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Combining ability and gene action for seed yield and its related traits in castor (*Ricinus communis* L.)

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Abstract
The experimental material consisting of 101 entries comprised of ten parents and their 45 hybrids and 45 F_2s developed through half diallel mating design and one standard check (GCH 7) were evaluated in a randomized block design with three replications. The analysis of variance for combining ability revealed that general combining ability (GCA) and specific combining ability (SCA) variances were significant for all the eleven characters in both the generations reflecting the importance of both additive and non additive genetic variances for controlling these traits. The ratio of σ^2GCA/σ^2SCA was more than unity for effective length of primary raceme in F_1 generation, while for the rest of the characters the ratio was less than unity in both the generations. Among the parents, PCS 124, JI 353 and JI 368 in F_1 generation and JI 353 and DPC 17 in F_2 generation exhibited good general combining ability effect for seed yield per plant. The highest yielding hybrid JI 368 x RG 2787 in F_1 generation and DPC 17 x SKI 343 in F_2 generation had also registered significant positive sca effect for seed yield per plant in both the generations.

Keywords: Castor, combining ability, GCA, SCA, gene action

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 *Ephorbiaceae* 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 percent 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) [11].

In genetic improvement, the choice of appropriate parents to be incorporated in hybridization programme is very crucial step for breeders, particularly if the aim is improvement of complex quantitative characters, such as seed yield and its components. For this, it is always essential to evaluate available promising lines in their hybrid combinations for yield and yield contributing characters (Giriraj *et al.*, 1973) [7]. The use of parents of known superior genetic worth ensures much better success. Some idea may be obtained from their *per se* performance, particularly for yield contributing characters. However, proper information on magnitude of heterosis, combining ability and gene action for seed yield per plant and its component characters involved in the inheritance of different parents and their crosses would be more helpful to plant breeders in selecting the elite parents and desirable cross combinations for commercial exploitation of hybrid vigour and also in formulating the efficient breeding programme for the improvement of seed yield and its components (Dangaria *et al.*, 1987) [5].

Materials and Methods
The experimental material comprised of a set of 10 diverse parents *viz.*, DPC-17, JI-353, JI-368, JI-411, DCS-485, SKI-215, SKI-343, JI-372, PCS-124 and RG-2787 of castor which were used for half diallel mating design. The experimental material, consisting of 101 entries including 10 parents, 45 crosses, 45 F_2s and one check hybrid (GCH 7) was raised in a Randomized Block Design with three replications at the Main Oilseeds Research Station, JAU, Junagadh during *kharif* 2016-17. Each entry was accommodated in a single row of 7.2 m. length spaced at 90 cm apart with plant-to-plant spacing of 60 cm. Recommended agronomic practices and plant protection measures were adopted timely to raise the healthy crop. Five competitive plants from parental lines and F_1s and 20 plants from each F_2s from each

replication were randomly selected before flowering and tagged for the purpose of recording observations on different characters (Except days to flowering and days to maturity) and their average values were used in the statistical analysis. The analysis of variance was performed to test the significance of differences among the genotypes for all the characters following fixed effect model as suggested by Panse and Sukhatme (1985) [12]. The analysis of variance for combining ability (Table 1) for all the eleven characters was carried-out according to the method suggested by Griffing (1956) [8] Method 2, Model 1.

Results and Discussion

The mean squares due to general (GCA) and specific combining ability (SCA) were highly significant for all the characters in both the generations. The variances due to GCA were lower in magnitude than those due to SCA for all the characters in both the generations except for effective length of primary raceme in case of F_1. The ratio of σ^2GCA/σ^2SCA was more than unity for effective length of primary raceme in F_1 generation, while for the rest of the characters the ratio was less than unity in both the generations.

The analysis of variance for combining ability (Table 1) revealed that general combining ability (GCA) and specific combining ability (SCA) variances were significant for all the eleven characters in both the generations reflecting the importance of both additive and non additive genetic variances for controlling these traits. The results are in accordance with the findings of Barad *et al.* (2009) [2], Yogitha *et al.* (2009) [18], Aher *et al.* (2015) [1], Patel *et al.* (2015), Patel *et al.* (2017), Jalu *et al.* (2017) [9], Bindu Priya *et al*. (2018) [3] and Delvadiya *et al.*, (2018) [6]. The ratio of GCA and SCA variances ($\sigma^2_{GCA}/\sigma^2_{SCA}$) was found more than unity for effective length of primary raceme in F_1 indicating the predominance of additive genetic variance (Table 1). Predominance of additive type of gene action for effective length of primary raceme has been reported by Solanki and Joshi (2000), Madariya *et al.* (2008), Barad *et al.* (2009) [2], Aher *et al.* (2015) [1], Patel *et al.* (2015) [1] and Rajani *et al.* (2015) [15].

Three parents *viz.*, JI 353 (27.01), JI 368 (22.54) and PCS 124 (30.00) displayed significant positive gca effect in F_1 generation, while two parents *viz.*, JI 353 (36.54) and DPC 17 (19.89) depicted significant positive gca effect in F_2 generation (Table 2). The parent JI 353 expressed significant and positive gca effect for seed yield per plant in both the generations.

Out of 45 hybrids, nine cross combinations in F_1 generation and 10 crosses in F_2 generation depicted significant and positive sca effect for seed yield per plant. The best five specific hybrids based on significant and positive sca effect for seed yield per plant were JI 368 x DCS 85 (143.53), DPC 17x SKI 343 (143.37), JI 411 x SKI 215 (109.24), DPC 17 x JI 353 (80.55) and DPC 17 x RG 2787 (80.38) in F_1 generation, while DPC 17 x SKI 215 (152.90), DPC 17 x SKI 343 (110.97), DPC17 x RG 2787 (82.90), SKI 215 x RG 2787 (78.97) and JI 353 x PCS 124 (73.52) in F_2 generation. Six crosses *viz.*, DPC 17 x SKI 343, DPC 17 x RG 2787, JI 411 x SKI 215, DCS 85 x JI 372, JI 353 x JI 368 and SKI 215 x RG 2787 depicted significant positive sca effect for seed yield per plant in both the generations (Table 3).

For other traits *viz.*, days to 50% flowering of primary raceme, days to maturity of primary raceme, plant height, number of nodes up to primary raceme, length of primary raceme, number of capsules on primary raceme, number of effective branches per plant, 100 seed weight, oil content and seed yield per plant the GCA/SCA ratio was less than unity in both the generations, suggesting the predominance of non-additive gene action for the inheritance of these traits (Table 1). Predominance of non-additive gene action for seed yield per plant and other characters has been reported by several researchers Ramesh *et al*. (2013) [16], Aher *et al.* (2015) [1], Patel *et al.* (2015) [1], Patel *et al.* (2017), Jalu *et al.* (2017) [9], Bindu Priya *et al*. (2018) [3] and Delvadiya *et al.*, (2018) [6].

Looking to the significance of both the types of gene actions in the expression of seed yield per plant and other characters under study, it is suggested that biparental mating with reciprocal recurrent selection should be employed so that additive as well as non-additive gene actions could be exploited simultaneously for population improvement. However, in view of the preponderance of non-additive gene action and high heterosis observed for seed yield and its attributing characters, it is suggested that heterosis breeding could profitable be used for exploitation of hybrid vigour in castor on commercial scale.

Among the parents, JI 368 and SKI 343 were found good general combiners for days to 50% flowering in F_1 and F_2 generation, respectively. For days to maturity of primary raceme, the parents JI 368, JI 411, DCS 85 and SKI 343 were good general combiners in both the generations. The parents JI 368, DPC 17, DCS 85 and SKI 343 were good general combiners for plant height in both the generations. For number of nodes upto primary raceme, only one parent DCS 85 was found good general combiner in both the generations while, DPC 17, SKI 343, JI 372 and PCS 124 in F_1 JI 368 and JI 411 in F_2 were also found good general combiners for number of nodes upto primary raceme. The parents DPC 17, JI 411, SKI 343 and SKI 215 were found good general combiners for length of primary raceme and effective length of primary raceme in both the generations. For number of effective branches per plant the parents JI 353, SKI 215 and PCS 124 were found good general combiners in both the generations. The parents DPC 17, JI 411, SKI 343 and SKI 215 were found as good general combiners for number of capsules on primary raceme in both the generations. For 100-seed weight, the parents JI 353, JI 411, SKI 215 and RG 2787 were found good general combiners in both the generations whereas, DPC 17 and PCS 124 in F_1 and SKI 343 and JI 372 in F_2 were also good general combiners for 100-seed weight. Only one parent JI 353 was found good general combiner for oil content in both the generations while, PCS 124 and RG 2787 were found good general combiners in F_2 generation. For seed yield per plant, the parent JI 353 was found good general combiner in both the generations whereas, JI 368 and PCS 124 in F_1 and DPC 17 in F_2 were also found good general combiners for seed yield per plant. The estimates of sca effect revealed that none of the crosses was consistently superior for all the traits. Out of 45 crosses studied, nine crosses in F_1 generation and 10 crosses in F_2 generation depicted significant and positive sca effect for seed yield per plant. The highest yielding hybrid JI 368 x RG 2787 in F_1 generation and DPC 17 x SKI 343 in F_2 generation had also registered significant positive sca effect for seed yield per plant in both the generations. Out of ten top most high yielding cross combinations, six cross combinations viz., JI 368 x RG 2787, DPC 17 x SKI 343, DPC 17 x JI 353, DPC 17 x RG 2787, JI 353 x JI 368 and SKI 215 x PCS 124 also manifested high and desirable sca effect for seed yield per plant.

The best cross combination JI 368 x RG 2787 involved the parents with good x average general combiners followed by DPC 17 x SKI 343, which exhibited significant and negative sca effect for days to 50% flowering of primary raceme and days to maturity were considered as good cross combinations for exploiting earliness. Similarly, DPC 17 x JI 353, JI 353 x JI 368 and DPC 17 x JI 368 for plant height up to primary raceme; DPC 17 x SKI 343, DPC 17 x JI 353, JI 353 x JI 368, DPC 17 x JI 368 and DPC 17 x PCS 124 for number of nodes up to primary raceme; DPC 17 x JI 353 for number of capsules on primary raceme; SKI 215 x PCS 124 for number of effective branches per plant; DPC 17 x RG 2787 for 100-seed weight and JI 368 x RG 2787, JI 353 x JI 368, JI 353 x PCS 124, PCS 124 x RG 2787 and DPC 17 x PCS 124 for oil content exhibited significant sca effect in desired direction and thus, were considered as the best specific combiners for the respective traits.

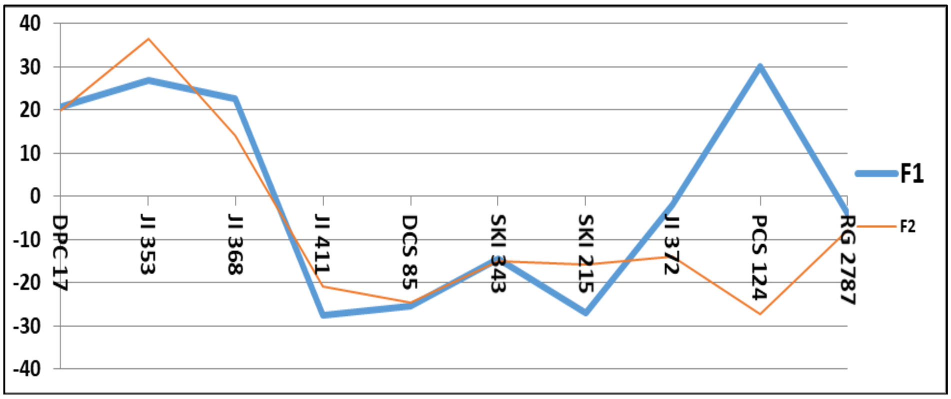

Fig 1: Estimates of general combining ability (GCA) effect of parents for seed yield per plant in F_1 and F_2 generations of castor.

Table 1: Analysis of variance for combining ability for different characters in $F_1$and F_2 generations of castor

Sources	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)			
		F_1		F_2		F_1		F_2		F_1		F_2		F_1		F_2		F_1		F_2		F_1		F_2	
GCA	9	40.60	**	50.7	**	191.7	**	190.8	**	475.8	**	573.2	**	6.99	**	2.43	**	117.3	**	111.2	**	124.1	**	104.5	**
SCA	45	25.1	**	27.4	**	121.0	**	139.0	**	131.3	**	148.3	**	1.64	**	1.17	**	18.16	**	27.78	**	12.2	**	26.4	**
Error	108	1.06		0.74		1.45		2.05		19.08		2.51		0.45		0.24		4.01		1.96		5.09		2.25	
σ^2_{GCA}		3.29		4.16		15.85		15.72		38.05		47.55		0.54		0.18		9.43		9.09		9.91		8.52	
σ^2_{SCA}		24.03		26.67		119.49		136.97		112.19		145.78		1.18		0.92		14.14		25.81		7.11		24.23	
$\sigma^2_{GCA}/\sigma^2_{SCA}$		0.13		0.15		0.13		0.11		0.33		0.32		0.45		0.19		0.66		0.35		1.39		0.35	

Sources	D.F.	Number of effective branches per plant				Number of capsules on primary raceme				100-seed weight (g)				Oil content (%)				Seed yield per plant (g)			
		F_1		F_2		F_1		F_2		F_1		F_2		F_1		F_2		F_1		F_2	
GCA	9	1.67	**	0.68	**	156.1	**	76.2	**	44.5	**	38.9	**	0.86	**	0.79	**	6574.0	**	5920.5	**
SCA	45	0.39	**	0.54	**	26.0	**	26.7	**	4.06	**	12.4	**	0.21	**	0.34	**	5527.2	**	4320.2	**
Error	108	0.09		0.05		4.35		1.12		0.05		0.07		0.09		0.12		416.11		1331	
σ^2_{GCA}		0.13		0.05		12.64		6.25		3.7		3.23		0.06		0.05		513.15		382.45	
σ^2_{SCA}		0.29		0.49		21.65		25.61		4.0		12.31		0.11		0.21		5111.08		2989.13	
$\sigma^2_{GCA}/\sigma^2_{SCA}$		0.44		0.10		0.58		0.24		0.92		0.26		0.55		0.25		0.10		0.12	

** Significant at 1 % level of significance

Table 2: Estimates of general combining ability (GCA) effect of parents for different characters in $F_1$and F_2 generations of 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)			
		F_1		F_2		F_1		F_2		F_1		F_2		F_1		F_2		F_1		F_2		F_1		F_2	
1	DPC 17	1.24	**	-1.18	**	-0.63		2.43	**	-5.85	**	-6.21	**	-0.52	**	0.30	*	1.77	**	3.98	**	3.21	**	3.51	**
2	JI 353	1.96	**	2.20	**	5.00	**	1.12	**	-0.41		-5.48	**	0.48	**	-0.23		-2.04	**	-3.98	**	-1.61	**	-4.06	**
3	JI 368	-3.00	**	-1.57	**	-3.13	**	-7.17	**	-5.77	**	-8.35	**	-0.14		-0.40	**	-0.73		-2.51	**	-1.17		-2.51	**
4	JI 411	-1.42	**	-1.60	**	-3.13	**	-1.01	**	3.35	**	-2.24	**	0.14		-0.57	**	4.73	**	3.65	**	3.98	**	3.46	**
5	DCS 85	-0.08		0.00		-1.02	**	-4.34	**	-4.32	**	-3.62	**	-0.49	**	-0.31	*	-3.37	**	-3.79	**	-4.26	**	-3.72	**
6	SKI 343	-2.70	**	-2.96	**	-7.27	**	-3.67	**	-4.11	**	-3.53	**	-0.51	**	-0.08		3.00	**	3.13	**	3.00	**	3.09	**
7	SKI 215	0.66	*	1.31	**	2.77	**	5.93	**	8.70	**	10.89	**	1.23	**	0.73	**	2.63	**	1.84	**	3.64	**	2.29	**
8	JI 372	-0.17		-1.24	**	-0.83	*	2.29	**	-0.13		5.95	**	-1.02	**	-0.22		-5.10	**	-2.05	**	-4.27	**	-1.14	**
9	PCS 124	1.71	**	1.58	**	3.13	**	1.62	**	-3.77	**	2.60	**	-0.37	*	-0.11		-1.83	**	-0.21		-1.99	**	-0.04	
10	RG 2787	1.80	**	3.47	**	5.13	**	2.79	**	12.33	**	9.99	**	1.21	**	0.68	**	0.95		-0.05		-0.39		-0.53	
	SE(g_i)±	0.28		0.23		0.33		0.39		1.19		0.43		0.18		0.13		0.54		0.38		0.61		0.44	

Sr.	Parents	Number of effective branches per plant				Number of capsules on primary raceme				100-seed weight (g)				Oil content (%)				Seed yield per plant (g)			
No.		F_1		F_2		F_1		F_2		F_1		F_2		F_1		F_2		F_1		F_2	
1	DPC 17	-0.45	**	-0.09		5.84	**	3.53	**	1.24	**	-2.91	**	-0.54	**	-0.47	**	20.89		19.89	*
2	JI 353	0.38	**	0.21	**	1.23	**	-1.86	**	1.96	**	2.88	**	0.50	**	0.42	**	27.01	*	36.54	**
3	JI 368	-0.26	**	0.12	*	-2.65	**	-2.89	**	-3.00	**	-0.33	**	-0.12		-0.16		22.54	*	14.11	
4	JI 411	0.08		0.08		3.63	**	2.33	**	1.42	**	0.59	**	0.03		-0.01		-27.40	*	-20.71	*
5	DCS 85	-0.12		-0.10		-4.93	**	-3.68	**	-0.08		-1.18	**	-0.14		-0.24	**	-25.33	*	-24.61	**
6	SKI 343	-0.26	**	-0.27	**	1.41	**	2.79	**	-2.70	**	0.74	**	-0.12		0.02		-14.47		-14.91	
7	SKI 215	0.70	**	0.30	**	2.92	**	1.84	**	0.66	**	0.72	**	0.06		-0.05		-27.05	*	-15.87	
8	JI 372	-0.32	**	-0.40	**	-4.58	**	-1.03	**	-0.17	*	0.81	**	0.12		0.06		-2.03		-13.89	
9	PCS 124	0.35	**	0.27	**	-0.67		0.19		1.71	**	-2.64	**	0.12		0.25	**	30.00	**	-27.30	**
10	RG 2787	-0.05		-0.13	**	-2.91	**	-1.22	**	1.80	**	1.32	**	0.09		0.17	*	-4.15		-7.85	
	SE(g_i)±	0.10		0.06		0.57		0.29		0.06		0.07		0.08		0.09		10.97		9.46	

* and ** significant at 5 % and 1 % levels of significance, respectively

Table 3: Estimates of specific combining ability (sca) effect for various characters in F_1 and F_2 generations of castor

Sr. No.	Hybrids	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)			
		F_1		F_2		F_1		F_2		F_1		F_2		F_1		F_2		F_1		F_2	
1	DPC 17 x JI 353	-6.79	**	-8.06	**	-14.42	**	11.06	**	-11.01	**	-11.28	**	-0.84		-0.45		1.46		-1.56	
2	DPC 17 x JI 368	-2.48	**	-3.62	**	-6.61	**	22.36	**	-14.66	**	-7.16	**	-2.51	**	0.21		-4.51	*	-0.22	
3	DPC 17 x JI 411	-2.40	*	-3.26	**	-3.94	**	-8.46	**	11.66	**	-20.01	**	1.05		-0.64		-0.24		-3.33	**
4	DPC 17 x DCS 85	-2.73	**	-1.53		-3.39	**	-7.13	**	-0.90		7.26	**	0.46		0.11		-2.00		6.32	**
5	DPC 17 x SKI 343	-3.16	**	-3.23	**	-2.14		-11.46	**	8.60	*	-5.26	**	0.24		0.09		-4.18	*	-9.49	**
6	DPC 17 x SKI 215	-2.15	*	-3.51	**	-8.19	**	-18.40	**	-0.78		26.34	**	-0.46		0.90	*	-0.15		-4.18	**
7	DPC 17 x JI 372	-2.65	**	-3.28	**	-7.92	**	-5.10	**	-17.87	**	-4.02	**	-1.96	**	-1.26	**	-5.30	**	-0.79	
8	DPC 17 x PCS 124	-2.87	**	-2.45	**	-6.89	**	-10.77	**	0.46		-9.93	**	0.41		-0.99		-2.51		-0.92	
9	DPC 17 x RG 2787	-1.29		-1.01		-4.89	**	-10.27	**	4.13		-9.68	**	-0.44		0.14		-6.10	**	1.59	
10	JI 353 x JI 368	-1.87	*	-5.67	**	-10.58	**	-7.65	**	-14.15	**	-0.52		-1.52	*	0.41		-3.15		11.55	**
11	JI 353 x JI 411	1.20		5.01	**	3.74	**	-11.49	**	0.98		-20.14	**	0.68		-1.02	*	-0.69		-4.23	**
12	JI 353 x DCS 85	0.87		4.74	**	4.96	**	2.17		-5.34		-14.98	**	-0.57		-2.53	**	-2.25		-3.88	**
13	JI 353 x SKI 343	-0.51		-3.95	**	-7.11	**	8.17	**	8.85	*	2.40		0.54		-0.50		0.83		-4.24	**
14	JI 353 x SKI 215	-0.21		3.43	**	7.16	**	9.23	**	16.71	**	-12.59	**	0.66		-0.46		3.40		-3.92	**
15	JI 353 x JI 372	-0.37		0.99		5.43	**	7.20	**	0.01		-3.44	*	0.79		0.54		-1.85		7.58	**
16	JI 353 x PCS 124	-0.26		0.15		5.80	**	-4.46	**	-1.55		9.67	**	0.43		0.41		1.54		0.77	
17	JI 353 x RG 2787	-0.34		2.26	**	9.13	**	-17.63	**	-0.64		13.44	**	0.98		0.80		4.41	*	-4.01	**
18	JI 368 x JI 411	-0.15		3.79	**	5.88	**	-8.18	**	-17.20	**	-16.00	**	0.11		-2.77	**	5.53	**	-6.06	**
19	JI 368 x DCS 85	-2.48	**	4.18	**	4.43	**	-1.85		4.40		-10.68	**	0.69		-0.15		0.77		-0.90	
20	JI 368 x SKI 343	2.79	**	7.82	**	12.35	**	-1.52		6.97		1.16		-0.29		-0.38		-2.77		-1.83	
21	JI 368 x SKI 215	0.09		1.87	*	0.30		-2.13		8.40	*	10.78	**	0.02		1.27	**	-2.10		4.97	**
22	JI 368 x JI 372	-0.40		-0.56		-2.08		0.50		6.88		-7.59	**	0.88		-0.76		4.60	*	-1.46	
23	JI 368 x PCS 124	-2.96	**	-5.53	**	-10.39	**	-1.49		-12.64	**	-5.00	**	0.03		-0.53		3.76	*	-1.62	
24	JI 368 x RG 2787	-0.04		2.04	**	9.60	**	-5.32		13.96	**	-4.37	**	1.84	**	-0.20		5.60	**	-1.66	
25	JI 411 x DCS 85	-1.40		0.21		-5.56	**	-0.68		17.77	**	-0.54		1.03		-0.30		9.30	**	1.39	

Sr. No.	Hybrids	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)			
		F_1		F_2		F_1		F_2		F_1		F_2		F_1		F_2		F_1		F_2	
26	JI 411 x SKI 343	-0.46		2.85	**	1.02		18.98	**	-9.41	*	-13.24	**	0.41		0.41		-0.93		2.69	*
27	JI 411 x SKI 215	-2.15	*	-4.42	**	-7.36	**	16.03	**	1.71		12.28	**	1.13		1.66	**	-3.70	*	9.54	**
28	JI 411 x JI 372	-1.98	*	-3.20	**	-4.42	**	-11.99	**	-20.39	**	-2.81		-2.47	**	0.01		-6.96	**	-8.87	**
29	JI 411 x PCS 124	-4.21	**	-6.03	**	-9.06	**	-4.99	**	-10.94	*	-0.29		0.00		0.22		-0.73		6.46	**
30	JI 411 x RG 2787	-4.29	**	-5.26	**	-10.72	**	-3.15	*	11.67	**	13.21	**	0.28		0.64		-0.36		1.41	
31	DCS 85 x SKI 343	0.20		-0.76		-0.91		3.64	**	6.60		8.47	**	0.45		0.85		-2.96		-8.67	**
32	DCS 85 x SKI 215	-4.82	**	-7.37	**	-11.81	**	-10.63	**	-8.97	*	-12.43	**	-0.88		-0.69		-6.59	**	-2.86	*
33	DCS 85 x JI 372	-3.65	**	-6.81	**	-9.86	**	-6.99	**	-10.67	**	-0.58		-0.95		0.92	*	-0.48		3.45	**
34	DCS 85 x PCS 124	-1.87	**	-1.31		-6.83	**	-11.99	**	-8.66		1.11		-1.38	*	0.23		-5.12	**	-2.19	
35	DCS 85 x RG 2787	-2.62	**	-3.20	**	-8.17	**	-7.15	*	-10.01	**	-1.63		-1.20	*	-1.20	**	0.91		-0.65	
36	SKI 343 x SKI 215	-2.21	*	-3.06	**	-4.56	**	-17.29	**	6.70		3.98	**	0.76		-1.53	**	6.55	**	-0.11	
37	SKI 343 x JI 372	-0.71		3.49	**	-0.95		-8.32	**	-6.86		-3.09	*	-0.41		1.08	*	1.43		7.26	**
38	SKI 343 x PCS 124	-0.93		-1.01		-3.58	**	4.34	*	-4.78		3.40		-1.30		0.09		0.66		12.02	**
39	SKI 343 x RG 2787	-2.01	*	-3.89	**	-7.58	**	14.17	**	0.80		10.94	**	-0.08		0.79		4.43	*	8.09	**
40	SKI 215 x JI 372	-5.40	**	-4.78	**	-12.67	**	9.73	**	-3.33		2.40		0.14		-0.49		3.63	*	3.22	*
41	SKI 215 x PCS 124	-2.96	**	-0.04		-5.64	**	-11.93	**	13.60	**	4.93	**	2.25	**	1.23	**	0.19		-3.03	*
42	SKI 215 x RG 2787	-1.71		5.15	**	6.68	**	9.89	**	6.56		2.62		2.06		0.71		2.93		-0.49	
43	JI 372 x PCS 124	-3.12	**	-2.06	**	-6.69	**	-7.96	**	5.07		-3.04	*	0.11		0.17		0.73		-5.14	**
44	JI 372 x RG 2787	-5.21	**	-5.28	**	-11.36	**	-7.13	**	2.99		-8.69	**	0.46		-1.53	**	-2.79		2.04	
45	PCS 124 x RG 2787	-1.43		3.21	**	1.33		6.53	*	6.73		-0.01		-0.70		-1.24	**	-1.12		-0.33	
SE(s_{ij}) ±		0.94		0.79		1.11		1.32		4.02		1.46		0.62		0.45		1.84		1.29	

* and ** significant at 5 % and 1 % levels of significance, respectively

Sr. No.	Hybrids	Effective length of primary raceme (cm)				Number of effective branches per plant				Number of capsules on primary raceme				100-seed weight (g)				Oil content (%)				Seed yield per plant (g)			
		F_1		F_2		F_1		F_2		F_1		F_2		F_1		F_2		F_1		F_2		F_1		F_2	
1	DPC 17 x JI 353	1.73		-1.56		0.32		1.53	**	9.32	**	-1.76		-2.80	**	-1.55	**	-0.45		-0.17		80.55	**	-1.58	
2	DPC 17 x JI 368	-3.62		0.57		0.74	**	1.99	**	-7.05	**	2.91	**	-2.04	**	-1.14	**	0.12		-0.32		33.01		17.38	
3	DPC 17 x JI 411	-0.05		-2.79		-0.47		0.73	**	1.39		-2.49	**	1.31	**	-1.99	**	-0.25		0.20		8.63		-43.49	
4	DPC 17 x DCS 85	-0.01		5.56	**	-0.49		-0.73	**	1.05		3.85	**	0.11		-4.65	**	0.21		-0.94	**	-33.76		-8.80	
5	DPC 17 x SKI 343	-3.07		-9.58	**	-0.38		-0.42	*	-0.98		-11.92	**	2.14	**	7.78	**	0.29		0.36		143.37	**	110.97	**
6	DPC 17 x SKI 215	-0.24		-4.62	**	-0.31		0.18		0.16		-6.13	**	-0.17		4.82	**	-0.01		0.83	*	13.95		152.90	**
7	DPC 17 x JI 372	-5.06	*	-1.54		0.63		-0.59	**	-8.66	**	-3.39	**	-0.49	*	1.55	**	-0.03		-0.33		4.27		-25.73	
8	DPC 17 x PCS 124	-2.91		-1.29		-0.47		-0.62	**	-6.16	**	-3.22	**	1.54	**	0.76		0.67	**	0.32		6.22		-0.97	
9	DPC 17 x RG 2787	-4.18	*	1.65		-0.04		0.00		0.58		1.08		4.05	**	-2.63	**	0.37		0.23		80.38	*	82.90	*
10	JI 353 x JI 368	-3.27		11.38	**	-0.20		0.45	*	-2.67		6.72	**	0.29		-1.45	**	-0.02		0.56		46.89	*	55.66	*
11	JI 353 x JI 411	0.23		-3.95	**	0.48		-0.39	*	-0.89		-5.95	**	-2.08	**	-1.95	**	0.33		-0.08		-39.10		-45.27	
12	JI 353 x DCS 85	-1.25		-3.36	*	-0.40		0.48	*	-5.59	**	-6.92	**	1.91	**	-2.42	**	0.43		0.18		-27.22		-18.67	
13	JI 353 x SKI 343	1.21		-4.33	**	0.04		-0.21		-3.17		-4.53	**	3.32	**	1.15	**	0.55		0.03		17.59		12.84	
14	JI 353 x SKI 215	3.17		-3.64	*	0.93	**	-0.12		0.36		-6.10	**	-1.17	**	4.24	**	0.02		-0.11		18.49		-0.82	
15	JI 353 x JI 372	-0.57		7.11	**	0.42		-0.02		-3.91	*	7.80	**	1.28	**	-0.73	**	0.50		-0.65	*	-5.18		-7.06	
16	JI 353 x PCS 124	0.80		0.42		-0.15		-0.18		7.81	**	2.46	**	1.25	**	6.69	**	0.39		0.54		28.77		73.52	**
17	JI 353 x RG 2787	3.33		-4.09	**	-0.28		-0.03		2.26		-2.04	*	3.37	**	4.58	**	0.05		0.14		14.14		55.32	*
18	JI 368 x JI 411	3.73		-4.42	**	0.36		-0.81	**	-2.94		-2.95	**	-1.59	**	0.31		-0.07		0.69	*	0.77		52.75	*
19	JI 368 x DCS 85	0.97		-0.95		-0.08		-0.77	**	2.49		-1.55		1.66	**	9.55	**	0.29		1.37	**	8.11		-9.30	
20	JI 368 x SKI 343	-0.44		-2.47	*	0.09		-0.08		0.91		-1.93	*	1.18	**	1.11	**	0.31		0.24		-80.51	**	-47.62	
21	JI 368 x SKI 215	-1.49		4.05	**	-0.07		0.70	**	1.50		5.93	**	0.49	*	2.06	**	0.37		0.20		13.56		-19.42	
22	JI 368 x JI 372	3.49		-2.20		-0.19		1.44	**	5.84	**	-1.77		-0.40		-5.57	**	-0.45		-1.20	**	-68.25	*	-54.93	**
23	JI 368 x PCS 124	3.77		-1.15		-0.23		0.18		2.93		-3.53	**	-0.74	*	-3.40	**	0.41		-1.58	**	1.63		-29.85	
24	JI 368 x RG 2787	2.53		-2.11		-0.03		-0.05		2.95		-2.28	*	-0.59		-1.31	**	0.33		0.10		143.53	**	47.99	
25	JI 411 x DCS 85	4.15	*	2.32		-0.30		0.44	*	15.26	**	3.16	**	-0.28		-3.43	**	0.37		0.21		38.92		48.81	
26	JI 411 x SKI 343	0.69		2.04		0.14		0.33		7.02	**	0.70		-1.42	**	2.25	**	-0.20		-0.07		51.00		26.90	
27	JI 411 x SKI 215	-2.41		9.04	**	-0.19		0.51	**	-2.01		8.61	**	0.51	*	-1.89	**	0.33		-0.79	*	109.24	**	68.71	**
28	JI 411 x JI 372	-5.49	**	-9.06	**	0.26		-0.75	**	-8.64	**	-10.21	**	0.53	**	-0.07		0.33		0.02		-25.63		6.62	
29	JI 411 x PCS 124	-1.94		5.66	**	-0.62		-0.56	*	-3.75		4.79	**	0.02		1.84	**	-0.23		-0.34		9.58		27.24	
30	JI 411 x RG 2787	1.94		2.35		-0.15		1.10	**	0.96		4.06		1.97	**	-2.44	**	0.20		-0.22		60.08		48.85	
31	DCS 85 x SKI 343	-3.19		-7.78	**	-0.21		-0.17		-4.11	*	0.38		-2.74	**	-0.17		-0.24		0.30		-13.06		3.37	
32	DCS 85 x SKI 215	-6.84	**	-2.85		-0.38		-0.70	**	-4.92	*	0.55		0.04		-5.03	**	0.19		-1.49	**	8.51		-13.57	
33	DCS 85 x JI 372	0.07		3.49	*	0.04		0.05		-2.68		3.10	**	-1.21	**	-3.01	**	0.33		0.05		75.23	*	53.46	*
34	DCS 85 x PCS 124	-2.87		-1.92		-0.27		0.52	**	-2.85		-2.60	*	-1.19	**	-0.89	**	-0.11		0.62	*	-68.01	*	-55.84	*
35	DCS 85 x RG 2787	-1.68		-0.64		-0.02		-0.01		-3.04		-0.84		2.12	**	1.38	**	0.32		-0.05		44.14		-12.83	
36	SKI 343 x SKI 215	7.16		0.80		-0.23		0.24		5.90	**	-0.51		0.40		-2.69	**	0.40		0.04		47.32		-5.51	
37	SKI 343 x JI 372	1.48		6.97	**	-0.18		-0.14		0.60		5.65	**	-1.82	**	-0.22		-0.18		0.17		16.44		18.43	
38	SKI 343 x PCS 124	-0.90		12.07	**	-0.42		0.54	**	-4.72	*	10.58	**	2.97	**	-1.36	**	0.44		-0.16		17.49		38.02	
39	SKI 343 x RG 2787	0.25		8.51	**	-0.16		-0.34	*	0.65		7.76	**	0.63		-0.19		0.25		0.09		-12.24		-20.87	

40	SKI 215 x JI 372	3.50		3.95	**	-0.41		0.54	**	5.12	**	1.62		2.87	**	1.66	**	0.21		0.68		33.61		38.85	

Sr. No.	Hybrids	Effective length of primary raceme (cm)				Number of effective branches per plant				Number of capsules on primary raceme				100-seed weight (g)				Oil content (%)				Seed yield per plant (g)			
		F_1		F_2		F_1		F_2		F_1		F_2		F_1		F_2		F_1		F_2		F_1		F_2	
41	SKI 215 x PCS 124	0.55		-1.76		2.36	**	0.63	**	2.22		1.16		-0.20		0.19		-0.47		0.71	*	52.83	*	29.71	
42	SKI 215 x RG 2787	3.94		-0.62		1.33	**	0.54	*	2.78		0.21		1.08	*	2.43	**	0.38		-0.03		36.66		78.97	**
43	JI 372 x PCS 124	-1.72		-4.97	**	-0.67	*	-0.27		5.32	**	-2.75	**	1.52	**	2.36	**	0.32		0.54		75.49	**	-31.82	
44	JI 372 x RG 2787	-3.33		2.16		-0.17		0.26		-4.85	**	0.81		0.21		3.70	**	-0.45		-0.05		-36.61		-24.97	**
45	PCS 124 x RG 2787	1.04		-1.05		-0.05		-0.02		1.67		-2.39	**	3.62	**	-3.50	**	0.00		0.26		37.90		48.74	
SE(s_{ij}) ±		2.07		1.49		0.28		0.20		1.92		0.97		0.21		0.25		0.25		0.33		36.91		33.60	

* and ** significant at 5 % and 1 % levels of significance, respectively

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