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Study of combining ability and gene action for seed yield and its component traits in castor (*Ricinus communis* L.)

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Abstract

The experimental material includes four lines, ten testers of castor, their forty hybrids developed by line × tester design and standard check (GCH- 9) were evaluated by the use of RBD with three replications. Mean sum of squares of both general and specific combining ability were significant for all traits when analysis of variance for combining ability tested, which signified presence of additive gene action and non-additive gene action were pivotal in the inheritance of these traits. The variance ratio lesser than unity of both general and specific combining ability were exhibited that the non-additive gene action was primary for the expression of most of the traits studied but variance ratio greater than unity of both general and specific combining ability were exhibited that the additive gene action for length of primary raceme(cm), plant height up to primary raceme and effective length of primary raceme (cm), Parents; IPC 30, JI 518, JI 531 and 532, were found good general combiner for seed yield per plant that is revealed by gca effects. The estimates of sca effects of crosses signified that crosses IPC 30 × JI 533, IPC 31 × JI 532 and SKP 126 × JI 532 displayed maximum significant and sca effects are positive for seed yield per plant.

Keywords: Castor, *Ricinus communis*, combining ability, gene action, seed yield

Introduction

In Indian economy, oilseeds crop account for about 10% of the total value of the country's agricultural commodities, among the non-edible oilseeds, castor is a substantial industrial crop cultivated in dry and semi-arid zone globally. Castor (*Euphorbiaceae* family; Chromosome No. 2n=20) is a basically cross-pollinated species, with outcrossing rates generally ranging from 5-50%, although some dwarf cultivars can show 90-100% outcrossing. The manifestation of male-sterile lines has confirmed precious for breeding improved varieties (Anonymous, 2016) ^[1]. The Line × Tester factorial mating design is especially well-suited for castor, among all the different mating designs. Kempthorne (1957) ^[2], suggested that Line × Tester analysis for polygenic inheritance, as it allows the evaluation of total genetic variance by splitting it into additive and non-additive components. Additionally, this method is also useful for effective screening of large no. of parents and crosses to assess combining ability effects. Combining ability studies play a key role in selecting high-performing parental lines that, when crossed, produce desirable hybrids. These studies also help to determine the nature and magnitude of the gene action controlling seed yield and their components, thereby conforming future breeding programs.

Materials and Methods

For experimental research study materials are required four female lines viz., IPC 30, IPC 31, SKP 84, SKP 126; ten male testers of castor viz., JI -518, 522, 523, 524, 525, 526, 528, 531, 532 and 533 and their forty F₁s crosses that is developed by Line X Tester design and one standard check (GCH 9). The experimental substance of recommended study was comprising of 55 entries which include 40 crosses developed through 4 Lines X 10 Testers mating design together with 14 parental lines and standard check GCH 9 were sown in RBD with triple replications at Sagdividi Farm, Department of Seed Science and Technology, COA, JAU, Junagadh. Observations were reported on twelve characters viz., plant height up to primary raceme, days to maturity, days to 50% flowering, primary raceme length, no. of nodes/plant raceme, effective

length of the primary raceme, number of effective branches/plants, number of capsules per primary raceme, 100-seed weight (seed index), shelling out turn, seed yield/plant and oil content. Data was prepared from five randomly selected plants for each genotype within every replication.

Results and Discussion

Mean sum of squares of both general and specific combining ability were significant for all traits (except days to maturity), when analysis of variance for these combining ability tested, against to error mean square. This indicated significance contribution of both male testers and female lines regarding total variation.

General and specific combining ability variance were significant for all the traits and revealed by statistical analysis of variance for combining ability, which represent that non-additive gene action and additive gene action were essential for the inheritance of all traits and most of the traits are governed by non-additive gene action. The Ratio of $\sigma^2_{gca}/\sigma^2_{sca}$ was less than unity for these traits confirmed the non-additive gene action superiority for most of the traits that is strongly support above results (Table 1). The parents were characterized for their ability to transfer desirable target genes to their own progenies. For all the characters not found any parents to be good in the research. For seed yield per plant better general combining effect was reported in one female parents IPC 30 and in three male parents JI 518, JI 531 and JI 532 shown in Table 2.

Among all the female lines, IPC 30 was found outstanding performance for general combiner for no. of nodes up to primary raceme, effective length and length of primary raceme (cm), 100 seed weight and yield/plant, no. of effective branches/plant and oil content; SKP 84 was found better general combiner for days to maturity of primary raceme, shelling out turn, days to 50 percent flowering of primary raceme, plant height up to primary raceme and 100 seed weight in grams. Among male testers JI 518 was found outstanding performance for general combiner for days to maturity of primary raceme, length and effective length of primary raceme (cm), 100 seed weight, no. of effective branches/plant, no. of capsules on primary raceme, seed yield/plant and oil content; JI 524 was found good general combiner for days to 50% flowering of primary raceme, number of nodes up to primary raceme, shelling out turn, length and

effective length of primary raceme (cm) and 100-seed weight (Table 2). These results were also recorded by Patel *et al.* (2017)^[3]; Mohanty *et al.* (2021)^[4]; Nivedha *et al.* (2023)^[5]; Sadaiah *et al.* (2023)^[6] and Pandor *et al.* (2025)^[7].

Here are the determines of the specific combining ability (sca) effects of hybrids on yield and attributing traits. The best five crosses for seed yield/plant based on the highest desirable positive specific combining ability effects and significant in IPC 30 × JI 533 (88.53) followed by IPC 31 × JI 532 (85.89), SKP 126 × JI 532 (55.16), SKP 84 × JI 518 (45.52) and IPC 30 × JI 523 (40.87). These hybrids also exhibited significant specific combining ability effects in the desirable directions for no. of effective branches/plant, 100 seed weight in gm, shelling out turn and oil content. These results were also found by Patel and Patil, (2013)^[8]; Golakia *et al.* (2015)^[9]; Patel *et al.* (2017)^[7]; Panera *et al.* (2018)^[10]; Yamunara *et al.* (2020)^[11]; Peng *et al.* (2024)^[12]; Nivedha *et al.* (2023)^[5] and Sharma *et al.* (2024)^[14].

Out of highest five yielding cross combinations, two cross combinations (SKP 126 × JI 531) and (SKP 84 × JI 518) also displayed the outstanding and desirable specific combining ability effect for seed yield/plant, which included poor X good and average X good respectively. A poor X poor cross was not necessarily a poor combination contribution or good general combiners was the always best crosses combination. However, a relative study of the crosses on the basis of *per se* performance, sca effects revealed that the most of the hybrids which had higher yield had either one parent as good general combiner for seed yield traits is necessarily present. In facts, in most of the cross combinations, the best specific combinations for different traits were either average × average, good × good, good × poor, average × poor and *vice versa* general combiners, and its signified additive × dominance type of gene interaction, which could be generate desirable type of transgressive segregants in further succeeding generations. In concluded that information on general combining ability effects should be expanded by specific combining ability effects and hybrid performance of cross combinations to predict the transgressive type possibly made accessible in segregating generations. Effects of sca and gca in similar direction helps in quick selection of hybrids. High sca effects of hybrids, included at least one parent having high mean value and good gca effect, they could be exploited for practical breeding programs.

Table 1: Analysis of variance for combining ability and variance components for different characters in castor

Source	d.f.	Days to 50% flowering of primary raceme	Days to maturity of primary raceme	Plant height up to primary raceme (cm)	Number of nodes up to primary raceme	Length of primary raceme (cm)	Effective length of primary raceme (cm)
Replications	2	1.40	5.42	2111.13***	9.97**	96.55*	22.73
Lines	3	81.84***	115.83	8534.89****	19.73***	2310.30****	2223.77****
Testers	9	69.99***	92.57	2499.66****	5.08**	456.88****	427.66****
Lines × Testers	39	18.59**	42.49**	430.24**	5.63**	136.00****	144.49***
Error	78	1.33	8.00	63.93	2.00	25.90	30.10
Variance components							
σ^2_l		2.68*	3.59	282.36**	0.59*	76.14**	73.12**
σ^2_t		5.71**	7.04	202.97**	0.25	35.91**	33.12*
σ^2_{gca}		3.54**	4.58**	259.68**	0.49**	64.65**	61.69**
$\sigma^2_{sca}(\sigma^2_{lt})$		5.73**	11.49**	122.10**	1.20**	36.69**	38.12**
$\sigma^2_{gca}/\sigma^2_{sca}$		0.61	0.39	2.12	0.40	1.76	1.61
Per cent contribution							
Lines		17.82	14.92	42.87	23.02	47.10	46.25
Testers		45.73	35.78	37.67	17.79	27.94	26.68
Lines × Testers		36.44	49.28	19.45	59.18	24.95	27.05

*, ** Significant at 5% and 1% against error, respectively

+, ++ Significant at 5% and 1% levels, respectively against line × tester interaction

The estimation of genetic variance contributed by lines (σ^2_l) and testers (σ^2_t)

Conti....

Source	d.f.	Number of effective branches per plant	Number of capsules on primary raceme	Shelling out turn (%)	100-seed Weight (g)	Seed yield per plant (g)	Oil content (%)
Replications	2	2.31*	397.00*	11.83	2.73*	718.05	0.13
Lines	3	2.98**	502.93**	93.99**	162.01***	21475.95***	0.64**
Testers	9	20.37***	1438.19***	47.96**	102.46***	18123.85***	0.80***
Lines × Testers	39	4.25**	307.70**	32.17**	38.92**	6287.55**	0.25**
Error	78	0.51	83.11	10.40	0.82	1123.07	0.08
Variance components							
σ^2_l		0.08	13.99	2.78	5.37*	678.42*	0.02
σ^2_t		1.65**	112.92**	3.12	8.47*	1416.73*	0.06**
σ^2_{gca}		0.53**	42.25**	2.88**	6.25**	889.37**	0.03**
$\sigma^2_{sca}(\sigma^2_{lt})$		1.24**	74.86**	7.25**	12.70**	1721.49**	0.05**
$\sigma^2_{gca}/\sigma^2_{sca}$		0.42	0.56	0.39	0.49	0.51	0.54
Per cent contribution							
Lines		2.91	6.62	17.82	19.76	16.21	12.14
Testers		59.66	56.86	27.27	37.49	41.05	45.34
Lines × Testers		37.41	36.50	54.90	42.73	42.72	42.50

*, ** Significant at 5% and 1% against error, respectively

+, ++ Significant at 5% and 1% levels, respectively against line × tester interaction

The estimation of genetic variance contributed by lines (σ^2_l) and testers (σ^2_t)**Table 2:** General combining ability effects for different characters in castor

Sr. No.	Parents	Days to 50% flowering of primary raceme	Days to maturity of primary raceme	Plant height up to primary raceme(cm)	Number of nodes up to primary raceme	Length of primary raceme (cm)	Effective length of primary raceme (cm)
Lines							
1	IPC 30	2.26**	2.75**	19.22**	-0.77**	5.57**	6.81**
2	IPC 31	-0.76**	-0.42	-12.14**	-0.56*	-12.48**	-12.12**
3	SKP 84	-1.56**	-1.92**	-16.02**	0.38	0.26	-0.07
4	SKP126	0.07	-0.42	8.93**	0.95**	6.64**	5.37**
	SE (g _i)	0.21	0.51	1.45	0.25	0.92	1.99
	CD at 5%	0.43	1.02	2.90	0.51	1.85	2.64
Testers							
1	JI 518	-0.32	-1.85*	8.50**	-0.41	4.84**	5.66**
2	JI 522	-1.82**	-3.02**	12.16**	0.63	-3.42*	-3.93*
3	JI 523	4.35**	4.65**	25.68**	0.80	10.47**	9.57**
4	JI 524	-0.32**	1.48	-0.93	-0.99*	4.84**	4.62**
5	JI 525	-3.15**	-1.26	-8.58**	-0.34	-8.01**	-7.56**
6	JI 526	2.26**	2.90**	-14.68**	-0.69	-8.75**	-9.72**
7	JI 528	-1.15**	-1.93*	0.43	-0.38	0.63	2.70
8	JI 531	2.10**	2.73**	8.71**	0.13	-4.03**	0.04
9	JI 532	-2.90**	-3.43**	-23.97**	0.50	-0.61	-0.89
10	JI 533	0.93**	-0.26	-7.32**	0.75	4.03**	-0.48
	SE(g _i)	0.34	0.81	2.30	0.40	1.46	3.15
	CD at 5%	0.67	1.62	4.59	0.81	2.92	4.18

*, ** Significant at 5% and 1% against error, respectively

Conti....

Sr. No.	Parents	Number of effective branches per plant	Number of capsules on primary raceme	Shelling out turn (%)	100-seed Weight (g)	Seed yield per plant (g)	Oil content (%)
Lines							
1	IPC 30	0.31**	1.08	-0.09	0.74**	32.73**	0.18**
2	IPC 31	-0.25*	-1.64	-2.22**	-3.41**	-29.76**	-0.16**
3	SKP 84	-0.28*	-4.52**	2.09**	1.80**	-11.11*	-0.03
4	SKP126	0.22	5.09**	0.23	0.86**	8.14	0.015
	SE(g _i)	0.13	1.66	0.58	0.16	6.11	0.05
	CD at 5%	0.26	3.31	1.17	0.32	12.18	0.10
Testers							
1	JI 518	2.42**	12.82**	-0.63	1.68**	76.26**	0.19*
2	JI 522	-1.06**	-12.05**	-0.08	-1.001**	18.94	-0.47**
3	JI 523	0.38	4.84	1.58	3.23**	4.03	-0.05
4	JI 524	-0.72**	-5.52*	2.06*	1.32**	-18.86	-0.22**
5	JI 525	-0.58**	-5.45*	-3.59**	3.34**	-38.45**	-0.21*
6	JI 526	-1.79**	-9.17**	-2.03*	-6.35**	-34.34**	-0.05
7	JI 528	-1.16**	-13.47**	-1.59	-0.07	-25.01*	0.29**

8	JI 531	1.42**	19.43**	2.21*	-1.38**	43.12**	0.28**
9	JI 532	0.58**	2.69	-0.01	-2.25**	15.20**	2.66**
10	JI 533	0.58**	5.87*	2.086	1.47**	-40.88**	-0.02
	SE(gi)	0.20	2.63	0.93	0.26	9.67	0.08
	CD at 5%	0.41	5.23	1.85	0.52	19.25	0.16

*, ** Significant at 5% and 1% against error, respectively

Table 3: Top five best specific cross combinations of sca effect for seed yield per plant along with their desirable sca effect of component characters including gca effect of their parents in castor

Crosses	sca effect for fruit yield per plant	Seed yield per plant (g)	gca effect for fruit yield per plant		Heterosis (%) over	
			Lines	Testers	Better parent	Standard check (GCH-9)
IPC 30 × JI 533	88.53**	451.43	32.73**	-40.88**	98.66**	22.62**
IPC 31 × JI 532	85.89**	442.37	-29.76**	15.20**	95.63**	20.16**
SKP 126 × JI 532	55.16**	449.56	8.14	15.20**	98.80**	22.11**
SKP 84 × JI 518	45.52**	367.76	-11.11*	76.26**	86.53**	30.85**
IPC 30 × JI 523	40.87**	448.69	32.73**	4.03	51.72**	21.87**

Conclusion

In our research study the non-additive gene action was dominant for the expression of most of the traits studied but for length of primary raceme (cm), plant height up to primary raceme and effective length of primary raceme (cm), additive gene action was dominant for the expression, by the use of variance ratio of gca and sca. The two hybrids, SKP 126 × JI 531 and SKP 84 × JI 518 displayed for higher *per se* performance along with significant and desirable specific combining ability effects for seed yield/plant and could be used as optimistic crosses for practical plant breeding programs. The female line IPC 30 and three male testers JI 531, JI 518 and JI 532 found as outstanding good general combiners for seed yield/plant and through desirable segregants these parents could be used in breeding program.

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