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Genetic Analysis for Seed Yield and Its Components in Castor (*Ricinus communis* L.)

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ABSTRACT

Combining ability analysis for ten characters was studied using line x tester mating design involving four diverse pistillate lines and ten inbred lines in castor. Combining ability analysis revealed that *gca* variances were significant for days to 50 per cent flowering, days to 50 per cent maturity, plant height, number of nodes up to primary spike, length of primary spike, number of effective branches per plant, 100 seed weight, seed yield per plant and oil content, whereas *sca* variances were highly significant for all the characters except days to 50 per cent maturity. However, the ratio of s^2*gca*/s^2*sca* reveals the preponderance of additive gene action for days to 50 per cent flowering, days to 50 per cent maturity, plant height, number of nodes up to primary spike and oil content, while remaining characters showed predominance of non-additive gene action. VP 1 among the females was observed as a good general combiner for majority of traits, while among males JI 381 was observed as the best general combiner for seed yield per plant and its related yield components. Parents *viz.*, *Geeta*, SKP 84, DCS 84, DCS 85and JI 381 were also observed as good general combiners for seed yield per plant and one or more of its related yield contributing traits. JP 65 and JI 387 were observed as the promising parents for imparting earliness and dwarfness. Based on the estimates of *sca* effects and *per se* performance hybrids *viz.*, JP 65 x JI 381, VP 1 x DCS 97 and *Geeta* x DCS 85 were found as the most promising cross combinations for exploiting the seed yield per plant.

Key words *Castor, combining ability, gca, sca*

Castor (*Ricinus communis* L.) is a non-edible oilseed crop belongs to family *Euphorbiaceae*, which had occupied a prime place in the country. Being a highly cross pollination in nature and due to availability of pistillate lines, the crop is ideal for exploiting heterosis. Nowadays, with the advancement of biometrical genetics several techniques are available which permits quantitative genetic analysis and help in selection of promising parents and cross combinations for further exploitation. Those parents who produce the good progenies on crossing are of immense value to the plant breeder. Combining ability analysis is a powerful tool to discriminate good as well as poor combiners and also helpful in choosing appropriate parental materials for hybridization programme. At the same time they are also provides the information about the nature of gene effects involved in the inheritance of a character. Combining ability analysis using line x tester mating design was carried out in the present study to obtain information on selection of better parents and cross combinations for their further use in a hybridization programme.

MATERIALS AND METHODS

Four pistillate lines *viz.,* VP 1, *Geeta*, JP 65 and SKP 84 were crossed with ten male parents *viz.,* DCS 9, DCS 78, DCS 84, DCS 85, DCS 97, JI 381, JI 384, JI 387, TMV 5 and TMV 6 in a line x tester mating design to obtain fourty hybrids during *Rabi* 2009-10. The fourty crosses, fourteen parents along with a standard check (GCH 7) were grown in a randomized block design with three replications during *Rabi* 2010-11 at College Farm, N. M. College of Agriculture, Navsari Agricultural University, Navsari. Each entry was planted in a single row of 10 dibbles with a spacing of 120 x 60 cm^2. All the recommended package of practices was followed for successfully raising the healthy crop. Observations were recorded on five randomly selected plants per plot for six characters *viz.,* number of nodes up to primary spike, plant height, length of primary spike, number of capsules on primary spike, number of effective branches per plant and seed yield per plant. However, for days to 50 per cent flowering, days to 50 per cent maturity, 100-seed weight and oil content observations were recorded on plot basis. The data were analyzed as per the method suggested by Kempthorne, 1957.

RESULTS AND DISCUSSION

Analysis of variance for combining ability (Table 1) revealed that general combining ability (*gca*) variances were significant for all the characters except number of capsules on primary spike indicating the role of additive gene actions in the inheritance of these characters. While, the variances due to specific combining ability (*sca*) were highly significant for all the characters except days to 50 per cent maturity indicating the role of non-additive gene action for the expression of those characters. Both s^2*gca* and s^2*sca* were found significant for all the characters except number of capsules on primary spike and days to 50 per cent maturity emphasizing the importance of additive as well as non additive gene actions. These results are akin to the reports of Gondaliya, *et al.*, 2001, Tank, *et al.*, 2003 and Solanki,

Table 1. Analysis of variance and variance estimates for combining ability for seed yield and its components

Source	df	Days to 50 % flowering	Days to 50% maturity	Plant height	No. Of nodes up to primary spike	Length of primary spike	Number of capsule on primary spike	No. of effective branches per plant	100 seed weight	Seed yield per plant	Oil content
Replication	2	5.27	1.23	34.58	0.02	9.81	23.50	0.06	0.20	5.83	0.02
Hybrids	39	45.21**	60.39**	279.07**	3.66**	130.87**	955.57**	9.28**	27.01**	2297.90**	6.34**
Females (F)	3	347.22**	434.46**	1900.45**	25.26**	232.78*	310.41	9.42	66.12**	5373.24	39.96**
Males (M)	9	37.32*	75.54**	177.07	2.37	305.54**	305.81	12.06	59.34**	2247.17	7.27**
F x M	27	14.29**	13.77	132.92**	1.69**	61.32**	1243.85**	8.34**	11.89**	1973.11**	2.29**
Error	78	2.75	14.95	13.11	0.26	6.51	27.90	0.22	0.85	245.12	0.47
σ^2f		11.50**	14.08**	62.97**	0.83**	7.56*	9.54	0.31	2.17**	172.14	1.32**
σ^2m		2.91*	5.30**	13.81	0.18	24.97**	23.46	0.99	4.86**	169.86	0.57**
σ^2 gca		9.04**	11.57**	48.92**	0.65**	12.54**	13.52	0.50*	2.94**	171.49**	1.10**
σ^2sca		3.98**	0.59	40.51**	0.47**	18.48**	406.52**	2.71**	3.63**	588.07**	0.63**
σ^2 gca/σ^2sca		2.27	19.61	1.21	1.38	0.68	0.033	0.18	0.81	0.29	1.75

*, ** significant at 5% and 1 % levels of probability, respectively.

et al., 2004. The estimates of component of variances and the ratio of s^2*gca*/s^2*sca* indicated predominant role of additive gene action in the expression of days to 50 per cent flowering, days to 50 per cent maturity, plant height, number of nodes up to primary spike, and oil content. Similar results were also reported by Mehta, *et al.,* 1991 and Dobaria, 1992. Whereas, non-additive gene action were predominant for length of primary spike, number of capsules on primary spike, number of effective branches per plant, 100-seed weight and seed yield per plant. These results are in conformity with the reports of Ramu, *et al.,* 2002, Lavanya and Chandramohan, 2003 and Barad, *et al.,* 2009.

Based on estimates of general combining ability effects for various characters (Table 2), it was observed that none of the parents was found to be good general combiner for all the traits. However, an overall appraisal of general combining ability effects revealed that VP 1 among females was found to be a good general combiner for majority of the traits *viz.,* days to 50 per cent flowering (-2.63), days to 50 per cent maturity (-1.58), number of nodes up to primary spike (-0.69), length of primary spike (1.81), number of effective branches per plant (0.23) and oil content (1.00). Female JP 65 was found to be good general combiner for days to 50 per cent flowering (-3.10), days to 50 per cent maturity (-4.62), plant height (-8.79), number of nodes up to primary spike (-0.87) and 100 seed weight (0.67), which suggested that JP 65 could be used for improving earliness. Females SKP 84 and *Geeta* showed good general combining ability effects for seed yield per plant (5.33 and 14.83) and some of the yield contributing traits. Among males, good general combining ability effect was displayed by the parent JI 381 for seed yield per plant (23.01) and its component characters like length of primary spike, number of capsule on primary spike, number of effective branches per plant, 100 seed weight, plant height and number of nodes up to primary spike. Male parental lines, DCS 84 and DCS 85 also showed good general combining ability effects for seed yield (11.92 and 9.44) and some of its component characters. Male parent JI 387 was identified as good general combiner for days to 50 per cent flowering (-2.57), days to 50 per cent maturity (-3.55), plant height (-2.99) and number of nodes up to primary spike (-0.68).

The estimates of *sca* effects (Table 3) revealed that none of the hybrid was found consistently superior for all the traits. Out of fourty hybrids, nine cross combinations exhibited significant and positive *sca* effects for seed yield per plant. The top three hybrids on the basis of significant positive *sca* effects and *per se* performance of seed yield per plant were JP 65 x JI 381 (55.90), VP 1 x DCS 97 (34.05) and *Geeta* x DCS 85 (33.22). These hybrids had also depicted significant positive *sca* effects for one or more of the yield attributing traits *viz.,* length of primary spike, number of capsules on primary spike, number of effective branches per plant and 100 seed weight. The estimates of *sca* effects revealed that none of the crosses was superior for all the characters. The highest significant *sca* effects in desired direction for various characters was exhibited by different hybrids *viz*., VP 1 x TMV 6 (-4.20), SKP 84 x JI 384 (-3.55) and JP 65 x DCS 78 (-2.40) for days to 50 per cent flowering; VP 1 x TMV 6 (-12.87), *Geeta* x DCS 97 (-10.04) and *Geeta* x JI 384 (-9.92) for plant height; *Geeta* x JI 384 (-1.15), *Geeta* x DCS 97 (-1.09) and SKP 84 x JI 387 (-0.88) for number of nodes up to primary spike; SKP 84 x TMV 6 (5.92), VP 1 x TMV 5 (4.56) and VP 1 x DCS 78 (4.50) for length of primary spike; *Geeta* x JI 387 (42.34), SKP 84 x TMV 6 (32.00), and SKP 84 x DCS 97 (28.01) for number of capsules on primary spike; JP 65 x

JI 381 (3.80), *Geeta* x DCS 78 (2.75) and VP 1 x JI 387 (2.56) for number of effective branches per plant; *Geeta* x DCS 85 (2.94), JP 65 x TMV 6 (2.79) and *Geeta* x DCS 78 (2.37) for 100 seed weight and *Geeta* x TMV 5 (1.43), JP 65 x JI 381 (1.36) and VP 1 x JI 384 (1.22) for oil content.

It was also observed that the *per se* performance of different characters in general agreed with the *gca* effects. However, this cannot be taken as a rule because parents or genotypes with high *per se* performance need not always be good general combiners e.g. *Geeta*, DCS 84 and DCS 85 were good general combiner for seed yield per plant but these parents found poor on the basis of per *per se* performance. This could be attributed due to the intra and/or inter-allelic interaction of genes concerned with the character modified by environmental factors (Dabholkar, 1999). It was further observed (Table 2) that parents possessing good general combining ability for seed yield also possessed high general combining ability for one or more of its yield components. It appeared that *per se* performance as such may give an indication of the general combining ability of the parents involved in crosses. This suggested that while selecting the parents for hybridization programme *per se* performance of the parents should be given due consideration. Such parallel behaviour of *per se* performance and general combining ability was also reported by Dangaria, *et al.,* 1987, Pathak, *et al.,* 1989, Lavanya and Chandramohan, 2003, Tank, *et al*., 2003; Parmar, 2006; and Barad, *et al.,* 2009. The best three hybrids for seed yield per plant *viz.,* JP 65 x JI 381 (poor x good), VP 1 x DCS 97 (poor x poor), *Geeta* x DCS 85 (good x good) and *Geeta* x JI 384 (good x average) had significant positive *sca* effects. High yielding hybrids also possessed high *sca* effects, high heterosis as well as high *per se* performance for most of its yield contributing characters. This appeared appropriate as yield being a complex character depends on a number of its component traits.

The perusal of data (Table 2 and 3) revealed that good general combining parents may not necessarily always produce good specific combinations for different traits. In many cases, it was observed that at least one good general combining parents was involved in heterotic hybrid having desirable *sca* effects but it was also observed that poor x poor crosses may also results into high *sca* effects. Similar results in castor were also reported by Tank, *et al*., 2003 and Kanwal, *et al.,* 2006. This suggested that information of *gca* effects of parents should be considered along with *sca* effects and *per se* performance of hybrid for predicting the value of any hybrid. It is desirable to search out parental lines with high *gca* effects and low sensitivity to environmental variation in a crop improvement programme. In a view of *per se* performance of parents and their *gca* effects for seed yield per plant and other characters studied, SKP 84 and *Geeta* among females and JI 381, JI 384, DCS

Table 2. Estimates of general combining ability (gca) effects of parents for yield and its components

Parents	Days to 50 % flowering	Days to 50% maturity	Plant height	No. of nodes up to primary spike	Length of primary spike	Number of capsule on primary spike	No. of effective branches per plant	100 seed weight	Seed yield per plant	Oil content
Females										
VP 1	-2.63**	-1.58*	4.25**	-0.69**	1.81**	0.44	0.23**	-0.01	-3.54	1.00**
Geeta	1.93**	2.65**	8.77**	0.98**	-2.60**	3.84**	0.37**	-2.06**	14.83**	0.86**
JP 65	-3.10**	-4.62**	-8.79**	-0.87**	-2.15**	-4.00**	-0.84**	0.67**	-16.62**	-1.45**
SKP 84	3.80**	3.55**	-4.23**	0.58**	2.90**	-0.28	0.24**	1.39**	5.33*	-0.41**
S.Ed	0.28	0.63	0.62	0.09	0.44	0.90	0.08	0.18	2.64	0.12
CD at 5%	0.56	1.26	0.97	0.19	0.88	1.79	0.16	0.36	5.25	0.23
Males										
DCS 9	-0.23	-4.47**	-2.23*	-0.11	-5.79**	-6.15**	-1.11**	-0.05	-22.25**	-0.32
DCS 78	2.43**	1.70	1.18	0.61**	0.91	4.01**	0.22	-0.49	-4.78	0.50**
DCS 84	2.68**	2.53*	-1.41	0.43*	0.63	3.20*	0.91**	-0.01	11.92**	1.22**
DCS 85	0.85	-0.05	-3.50**	-0.14	-6.10**	-3.50**	0.80**	-0.33	9.44*	0.40*
DCS 97	-0.48	1.45	-1.51	-0.40**	-0.03	7.51**	-1.54**	-4.74**	-12.32*	0.61**
JI 381	-0.32	3.20**	-1.98*	-0.39*	5.37**	3.93**	1.34**	2.28**	23.01**	-1.67**
JI 384	-0.65	0.87	3.03**	0.23	-0.67	3.27*	0.77**	2.81**	8.12	-0.45*
JI 387	-2.57**	-3.55**	-2.99**	-0.68**	-1.84*	-7.25**	-0.09	0.78**	-6.13	-0.16
TMV 5	-2.48**	-1.22	0.02	-0.39*	-3.18**	-4.12**	-1.24**	-2.12**	-11.48**	-0.22
TMV 6	0.77	-0.47	9.38**	0.59**	10.70**	-0.91	-0.07	1.87**	4.48	0.09
S.E. (gi)	0.44	1.00	0.97	0.15	0.70	1.42	0.13	0.29	4.17	0.19
CD at 5 %	0.88	1.99	1.94	0.30	1.39	2.83	0.25	0.57	8.31	0.37

*,** significant at 5 % and 1 % levels of probability, respectively.

Table 3. Estimates of specific combining ability (sca) effects of hybrids for yield and its components

Hybrids	Days to 50 % flowering	Days to 50% maturity	Plant height	No. of nodes upto primary spike	Length of primary spike	No. of capsule on primary spike	No. of effective branches per plant	100 seed weight	Seed yield per plant	Oil content
VP 1 x DCS 9	2.47**	3.00	-1.27	-0.51	1.47	0.57	0.09	2.12**	-11.90	-0.30
VP 1 x DCS 78	0.13	2.83	2.26	-0.57	4.50**	15.76**	052*	0.63	8.17	0.45
VP 1 x DCS 84	0.55	0.67	2.36	-0.18	3.94**	6.86*	-1.54**	0.51	14.40	-0.29
VP 1 x DCS 85	1.72	1.25	-0.94	-0.37	-1.23	-17.62**	0.35	-0.01	-8.57	-0.18
VP 1 x DCS 97	0.05	1.42	1.82	0.96**	1.58	25.49**	1.25**	-0.29	34.05**	-0.76*
VP 1 x JI 381	-0.12	-2.33	-2.98	-0.24	-2.56	-4.55	-1.16**	0.29	-24.11**	-1.43**
VP 1 x JI 384	1.22	-1.00	8.90**	0.64*	-4.85**	2.53	-1.43**	-0.10	-16.44	1.22**
VP 1 x JI 387	0.13	-0.92	2.50	0.49	-1.48	-9.47**	2.56**	0.99	25.20**	0.68
VP 1 x TMV 5	-1.95*	-1.25	0.22	0.03	4.56**	-0.52	-0.85**	-0.71	-17.56*	0.20
VP 1 x TMV 6	-4.20**	-3.67	-12.87**	-0.25	-5.92**	-19.05**	0.21	-3.43**	-3.24	0.41
Geeta x DCS 9	-0.77	-1.57	1.42	0.33	-7.02**	-15.49**	0.35	-3.54**	1.02	-0.56
Geeta x DCS 78	-0.43	-0.40	5.63**	0.82**	3.90**	-8.67**	2.75**	2.37**	12.41	-1.22**
Geeta x DCS 84	-2.35**	0.10	0.16	-0.75*	1.20	18.13**	-0.64*	0.76	-2.53	1.06**
Geeta x DCS 85	-1.85*	-0.31	3.97*	0.85**	2.88*	26.18**	1.24**	2.94**	33.22**	0.20
Geeta x DCS 97	2.82**	0.18	-10.04**	-1.09**	-6.42**	-32.05**	-1.29**	1.79**	-7.24	0.34
Geeta x JI 381	-0.35	0.10	-5.24**	-0.84**	2.24	-2.51	-1.87**	-1.57**	-22.95**	-0.08
Geeta x JI 384	2.32*	0.10	-9.92**	-1.15**	1.82	2.35	1.43**	-1.53**	29.94**	-0.41
Geeta x JI 387	-0.77	1.52	0.56	0.79**	1.38	42.34**	-0.58*	1.13	15.96	-0.35
Geeta x TMV 5	-1.52	-0.15	-4.37*	0.22	-2.14	-19.76**	-1.39**	-0.90	-28.59**	1.43**
Geeta x TMV 6	2.90**	0.43	17.83**	0.81**	2.15	-10.51**	0.01	-1.45*	-31.27**	-0.41
JP 65 x DCS 9	-0.40	-0.97	5.10*	0.91**	3.76**	19.58**	1.02**	0.54	22.38**	0.11
JP 65 x DCS 78	-2.40**	-3.80	-5.44**	-0.47	2.59	6.46*	-1.25**	-1.56*	1.90	0.93*
JP 65 x DCS 84	-0.65	-2.63	-5.25**	0.06	-6.53**	-15.26**	0.53*	-0.64	-15.90	-0.91*
JP 65 x DCS 85	-0.82	-1.71	2.31	-0.53	-0.47	-1.39	-2.16**	-2.52**	-30.19**	-1.03**
JP 65 x DCS 97	-0.48	0.45	1.65	-0.25	1.07	-21.44**	0.51*	0.69	-21.06*	0.19
JP 65 x JI 381	0.35	4.03*	5.05*	0.74*	3.77**	22.15**	3.80**	2.09**	55.90**	1.36**
JP 65 x JI 384	0.02	-0.30	-2.89	-0.35	-0.03	1.17	-0.13	1.17*	-21.08*	-0.09
JP 65 x JI 387	1.93*	0.12	-3.37	-0.40	-1.02	-16.77**	-1.44**	-3.10**	-15.88	0.22
JP 65 x TMV 5	3.18**	3.12	4.12*	0.40	-0.99	7.93**	0.28	0.55	21.15*	-0.22
JP 65 x TMV 6	-0.73	1.70	-1.30	-0.12	-2.15	-2.44	-1.16**	2.79**	2.77	-0.58
SKP 84 x DCS 9	-1.30	-0.47	-5.25**	-0.74*	1.80	-4.66	-1.46**	0.88	-11.50	0.74
SKP 84 x DCS 78	2.70**	1.37	-2.46	0.22	-10.99**	-13.55**	-2.02**	-1.44*	-22.48**	-0.16
SKP 84 x DCS 84	2.45**	1.87	2.73	0.88**	1.39	-9.73**	1.65**	-0.63	4.03	0.13
SKP 84 x DCS 85	0.95	0.78	-5.34**	0.04	-1.19	-7.17*	0.57*	-0.41	5.55	1.01**
SKP 84 x DCS 97	-2.38**	-2.05	6.57**	0.37	3.78**	28.01**	-0.46	-2.19**	-5.76	0.23
SKP 84 x JI 381	0.12	-1.80	3.17	0.34	-3.46*	-15.10**	-0.77**	-0.81	-8.84	0.15
SKP 84 x JI 384	-3.55**	1.20	3.91*	0.86**	3.07*	-6.04*	0.13	0.46	7.57	-0.71
SKP 84 x JI 387	-1.30	-0.72	0.31	-0.88**	1.12	-16.10**	-0.55*	0.98	-25.29**	-0.55
SKP 84 x TMV 5	0.28	-1.72	0.031	-0.65*	-1.43	12.35**	1.97**	1.06	25.00**	-1.41**
SKP 84 x TMV 6	2.03*	1.53	-3.66	-0.44	5.92**	32.00**	0.94**	2.10**	31.72**	0.58
S. E (Sij).	0.89	2.00	1.95	0.30	1.40	2.85	0.26	0.57	8.34	0.37
CD at 5 %	1.76	3.98	3.88	0.59	2.79	5.67	0.51	1.14	16.61	0.74

*, ** significant at 5 % and 1 % levels of probability, respectively.

84 and DCS 85 among males were identified as the most promising parents and hence they could be used extensively in breeding programme for improving seed yield in castor. Parents JP 65 and JI 387 were good general combiner for days to 50 per cent flowering, days to 50 per cent maturity and number of nodes up to primary spike and hence could be involved in the initial stages of crossing to impart earliness. A combination of poor combiners also gives several crosses with high and significant *sca* effects across the traits, such crosses could be expected to through up some transgressive segregants in recurrent selection. A progeny selection with pedigree method in such crosses

may through up transgressive segregants leading to development of good inbreds.

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