.53	-18.01**	-0.33	2.00*	-18.91*	-0.54
DPC-17	0.50	0.60*	-0.10	-2.09	-0.25	1.36	0.58	-0.32	-0.29	11.84*	0.12	-0.76	3.39	0.77
JP-87	1.80**	1.40**	1.63**	30.98**	2.65	0.68	11.28*	1.47	0.82	6.16	0.20	-1.24	15.52*	0.22
SEi ±	0.29	0.34	0.46	4.05	1.82	2.04	5.16	1.19	1.19	4.13	0.16	0.84	7.17	0.72
Crosses														
DPC - 9 x DCS-106	0.63	-0.66	-0.67	4.56	4.84	1.57	4.42	4.24	3.90	24.34*	0.10	2.77	2.96	-0.07
DPC - 9 x DCS-107	-2.03**	0.66	-1.40	-1.97	6.87	6.70	7.19	0.28	-0.36	3.94	0.23	-0.15	14.86	-0.07
DPC - 9 x RG-156	0.63	2.16*	2.76*	-5.00	-1.06	-1.49	4.89	0.38	0.73	3.81	0.03	4.19*	3.33	-1.32
DPC - 9 x DCS-119	0.63	-1.00	0.16	13.16	-1.69	0.17	5.46	-3.08	-1.83	-19.15	0.03	0.54	14.30	2.41
DPC - 9 x RG 1740/A	0.13	-1.16	-0.84	-10.74	-8.96*	-6.96	-21.97	-1.82	-2.43	-12.95	-0.40	-7.35**	-35.46*	-0.95
DPC -17 x DCS-106	1.33	0.26	0.10	1.56	-1.82	-0.02	-11.11	-2.37	-2.14	-15.31	-0.16	-0.35	-7.24	-1.04
DPC -17 x DCS- 107	2.16**	0.06	0.17	-1.37	-0.18	0.10	-2.34	-1.54	-1.30	10.28	-0.12	1.96	0.85	0.11
DPC -17 x RG-156	-3.16**	0.56	-0.56	-2.90	1.88	2.70	1.65	-1.16	1.49	-0.94	-0.02	-6.83**	11.37	0.06
DPC 17 x DCS-119	0.83	1.40	0.84	-2.44	-1.15	0.17	9.52	2.29	1.52	15.68	0.17	-1.68	-6.76	-0.60
DPC 17 x RG-1740/A	-1.16	-1.76*	0.44	5.16	1.28	-2.96	2.28	0.46	0.42	-9.71	0.14	6.91**	1.77	1.47
JP -87 x DCS-106	1.96**	0.93	0.56	-6.12	-3.02	-1.54	6.68	-1.87	-1.76	-9.03	0.06	-2.42	4..27	1.11
JP -87 x DCS-107	-0.13	-0.73	1.23	3.34	-6.68	-6.81	-4.84	1.26	1.67	-14.23	-0.10	-1.80	-15.72	-0.04
JP -87 x RG-156	2.53**	-2.73**	-1.20	7.91	-0.82	-1.21	-6.54	-1.54	-2.22	-2.86	-0.00	2.64	-14.70	1.26
JP -87 x DCS-119	-1.46*	-0.40	-1.00	-10.72	2.84	-0.34	-14.98	0.79	0.30	3.46	-0.20	1.14	-7.54	-1.80
JP -87 x RG-1740/A	1.03	2.93**	0.40	5.58	7.68	9.92*	19.68	1.36	2.00	22.66*	0.26	0.44	33.69	0.52
SEij	0.65	0.76	1.03	9.06	4.08	4.56	11.5	2.66	2.68	9.23	0.37	1.88	16.04	1.61

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

Table 4. Estimates of mean seed yield, standard heterosis and sca effects for 5 best hybrids

S. No	Hybrid	Mean seed yield	StandardheterosisDCH-177	sca effect	Female	Male
1	JP-87 x RG-1740 / A	147.0	50.08*	33.69	15.52 (H)	-2.51(A)
2	JP-87 x DCS-106	134.7	37.52	4.27	15.52(H)	14.6(H)
3	DPC-17 x RG-156	118.6	20.98	11.37	3.39(A)	3.47(A)
4	DPC-17 x DCS-106	111.6	13.37	-7.24	3.39(A)	14.60*(H)
5	DPC-17 x DCS-107	107.0	9.29	0.85	3.39(A)	2.50(A)

* Significant at 5 % level ** Significant at 1 % level, Where, H = High gca (Significant positive gca effect), A = Average gca (Non significant positive gca effect)

106 (13.37) and DPC-17 × DCS-107(9.3%) were on par with the check. None of the hybrids had significant *sca* effects. Thus the selection of the hybrids should not be based on sca effects alone. The *per se* performance and sca effects of the best five hybrids over different environments will further strengthen the present results.

The present study also indicated the best performing hybrids with high mean seed yield and positive significant sca effects for seed yield generated from either high x average (JP-87 × RG-1740/A), high x high (JP-87 × DCS-106), average x average (DPC-17 × RG-156; DPC-19 × DCS-107); average × high (DPC-17 × DCS-106) combiners for seed yield. The involvement of at least one good general combiner was also reported by several researchers by Golakia *et al.,* 2008; Lavanya and Chandra Mohan (2003); Lavanya *et al.* (2006); Bard *et al.,* (2009) and Mehta (2000). The crosses with significant standard heterosis involving high x low or low x high general combiners indicate dominance type of gene action. The crosses with high *sca* from average x average combiners indicate the role of epistatic gene action for seed yield.

Majority of the hybrids with high sca effects involved the hybrids having high × high or high × low general combiner for all the characters indicating the significance of both additive and non-additive gene action in governing the traits. It is in conformity with the results of Tank *et al.* (2003); Kanwal *et al.* (2006); Chandramohan *et al.* (2006); Patel *et al.* (2007) and Patel *et al.,* (2012).

The present study indicated that the hybrid., JP-87 x RG-1740/A, with high mean seed yield per plant and standard heterosis over DCH-177 as the significant outcome of the study on heterosis and combining ability other four hybrids JP-87 × DCS-106 (37.52) DPC-17 × RG-156 (20.98), DPC-17 × DCS-106 (13.37) and DPC-17 × DCS-107 (9.29) with high mean seed yield were also promising. The results need to be further strengthened for the genotype x environment (G × E) interaction of these best five hybrids over different seasons and or locations.

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