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Heterosis Effects for Pistillate x Pistillate Crosses under *Rabi* Season in Castor (*Ricinus communis* L.)

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A B S T R A C T

Thirty six castor hybrids developed by half diallel mating design (9 pistillate parents) were studied along with parents for relative heterosis and better parent heterosis of yield and yield determinate characters. The relative heterosis and heterobeltiosis for seed yield ranged from -30.09 to 383.58 and -35.04 to 267.39, respectively. The magnitude of both relative heterosis and heterobeltiosis was positive for seed yield and other yield contributing characters. The hybrids ANDCP-08-01 x JP-65, ANDCP-06-07 x JP-65 and JP-65 x ANDCP-06-07-1 were found as promising hybrids. For full exploitation of existing genetic variance in these crosses inter-mating of elite plants in the early segregating generations would be profitable to build up elite population for early and dwarf pistillate lines with high seed yield.

Introduction

The genus *Ricinus*is monotypic and *R. communis* is the only species with the most polymorphic forms known. Several of these forms were designated as species (*R. communis*, *R. macrocarpus*, *R. microcarpus*) (Weiss, 2000) but they are inter-crossable and fertile and are not true species. All the varieties investigated cytologically are diploids and it is presumed to be a secondary-balanced polyploid with a basic number of x=5 (Singh, 1976). Sexually it is consider as polymorphic species with different sex forms *viz*., monoecious, pistillate, hermaphrodite and pistillate with interspersed staminate flowers (ISF). A variant of pistillate form with male flowers interspersed throughout the female flowers on the spike is termed as interspersed staminate flower (ISF). Sex revertant is basically a female form that turns to monoecious form or reverts at later stage

(Lavanya, 2002). Dominant female mutants are genetically unstable and found spontaneously. These plants produce female racemes at first, but later revert to production of monoecious racemes having both male and female flowers. Such females are used in hybrid seed production programme and could be maintained easily. For development new pistillate genotypes thirty six crosses were attempted and evaluated in *rabi* season to estimate the magnitude of better parent heterosis (heterobeltiosis) and relative heterosis for sixteen characters.

Materials and Methods

The experimental materials consisted of nine genetically diverse pistillate lines *viz*. ANDCP-08-01, ANDCP-06-07, ACP-1-06-07, SKP-84, VP-1, DPC-9, JP-65, ANDCP-06-07-1 and ANDCP-06-07-2 were crossed in half diallel mating fasion. The resulting 46 genotypes (36 hybrids + 9 parent + GCH-7 as check) were evaluated in Randomized Complete Block Design with three replications. The investigation was carried out at Regional Research Station, Anand Agricultural University, Anand during *Rabi* 2012-13. Each genotype was grown in a single row of 7.2 meter length with 0.90 x 0.45 m^2 spacing. The observations were recorded for sixteen yield and yield contributing characters (Table 1). The relative heterosis and heterobeltiosis were estimated as per Turner (1953) and Fonseca and Patterson (1968), respectively.

Results and Discussion

The analysis of variance for experimental design of sixteen characters (Table 1) revealed that mean sum of squares due to genotypes were significant for all the characters, accordingly parents and hybrids differed among themselves for all the characters except days to 50 % maturity of primary raceme. In other hand parents *vs* hybrids were significant for all the characters, except number of nodes up to primary raceme and shelling out turn which indicated considerable differences between parents and hybrids for their *per se* performance. This showed that the material was appropriate for study of manifestation of heterosis and genetic parameters involved in the inheritance of different traits.

The magnitude of heterosis effect and comparative performance of the most three heterotic crosses for seed yield per plant and other attributes have been presented in table 2. The estimates of relative heterosis (RH) and heterobeltiosis (HB) for sixteen characters revealed that both the heterotic effects varied with crosses irrespective of character. For seed yield per plant, out of 36 hybrids total 23 and 12 hybrids depicted significant and positive relative heterosis and heterobeltiosis, respectively. This revealed positive magnitude for both the heterotic effects. Similar results were reported by Aher *et al.,* (2014). Accordingly, similar extent of heterotic effects was observed for plant height up to primary raceme, number of effective branches per plant, number of secondary spikes per plant, number of capsules per primary raceme, total number of capsules per plant, 100 seed weight and oil content. Similarly, significant positive magnitude and higher estimates of relative heterosis were observed for total length of primary raceme, effective length of primary raceme, number of tertiary spikes per plant and volume weight. In respect to heterobeltiosis, significant positive and higher magnitude was noticed for number of nodes up to primary raceme; whereas equal magnitude of heterobeltiosis was observed in days to 50 % flowering of primary raceme, days to 50% maturity of primary raceme, total length of primary raceme, effective length of primary raceme and number of tertiary spikes per plant.

Table.1 Analysis of variance for yield and yield attributing character in castor for *Rabi* season

Source of variation	df	Days to 50 % flowering of primary raceme		No. of nodes up to primary raceme		Plant height up to primary raceme (cm)		Days to 50 % maturity of primary raceme		Total length of primary raceme (cm)		Effective length of primary raceme (cm)		Number of effective branches per plant		Number of secondary spikes per plant	
Replications	2	230.72	**	7.61	*	138.10	*	24.63	NS	136.66	*	80.91	NS	0.49	NS	0.73	NS
Genotypes	45	129.52	**	10.51	**	2392.48	**	151.19	*	354.95	**	319.65	**	9.59	**	4.08	**
Parents (P)	8	278.12	**	19.98	**	2037.57	**	234.17	*	580.49	**	593.69	**	3.88	**	1.80	**
Hybrids (H)	35	89.52	**	8.87	**	2422.28	**	120.10	NS	265.42	**	230.11	**	8.28	**	3.86	**
P *vs* H	1	409.07	**	1.71	NS	3817.68	**	689.05	**	2035.38	**	1569.76	**	81.48	**	15.60	**
Check *vs* Hybrids	1	60.93	NS	0.92	NS	2763.36	**	37.84	NS	3.78	NS	10.89	NS	29.02	**	18.55	**
Error	90 (270)	23.08		2.21		34.71		87.94		36.56		27.13		0.60		0.36	

Source of variation	df	Number of tertiary spikes per plant		Number of capsules per primary raceme		Total number of capsules per plant		100 Seed weight (g)		Volume weight (g/100ml)		Seed yield per plant (g)		Oil content (%)		Shelling out turn (%)	
Replications	2	1.22	**	97.63	NS	8382.75	**	1.89	NS	2.49	NS	35.00	NS	4.46	**	30.25	*
Genotypes	45	4.44	**	962.84	**	22769.40	**	17.41	**	7.14	**	14931.70	**	6.15	**	33.41	**
Parents (P)	8	3.64	**	1084.55	**	15030.16	**	13.09	**	10.60	**	8218.70	**	9.15	**	80.90	**
Hybrids (H)	35	3.72	**	842.27	**	21488.88	**	16.13	**	6.17	**	13416.05	**	4.71	**	19.98	**
P *vs* H	1	2.11	**	5104.17	**	152192.59	**	96.53	**	9.67	*	136228.72	**	38.86	**	8.72	NS
Check *vs* Hybrids	1	38.24	**	67.81	NS	78.31	NS	17.75	NS	10.86	**	386.34	NS	0.07	NS	148.30	**
Error	90 (270)	0.23		172.53		1590.13		3.48		1.42		790.33		0.47		8.77	

*, ** Significant at 0.05 and 0.01 levels of probability, respectively; figure in parenthesis is pooled error df

Table.2 Magnitude of heterosis effects and promising heterotic crosses for yield and yield attributing traits

Character	*Per se* Mean	Average/Range of heterosis		Significant crosses				Three promising crosses in respect to heterosis							
		RH	HB	RH		HB		For relative heterosis (RH)				For heterobeltiosis (HB)			
				+ve	- ve	+ve	-ve	Cross	RH (%)	SCA effect	*Per se* per-formance	Cross	HB (%)	SCA effect	*Per se* per-formance
Days to 50 % flowering of primary raceme	76.0	(-5.06) -22.14 to 9.01	(2.62) -18.22 to 25.12	4	15	12	10	ACP-1-06-07 x DPC-9,	-22.14**	-10.91**	70.3	ACP-1-06-07 x DPC-9,	-18.22**	-10.91**	70.3
								ANDCP-08-01 x JP-65,	-21.50**	-10.94**	66.3	ANDCP-08-01 x JP-65,	-14.59**	-10.94**	66.3
								ANDCP-08-01 x ACP-1-06-07	-18.76**	-7.82**	70.0	ANDCP-08-01 x ANDCP-06-07	-12.02**	-4.24	68.3
No. of nodes up to primary raceme	14.9	(-1.32) -23.52 to 27.68	(11.63) -20.43 to 77.70	11	17	18	12	ANDCP-08-01 x ACP-1-06-07,	-9.89**	-2.60**	12.5	ANDCP-08-01 x ACP-1-06-07,	-20.43**	-2.60**	12.5
								ANDCP-08-01 x DPC-9,	-20.00**	-1.72*	12.0	ANDCP-08-01 x DPC-9,	-16.28**	-1.72*	12.0
								ANDCP-06-07 x VP-1	-16.15**	-2.19	10.7	ANDCP-06-07 x JP-65	-9.39**	-0.94	14.8
Plant height up to primary raceme (cm)	67.1	(21.64) -19.59 to 73.34	(69.50) -4.40 to 236.56	27	4	32	0	VP-1 x ANDCP-06-07-2,	-19.59**	-10.94**	31.3	ACP-1-06-07 x ANDCP-06-07-2,	-4.40	-10.95**	44.9
								ANDCP-06-07 x VP-1,	-12.12**	-8.95**	34.3	ANDCP-06-07 x SKP-84	-4.10	-7.34*	36.7
								ANDCP-08-01 x SKP-84	-8.64*	-5.92	36.7	-	-	-	-
Days to 50 % maturity of primary raceme	145.1	(-3.70) -12.70 to 2.78	(-0.16) -11.45 to 11.19	0	12	5	5	DPC-9 x ANDCP-06-07-2,	-12.70**	-13.15**	134.0	DPC-9 x ANDCP-06-07-2,	-11.45**	-13.15**	134.0
								ACP-1-06-07 x DPC-9,	-10.70**	-10.03**	137.7	ACP-1-06-07 x DPC-9,	-9.03**	-10.03**	137.7
								ANDCP-08-01 x ANDCP-06-07-1	-9.11**	-8.48**	133.0	ANDCP-08-01 x ANDCP-06-07-1	-7.64*	-8.48**	133.0
Total length of primary raceme (cm)	83.9	(13.93) -18.54 to 41.22	(3.15) -24.19 to 38.06	20	1	12	10	JP-65 x ANDCP-06-07-1,	41.22**	14.00**	96.7	JP-65 x ANDCP-06-07-1,	38.06**	14.00**	96.7
								ANDCP-08-01 x DPC-9,	39.29**	9.64**	81.5	ANDCP-08-01 x DPC-9,	33.95**	9.64**	81.5
								DPC-9 x JP-65	35.03**	6.64*	83.1	DPC-9 x JP-65	24.20**	6.64*	83.1
Effective length of primary raceme (cm)	75.3	(13.91) -17.46 to 43.90	(2.21) -25.20 to 41.22	19	1	11	13	VP-1 x DPC-9,	43.90**	13.25**	75.1	JP-65 x ANDCP-06-07-1,	41.22**	13.60**	88.7
								JP-65 x ANDCP-06-07-1,	42.43**	13.60**	88.7	VP-1 x DPC-9,	36.40**	13.25**	75.1
								ANDCP-08-01 x DPC-9	42.39**	-5.62*	73.7	ANDCP-08-01 x DPC-9	35.87**	-5.62*	73.7
Number of effective branches per plant	7.3	(39.86) -21.21 to 174.60	(23.80) -30.36 to 121.79	31	4	23	11	ANDCP-06-07 x JP-65,	174.60**	4.41**	11.5	ANDCP-06-07 x JP-65,	121.79**	4.41**	11.5
								DPC-9 x JP-65,	120.99**	1.13**	9.3	DPC-9 x JP-65,	78.66**	1.13**	9.3
								ANDCP-08-01 x JP-65	105.84**	1.60**	9.4	DPC-9 x ANDCP-06-07-2	65.82**	2.13**	8.7
Number of secondary spikes per plant	4.6	(23.40) -31.78 to 104.40	(10.23) -38.03 to 93.75	30	6	21	13	VP-1 x DPC-9,	104.40**	2.05**	6.2	VP-1 x DPC-9,	93.75**	2.05**	6.2
								ANDCP-06-07 x JP-65,	96.75**	3.19**	8.1	ANDCP-06-07 x JP-65,	86.15**	3.19**	8.1
								SKP-84 x DPC-9	59.65**	1.37**	6.1	ACP-1-06-07 x DPC-9	41.18**	0.69*	4.8
Number of tertiary spikes per plant	3.7	(10.94) -58.33 to 84.76	(-3.26) -64.29 to 83.02	23	13	18	18	DPC-9 x ANDCP-06-07-2,	84.76**	2.61**	6.5	DPC-9 x ANDCP-06-07-2,	83.02**	2.61**	6.5
								ANDCP-06-07 x VP-1,	77.27**	1.41**	5.2	ANDCP-06-07 x VP-1,	47.17**	1.41**	5.2
								ACP-1-06-07 x VP-1	76.74**	1.51**	5.1	ACP-1-06-07 x VP-1	43.40**	1.51**	5.1
Number of capsules per primary raceme	81.5	(27.19) -27.36 to 131.55	(9.36) -40.06 to 116.64	18	2	10	5	VP-1 x JP-65,	131.55**	29.68**	99.8	VP-1 x JP-65,	116.64**	29.68**	99.8
								VP-1 x DPC-9,	94.72**	22.43**	83.6	DPC-9 x JP-65,	91.90**	4.10	88.4
								DPC-9 x JP-65	92.59**	4.10	88.4	VP-1 x DPC-9	82.80**	22.43**	99.8
Total number of capsules per plant	259.0	(60.79) -34.54 to 293.46	(24.46) -41.26 to 216.30	17	0	5	0	ANDCP-08-01 x JP-65,	293.46**	68.93**	323.0	ANDCP-08-01 x JP-65,	216.30**	68.93**	323.0
								ANDCP-06-07 x JP-65,	252.35**	183.00**	464.9	ANDCP-06-07 x JP-65,	130.35**	183.00**	464.9
								JP-65 x ANDCP-06-07-1	164.82**	112.91**	575.6	ACP-1-06-07 x JP-65	71.88**	67.13**	324.5
100 Seed weight (g)	30.7	(7.43) -8.16 to 25.99	(3.01) -11.51 to 20.68	27	1	17	8	ANDCP-08-01 x JP-65,	25.99**	4.37**	36.5	DPC-9 x JP-65,	20.68**	2.73**	34.2
								DPC-9 x JP-65,	24.07**	2.73**	34.2	ANDCP-08-01 x JP-65,	17.28**	4.37**	36.5
								DPC-9 x ANDCP-06-07-1	18.34**	1.93	31.6	VP-1 x DPC-9	15.12**	1.99*	30.7
Volume weight (g/100ml)	55.7	(1.24) -4.16 to 5.51	(-0.76) -7.28 to 3.54	18	6	3	7	ACP-1-06-07 x SKP-84,	5.51**	0.77	55.6	ACP-1-06-07 x SKP-84,	3.54**	0.77	55.6
								ACP-1-06-07 x VP-1,	5.28**	1.79**	57.3	SKP-84 x DPC-9,	2.79**	1.23	55.2
								SKP-84 x ANDCP-06-07-2	4.56**	1.43*	57.6	SKP-84 x ANDCP-06-07-2	2.00*	1.43*	57.6
Seed yield per plant (g)	214.8	(74.26) -30.09 to 383.58	(34.80) -35.04 to 267.39	23	0	12	0	ANDCP-08-01 x JP-65,	383.58**	97.43**	320.6	ANDCP-08-01 x JP-65,	267.39**	97.43**	320.6
								ANDCP-06-07 x JP-65,	276.93**	139.28	364.5	ANDCP-06-07 x JP-65,	146.17**	139.28	364.5
								JP-65 x ANDCP-06-07-1	200.00**	86.31**	326.7	JP-65 x ANDCP-06-07-1	89.43**	86.31**	326.7
Oil content (%)	48.1	(2.92) -3.06 to 11.06	(0.77) -3.15 to 10.07	11	0	4	0	ANDCP-06-07 x DPC-9,	11.06**	2.43**	51.1	ANDCP-06-07 x DPC-9,	10.07**	2.43**	51.1
								ACP-1-06-07 x DPC-9,	8.60**	1.96**	50.6	VP-1 x DPC-9,	7.70**	1.76**	49.9
								VP-1 x DPC-9	8.54**	1.76**	49.9	ACP-1-06-07 x DPC-9	6.37**	1.96**	50.6
Shelling out turn (%)	62.4	(1.23) -9.85 to 12.63	(-3.42) -14.70 to 3.89	9	5	1	11	ACP-1-06-07 x JP-65,	12.63**	3.33*	62.6	ANDCP-08-01 x JP-65,	3.89	2.11	61.9
								ANDCP-08-01 x JP-65,	12.38**	2.11	61.9	ANDCP-08-01 x ACP-1-06-07,	3.34	1.00	62.7
								JP-65 x ANDCP-06-07-2	9.69**	2.75	63.6	ACP-1-06-07 x JP-65	3.31	3.33*	62.6

* Significant at 0.05 probability level, ** Significant at 0.01 probability level; Figure in parenthesis indicates average heterosis.

In shelling out turn equal magnitude of relative heterosis was noticed whereas, 11 crosses showed significant higher heterobeltiosis in negative direction. Similarly, the three characters days to 50 % flowering of primary raceme, number of nodes up to primary raceme and days to 50 % maturity of primary raceme showed significant relative heterosis in negative direction. The overall results confirmed with finding of Patel *et al.,* (2012).

In comparative performance the results revealed that hybrids ANDCP-08-01 x JP-65 depicted the highest relative heterosis (383.58%) and heterobeltiosis (267.39%) for seed yield; whereas, ANDCP-06-07 x JP-65 depicted maximum *per se* performance and SCA effect and second highest relative heterosis (276.93%) and heterobeltiosis (146.17%).

The hybrid ANDCP-08-01 x JP-65 also registered higher estimates of relative heterosis and heterobeltiosis for days to 50 % flowering of primary raceme, total number of capsules per plant, 100 seed weight and shelling out turn; whereas, the hybrid ANDCP-06-07 x JP-65 registered higher estimates of relative heterosis and heterobeltiosis for number of effective branches per plant, number of secondary spikes per plant and total number of capsules per plant.

Another promising hybrid JP-65 x ANDCP-06-07-1 exhibited 200.00% relative heterosis and 89.43% heterobeltiosis for seed yield per plant and it had excellent per se performance and SCA effect. The same hybrid also exhibited significant and desired relative heterosis and heterobeltiosis for important yield attributes *viz*. total length of primary raceme, and effective length of primary raceme. The results confirmed with finding of Aher *et al.,* (2015).

The magnitude of heterobeltiosis revealed that for seed yield and other traits, it was positive as well as in both the directions; which would be ideal signed to develop new pistillate lines with high yield, earliness, dwarf plant stature and oil content. The crosses depicted high estimates of heterobeltiosis for various characters also registered significant SCA effects in accordance to direction / magnitude of heterobeltiosis of respective cross; thereby, revealing that pistillate parents involved in different cross combinations could be carrier genes causing non additive gene effects, and thereby its preponderance. For full exploitation of existing genetic variance in these crosses inter-mating of elite plants in the early segregating generations would be profitable to build up elite population for early and dwarf pistillate lines with high seed yield.

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