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Inheritance of quantitative traits in castor (*Ricinus communis* L.)

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Abstract
Five generations (P_1, P_2, F_1, F_2 and F_3) of four crosses of castor were used for estimation of genetic parameter for seed yield and its related eleven traits days to flowering of main raceme, days to maturity of main raceme, plant height up to main raceme (cm), number of nodes up to main raceme, length of main raceme (cm), effective length of main raceme (cm), number of effective branches per plant, number of capsules on main raceme, shelling out turn (%), 100-seed weight (g) and oil content (%). Both additive and dominance gene actions were involved in the inheritance of number of nodes up to main raceme in the cross JP 100 x SKI 215 and number of effective branches per plant in the cross JP 96 x JI 355. Whereas, only dominance gene effect was prevailing in the inheritance of days to flowering of main raceme in the cross JP 100 x JI 362. Additive x additive (i) and dominance x dominance (l) gene actions were important for days to flowering of main raceme in cross JP 96 x JI 355; seed yield per plant in the cross JP 100 x SKI 215; days to maturity of main raceme, plant height up to main raceme, number of nodes up to main raceme, length of main raceme, effective length of main raceme and seed yield per plants in the cross JP 100 x JI 362; number of capsules on main raceme in the cross JP 100 x JI 363 and for shelling out turn in all the four crosses. In view of the importance of both additive and non-additive gene effects a biparental mating and reciprocal recurrent selection may be utilized for genetic improvement of the seed yield and related in castor.

Keywords: Generation mean, gene action, additive, dominance

Introduction
Castor (*Ricinus communis* L.) is an important non-edible oilseed crop of India. Castor has chromosomes 2n=20 and belongs to monospecific genus Ricinus of Euphorbiaceae family. It has cross pollination up to the extent of 50 per cent. Because of its hardiness, castor plays an important role in the economy of arid and semi-arid regions of the country. Castor seed contains 48 to 56 per cent oil of tremendous industrial value and is mainly utilized in the production of soaps, refined and perfumed hair oil, printing inks, varnishes, synthetic resins, carbon paper, lubricant, ointments, other cosmetics and processed leather etc. The refined oil also has a good domestic market. Castor oil is the source of sebacic acid which is used in the manufacture of nylon and vinyl resins (Nagraj, 1996) [6]. A distinct knowledge of the type of gene action, its magnitude and composition of genetic variance are of fundamental importance to a plant breeder, which help in formulating an effective and sound breeding programme. Information on nature and relative magnitude of genetic component of variation (additive and dominance) are being generated through diallel analysis or lines x tester analysis in castor which unlike generation mean analysis does not provide information on non-allelic gene actions operating in the inheritance of the most of the traits. The non-allelic interaction could inflate the measure of additive and dominance components. It is, therefore important to estimate the components of epistasis along with the additive and dominance components. Therefore, a plant breeder should have the deep knowledge and information on types of gene action and mode of inheritance.

Materials and Methods
Five generations *viz*., P_1, P_2, F_1, F_2 and F_3 of four crosses of castor *viz*., JP 96 x JI 355, JP 100 x SKI 215, JP 100 x JI 362 and JP 100 x JI 363 were raised in a Compact Family Block Design with three replications at Main Oilseeds Research Station, Junagadh Agricultural University, Junagadh. Each entry consisted of a single row of 7.2 m length for each P_1, P_2 and F_1 and five rows each of F_2 and F_3 progenies with an inter and intra row spacing of 90 and 60 cm, respectively. Five randomly selected plants each from P_1, P_2 and F_1 and 40 plants each from F_2 and F_3 generations were utilized for recording observations for twelve characters *viz*., The data were first subjected to analysis of variance separately for each cross followed by application of individual scaling test given by Mather (1949) [4] and joint scaling test of Cavalli

(1952) [1] for detection of epistasis. The gene effects were estimated as per five parameter model suggested by Hayman (1958) [3].

Results and Discussion

The analysis of variance among families (crosses) indicated significant differences among all the crosses for all the characters except days to flowering of main raceme, length of main raceme and effective length of main raceme. The estimates of various gene effects are presented in Table1. Perusal of data indicted that individual scaling tests C and D and joint scaling test, the additive-dominance model was found adequate for description of variation in generation means for length of main raceme and number of effective branches per plant in the cross JP 96 x JI 355; days to flowering of main raceme, number of nodes up to main raceme, number of capsules on main raceme and oil content in the cross JP 100 x SKI 215 and days to flowering of main raceme in the cross JP 100 x JI 362. For remaining cases, either both or one individual scaling tests C or D were found significant. The application of joint scaling test also expressed significant chi-square values for these cases confirming the involvement of digenic interaction parameters in the inheritance of all the characters except mentioned for additive-dominance model.

The additive and dominance effects were found significant for number of nodes up to main raceme in the cross JP 100 x SKI 215 and number of effective branches per plant in the cross JP 96 x JI 355 thereby showing the presence of both additive and dominance gene actions. Whereas, dominance effect was prevailing in the inheritance of days to flowering of main raceme in the cross JP 100 x JI 362. The silmilar results supported by Monapara (2010) [5] and Yogitha *et al.* (2009) [8].

Five parameter model revealed that, in addition to the significance of additive and dominance effects, both interaction effects *viz*., additive x additive (i) and dominance x dominance were significant for days to flowering of main raceme in cross JP 96 x JI 355; seed yield per plant in the cross JP 100 x SKI 215; days to maturity of main raceme, plant height up to main raceme, number of nodes up to main raceme, length of main raceme, effective length of main raceme and seed yield per plant in the cross JP 100 x JI 362; number of capsules on main raceme in the cross JP 100 x JI 363 and for shelling out turn in all the four crosses. These findings are accordance with the results obtained by Golakia *et al*. (2004) [2] and Pathak *et al*. (1988) [7].

The characters showing evidence of digenic interaction, had significant dominance effect for days to flowering of main raceme in two crosses *viz.,* JP 96 x JI 355 and JP 100 x JI 363; days to maturity of main raceme in the crosses JP 100 x SKI 215, JP 100 x JI 362 and JP 100 x JI 363; plant height up to main raceme in the crosses JP 100 x JI 362 and JP 100 x JI 363; number of nodes up to main raceme in the crosses JP 96 x JI 355, JP 100 x JI 362 and JP 100 x JI 363; length of main raceme and effective length of main raceme in three crosses *viz.,* JP 96 x JI 355, JP 100 x SKI 215 and JP 100 x JI 363; number of effective branches per plant in the crosses JP 100 x SKI 215 and JP 100 x JI 363; number of capsules on main raceme in the crosses JP 100 x JI 362 and JP 100 x JI 363; shelling out turn in all the four crosses; 100- seed weight in the crosses JP 100 x SKI 215 and JP 100 x JI 362; oil content in the crosses JP 96 x JI 355, JP 100 x JI 362 and JP 100 x JI 363 and seed yield per plant in the crosses JP 96 x JI 355, JP 100 x SKI 215 and JP 100 x JI 362. The results showed predominance of dominance gene action in the genetic control of these characters in the respective crosses. Similar findings were also reported for different by Monapara (2010) [5] and Yogitha *et al.* (2009) [8] Golakia *et al*. (2004) [2].

Duplicate type of epistasis was present for the genetic control of the most of the characters in the crosses studied. Under a situation, it would be difficult for the breeder to get promising segregants better than parents involved through conventional breeding methods such as making simple crosses and their exploitation through straight pedigree method. Breeding procedures involving multiple crosses and biparental crosses may be restored to get transgressive segregants. This is especially important to develop inbred lines having superiority in different characters, which crossing can give better yielding hybrids. While, in case of complementary type of epistasis, material can be utilized directly in breeding programme.

Table 1: Estimates of genetic parameters for seed yield and its attributes in castor

Character	Cross	Scaling test		Genetic parameter					Type of epistasis
		C	D	m	d	h	i	l	
Days to flowering of main raceme	C1	-9.30**±2.88	-7.68**±2.41	57.40**±0.43	-2.26**±0.71	6.50**±1.47	-0.96*± 0.48	-2.15*±1.02	D
	C2	1.96±2.98	1.55±1.58	-	-	-	-	-	-
	C3	2.00±1.51	1.63±1.24	-	-	-	-	-	-
	C4	5.00±3.88	0.23*±0.10	59.08**±0.20	1.53±1.83	3.14**±0.90	3.74±2.12	-6.35*±2.61	D
Days to maturity of main raceme	C1	-34.40**±3.50	-11.60**±4.08	143.75**±0.79	1.09**±0.29	2.63±2.99	4.19±2.73	30.40**±8.26	C
	C2	-36.50*±3.04	-22.05**±3.09	144.32**±0.72	0.167±0.35	10.25**±2.30	8.95**±2.25	19.26**±0.68	C
	C3	1.86±2.29	-42.03**±2.27	145.20**±0.47	7.06**±0.57	21.26**±1.50	42.46**±1.93	-58.53**±4.50	D
	C4	-19.46**±2.72	6.80*±2.87	138.15**±0.57	0.56±0.31	-8.61**±2.05	-6.64**±1.96	35.02**±5.86	D
Plant height up to main raceme (cm)	C1	55.46**±10.7	8.26±10.16	66.28**±2.23	-7.50**±2.02	4.23±6.87	-11.26±7.18	62.93**±20.77	D
	J C2	45.34**±12.9	-3.83±13.02	93.75**±1.2.41	-12.16**±3.15	-5.55±8.15	-14.22±9.72	-65.55**±23.81	C
	C3	38.83**±9.68	4.75±7.95	82.62**±2.01	18.83**±1.52	-11.86*±5.93	40.97**±6.70	-45.44*±18.91	C
	C4	-39.83*±15.75	-74.25**±13.65	72.45**±2.35	2.50±4.34	26.69**±8.48	47.86**±9.84	-45.88**±26.01	D
Number of nodes up to main raceme	C1	2.46±1.69	5.56**±1.39	13.75**±0.21	-0.66±0.41	-1.83*±0.91	-4.63**±1.13	4.13±2.71	D
	C2	2.03±1.42	-1.48±1.24	-	-	-	-	-	-
	C3	4.46**±1.38	-5.50**±1.13	16.81**±0.25	1.66**±0.31	1.81*±0.71	7.74**±0.87	13.28**±2.33	D
	C4	-2.50±1.56	-9.21**±0.86	14.84**±0.21	0.73±0.38	4.92**±0.81	7.19**±0.97	-8.95**±2.52	D
Length of main raceme (cm)	C1	-3.50±6.98	10.58±6.33	-	-	-	-	-	-
	C2	-35.00**±7.36	-16.16**±4.94	50.41**±0.86	2.00±1.63	11.27**±3.37	8.94±4.59	25.11*±111.06	C
	C3	38.00**±8.24	-20.33**±4.57	60.50**±0.1.04	4.00**±1.08	13.88**±3.49	27.88**±4.29	-77.77**±1.23	D
	C4	-23.16**±7.22	-37.25**±5.86	53.37**±1.06	-0.33±1.86	22.63**±3.84	20.30**±4.83	-18.77**±11.99	D
Effective	C1	-9.23±6.99	11.61*±5.29	47.35**±0.91	-1.33±1.41	-8.61*±3.62	-11.95**±4.40	27.80**±110.64	D

length of main raceme (cm)	C2	-30.33**±7.75	-16.00**±4.92	50.25**±0.85	2.00±1.63	9.27**±3.48	9.61*±4.70	19.11±141.65	C
	C3	37.86**±8.22	-20.26**±4.57	60.46**±1.03	4.00**±1.08	13.82**±3.48	27.82**±4.28	--77.51**±12.28	D
	C4	-32.60**±7.49	-35.20**±5.94	50.85**±1.13	2.20**±0.16	20.03**±3.95	18.03**±4.90	-3.46±12.44	D
Number of effective branches per plant	C1	-0.36±1.02	0.31±0.82	-	-	-	-	-	-
	C2	-5.40**±0.96	-3.30**±0.65	3.85**±0.13	0.06±0.18	1.43**±0.47	1.43*±0.59	2.80*±1.42	C
	C3	-2.66**±0.95	1.63*±0.67	3.06**±0.12	0.46*±0.16	-0.20±0.45	-0.60*±0.29	5.73**±1.49	D
	C4	0.10±0.75	2.45**±0.74	3.62**±0.13	0.20±0.16	-1.21*±0.50	-1.21*±0.51	3.13*±1.45	D
Number of capsules on main raceme	C1	-22.80**±110.71	13.46±7.61	52.00**±1.53	0.40±1.59	-9.24±5.82	-11.97*±6.07	48.35**±18.38	D
	C2	-5.30± 10.18	8.08±8.89	-	-	-	-	-	_
	C3	70.90**±9.82	2.71±7.05	81.65**±1.40	2.66±2.00	19.73**±4.98	15.33**±5.49	-90.91**±16.09	D
	C4	-26.56**±10.14	-16.25±8.50	57.40**±1.49	5.36*±2.54	14.43**±5.50	17.13**±6.02	13.75*±6.45	C
Shelling out-turn (%)	C1	-16.93**±1.51	-1.50±1.60	58.01**±0.35	7.10**±0.12	5.27**±1.18	12.37**±1.12	20.57**±3.46	C
	C2	-9.46**±1.56	3.50*±1.61	58.85**±0.36	3.70**±0.12	6.58**±1.20	3.48**±1.15	17.28**±3.54	C
	C3	-5.86**±1.05	5.50**±1.16	62.71**±0.24	-0.50**±0.14	3.38**±0.83	-5.64**±0.81	15.15**±2.43	C
	C4	-9.80**±0.99	2.46*±0.96	62.13**±0.21	-1.50**±0.14	3.28**±0.71	-6.27**±0.71	16.35**±2.12	C
100-seeds weight (g)	C1	3.49*±1.74	0.95±1.81	35.05**±0.42	7.03±8.82	-1.33±1.36	14.02**±1.30	-3.38±4.04	C
	C2	-0.67±0.56	2.92**±0.59	27.20**±0.13	-0.55±4.37	1.41**±0.44	-3.16**±0.42	4.79**±1.31	C
	C3	-6.84**±0.80	0.50±0.85	28.91**±0.18	-3.39±8.11	2.92**±0.62	-8.26**±0.58	9.79**±1.80	C
	C4	9.47**±2.69	-3.59±3.02	35.58**±0.67	-11.97**±2.84	-3.84±2.23	-19.96**±2.07	-17.42**±6.46	C
Oil content (%)	C1	-6.28**±0.96	-0.47±0.82	50.37**±0.23	0.71±7.11	1.92**±0.64	0.68±0.67	7.75**±2.09	C
	C2	-0.82±0.50	-0.01±0.44	-	-	-	-	-	-
	C3	-3.36**±0.41	-1.57**±0.53	50.55**±9.80	0.96±5.39	1.92**±0.38	0.33±0.34	6.58**±.02	C
	C4	-3.63**±0.45	-2.26**±0.46	51.51**±0.10	-2.03±2.86	0.88**±0.34	-3.15**±0.33	1.82±1.03	C
Seed yield per plant (g)	C1	-33.03*±15.22	-36.65*±16.26	105.35**±2.88	0.96±4.19	22.22*±10.39	20.86*±10.51	-4.82±28.39	D
	C2	-143.36**±12.52	-102.05**±10.98	90.70**±2.59	17.36**±1.80	75.17**±8.19	78.87**±8.86	55.08*±25.44	C
	C3	-199.63**±20.30	-52.31**±12.20	67.17**±2.26	22.50**±3.26	32.90**±9.52	46.60**±10.48	196.42**±31.49	C
	C4	-55.36**±14.03	-25.11±13.00	92.20**±3.33	-0.90±1.75	12.48±19.75	5.71*±2.81	40.33**±14.37	C

C1- JP 96 x JI 355, C2 - JP 100 x SKI 215, C3 - JP 100 x JI 362 and C4 - JP 100 x JI 363

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