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Research Article

Identification of early, wilt resistant and good combining male lines of castor (*Ricinus Communis* L.,) suitable for rainfed conditions

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Abstract
Prolonged crop duration (150-210 days) and tall plant height (>100 cm) of castor either hinders its adaptability to newer and niche areas or fitting into the cropping sequence of conventional castor growing areas. The present study aims at evaluating male lines for their agro-morphological characters, combining ability for seed yield, yield components and resistance to *Fusarium* wilt. Node number to primary, first and second order of secondary (P, S_1 and S_2) racemes were taken as indicators of flowering and maturity duration of male lines while data on plant height up to primary spike was recorded for plant stature. Twenty-six improved monoecious lines were evaluated for their agro-morphological characters in an ARBD design along with three checks replicated five times during 2017-18 *kharif* season. Simultaneously all the 26 lines were screened for wilt resistance in wilt sick plot in two replications. Nineteen monoecious lines were resistant to wilt (0-20% wilt incidence) while four lines were moderately resistant to wilt (20-30%). Four lines *viz*., ICS-121, ICS-150, ICS-127 and ICS-139 were promising with significantly low node number to P, S_1 and S_2 order of racemes compared to early maturing check, DCS-9 (12.1, 5.8, 4.9). Eight male lines were significantly shorter than the very tall type checks, 48-1 and DCS-107 (>85 cm) while ICS-121 (57.5 cm) was on par with the medium statured check, DCS-9 (59.7 cm). Fifteen hybrids, generated by crossing three pistillate lines and five selected wilt resistant male lines in a line x tester design were evaluated along with eight parents and two hybrid checks during 2019-20 *kharif* season. SKP-84 (pistillate line) and ICS-139 (male line) were identified as good combiners for seed yield and majority of the yield components.

Keywords: Monoecious, combining ability, gca, sca, Castor

INTRODUCTION

Castor, a perennial, rainfed crop has been transformed as the most successful commercial crop suitable for both rainfed and irrigated conditions owing to the success story of castor hybrids (Lavanya and Varaprasad, 2012). Castor oil and its derivatives are used in multiple sectors ranging from agriculture, food, papers, plastic and rubber, cosmetics, perfumes etc. (Liv *et al.*, 2012, Lu *et al.,* 2019). In India it is cultivated in 0.83 m.ha with an annual production of 1.9 m.t and a productivity of 2.3 t ha^{-1} (Anonymous, 2022-23). However, castor area in India and elsewhere is decreasing due to several biotic stresses *viz*., gray rot, wilt, leaf eating caterpillars, capsule borer and sucking pests. Plant protection measures during monsoon season are difficult to be carried out due to luxurious vegetative growth and medium to tall plant height. Research parameters need to focus on development of short and early maturing genotypes in a high yielding back ground.

Castor, being a monotypic genus, parental line diversity is generated through intra specific or inter varietal hybridization using single to multiple crosses involving dominant resistant sources to wilt, leaf hopper or moderately resistant sources to gray rot

(Lavanya *et al.,* 2018). Segregating generations are handled mostly through pedigree method of selection (Liv *et al.,* 2012), while single seed descent (SSD) method also resulted in nearly 30 new male lines (Lavanya *et al.,* 2021). Nearly 300 diverse monoecious lines and several advanced selections have been developed during the last five years at ICAR-Indian Institute of Oilseeds Research (IIOR). Promising male lines were further evaluated for their combining ability for seed yield and yield components to be used in heterosis breeding programme. In the present study, an attempt was made to characterize five new monoecious lines for agro-morphological characters, wilt resistance and combining ability through a line x tester mating design.

MATERIALS AND METHODS

Twenty six monoecious lines developed through recombination breeding were evaluated in an Augmented RBD along (ARBD) with three checks, viz., DCS-9, 48-1 and DCS-107 during *kharif* 2017-18. Ten seeds of each entry were sown in a single row of 6 m length with a spacing of 90 x 60 cm and three checks, DCS-9, 48-1, DCS-107 were repeated after every five entries. In addition to the data on seed yield and yield components, number of nodes to S_1 and S_2 were also recorded. The data were analyzed for seed yield and yield components based on standard procedure followed for ARBD analysis.

The same set of entries were screened under wilt sick plot conditions at ICAR-IIOR, Hyderabad in two replications at a spacing of 90 x 60 cm during *kharif* 2017-18. Susceptible and resistant checks *viz*., JI-35 and 48-1 were sown after every five test genotypes. Inoculum load of 2×10^3 CFU/g of soil was maintained in the sick plot. The data on number of total plants and wilted plants at monthly intervals was recorded up to 150 DAS and wilt incidence in percent was derived using the formula: [(number of wilted plants/ total number of plants) x 100]. Based on wilt incidence % in sick plot, entries were ranked as highly resistant (0-10%), resistant (10.1-20%), moderately resistant (20.1-40%), moderately susceptible (50.1-75 %) and highly susceptible (>75%) (Santhalakshmi *et al.* 2019).

Five promising wilt resistant monoecious lines *viz*., ICS-127, ICS-128, ICS-134, ICS-139 and ICS-141 were identified based on screening in the sick plot. These lines were used as pollen parents and hybridized with three pistillate lines *viz*., M-574, IPC-21 and SKP-84 in a line x tester mating fashion during *Rabi* 2018-19 which resulted to 15 hybrids. The fifteen hybrids along with eight parental lines and two hybrid checks, ICH-66 and GCH-8 were sown in a randomized block design with three replications during *kharif* 2019-20 in single row plot and a spacing of 90 x 60 cm under rainfed conditions. Adoption of agronomic packages and data recording on seed yield and its components were done as per guidelines of AICRP-castor network (Suresh *et al*., 2020). Data on agronomic characters like seed yield (g/plant), plant height up to primary spike (cm), number of nodes to primary raceme, total primary spike length (cm), effective primary spike length (cm), number of capsules per primary, hundred seed weight (g) and oil content (%) were recorded from five randomly selected plants. Seed sample (15g) randomly collected from each genotype was used to estimate oil content using Nuclear Magnetic Resonance (NMR) method and expressed in per cent (%). Combining ability analysis was performed following standard procedure using OPSTAT software.

RESULTS AND DISCUSSION

Castor being a monotypic genus still maintains lot of diversity for several morphological characters like stem color, bloom, spike compactness, capsule spines, branching and plant types like normal or dwarf types etc. Majority of the morphological characters are monogenic with no linkage. Genetic diversity is created through planned single, double or triple crosses involving genotypes with diverse morphological characters at IIOR. Single plant selection of morphological recombinants in segregating generations following pedigree method and progeny row selection resulted in 26 promising advanced selections.

Based on the adjusted means of ARBD analysis, 12 monoecious lines of castor with significantly higher seed yield compared to the best high yielding check, DCS-107 (328 kg/ha) were identified for further use **(Table 1)**. Among them, except ICS-126, ICS-138, ICS-141, six male lines *viz*., ICS-121, ICS-135, ICS-137, ICS-128, ICS-142, ICS-139 (0-10%) were highly resistant while three male lines viz., ICS-124, ICS-127 and ICS-144 were resistant to wilt (10.0-20%) (**Table 1**).

Data on mean and range of promising monoecious lines for yield components like plant height, number of nodes to primary raceme, S_1, S_2, total and effective primary spike length, number of effective spikes per plant and hundred seed weight are presented in **Table 2**. As per the ideal plant type worked out for rainfed conditions, genotypes with short to medium plant height (30-60 cm), low to medium node number to primary spike (10-14), longer productive spikes (50-60 cm) and higher hundred seed weight (28-32g) are preferred (Lakshmamma *et al.,* 2000).

Flowering and maturity duration to first and second picking in castor are indirectly measured through the node number to primary, S_1 and S_2 racemes as each node takes approximately 3-6 days to develop on the main or secondary stem (Manjunatha *et al*., 2020, Moshkin, 1986). In the present study, four monoecious lines *viz*., ICS-121, ICS-150, ICS-127 and ICS-139 were identified as early maturing compared to DCS-9 with low node number to primary (12.1), S_1 (5.8) and S_2 (4.9). Ramana et al (2005) in their study of 5 x 5 line x tester analysis identified good combiners for S_1 and S_2, in addition to the node number to primary spike. Effective primary spike length

Table 1. Promising male lines of castor for seed yield, components and wilt resistance

Entry	PHT	NPR	NS1	NS2	TPSL	EPSL	ESPP	HSW	FSY	Wilt incidence (%)
ICS-121	57.5	12.6	4.6	4.6	35	34.2	12.1	26.1	668	6.7
ICS-127	82.2	12.4	4.9	4.2	44.9	45	9.7	30	637	18.3
ICS-138	87.7	14	6.1	4.2	43.2	41.2	9.6	35.6	603	**29.2**
ICS-135	98.2	14.6	5.3	4.4	44.3	44.2	12.1	37.2	562	0.0
ICS-141	89.9	13.6	6.9	5.6	43	44.2	7.0	22.8	520	25.6
ICS-126	103.9	14.7	6.4	5.9	43.5	42.8	9.0	27.9	495	47.2
ICS-137	97.6	13.6	5.3	4.6	56.3	57.6	15.3	34.4	490	7.6
ICS-128	102.8	13.4	6.5	5.6	30.1	32.2	7.1	27.3	486	0.0
ICS-144	69.3	14.6	6.2	5.8	36.2	35.4	9.3	23.5	474	16.7
ICS-142	89.5	16.6	6.6	6.2	41.4	40.6	10.9	22	473	5.0
ICS-124	110.7	16.4	6.6	6	40.8	40.0	7.5	25.2	401	17.2
ICS-139	67.5	11.8	5.5	5	31.8	28.8	6.6	32.5	398	3.8
DCS-9 (C)	59.7	12.1	5.8	4.9	31.3	30.6	7.3	26	159	Nt
48-1 (C)	108	15	6.5	5.8	38.4	37.1	8.2	26.5	200	2.5
DCS-107 (C)	113.5	14.8	6.6	6	38.9	38.6	7.6	32.2	328	3.0
JI-35 (Susceptible check)										95.8
Mean	84.8	13.4	6.3	5.5	37	36.5	8.2	28.4	302.7	
CV (%)	17.4	8.1	6.4	6.2	9.9	10.4	11.5	9.2	12	
C D (p=0.05)										
Check vs genotype	15.8	NS	0.4	0.4	3.9	4.1	1	2.8	39.1	
Genotypes within block	44.8		1.2	1.0	11.1	11.5	2.9	8	110.6	
Genotypes bet. blocks	54.8	NS	1.5	1.3	13.6	14.1	3.5	9.7	135.5	
Between checks	39.6		1.1	0.9	9.8	10.1	2.5	7	97.8	

PHT-Plant height up to primary (cm), NPR, NS1, NS2-Number of nodes to primary, secondary 1 and secondary 2, TPSL/EPSL-Total/Effective primary spike length, ESPP-Number of effective spikes per plant, HSW-Hundred seed weight, FSY-Final seed yield (kg/ha)

Score for wilt resistance: 0-10%: Highly resistant; 10.1-20%: Resistant; 20.1-40%-Moderately resistant; 40.1-50% Moderately susceptible; 50.1 to 75% Susceptible; >75% highly susceptible. Nt-Not tested

Table 2. Improvement for yield components and seed yield in 26 male lines of castor

Trait	Mean	Range	SD	Promising entries		Best check	C.D. p=(0.05) between varieties and checks
				Number	Promising*		
PHT	87.5	52.8-123.6	18.3	3	ICS-121 (57.5), ICS-150 (52.8)	DCS-9 (59.7)	15.8
NPR	13.7	10.7-16.6	1.4	5	ICS-150 (10.7), ICS-139 (11.8)	DCS-9 (12.1)	ns
NS1	6.1	4.6-9.4	0.9	8	ICS-121 (4.6),ICS-127 (4.9)	DCS-9 (5.8)	0.4
NS2	5.3	4.2-9.0	1.0	5	ICS-121 (4.6), ICS-127 (4.2)	DCS-9 (4.9)	0.4
TSPL	41.4	30.1-61.3	7.4	12	ICS-133 (61.3), ICS-137 (56.3)	DCS-107(38.9)	3.9
ESPL	41.3	28.8-61.8	8.0	10	ICS-133 (61.3), ICS-137 (56.3)	DCS-107(38.6)	4.1
ESPP	9.3	6.3-15.3	2.4	12	ICS-137 (15.3), ICS-132 (13.9)	48-1 (8.2)	1
HSW	28.0	18.1-37.2	4.8	2	ICS-135 (37.2), ICS-138 (35.6)	DCS-107 (32.2)	2.8
SY	392	117-668	137	12	ICS-121 (668), ICS-127 (637) ICS-135 (562), ICS-141 (5200	DCS-107 (668)	39.1

PHT-Plant height up to primary (cm), NPR, NS1, NS2-Number of nodes to primary, secondary 1 and secondary 2, TPSL/EPSL-Total/Effective primary spike length, ESPP-Number of effective spikes per plant, HSW-Hundred seed weight, SY-Final seed yield (kg/ha) was maximum in ICS-133 (61.8 cm) followed by ICS-137 (57.6cm) while 12 monoecious lines were significantly superior to the best check, 48-1 (8.2) for number of effective spikes per plant. Five monoecious lines *viz*., ICS-127, ICS-128, ICS-134, ICS-139 and ICS-141 were selected based on their node number, plant height and other yield components as pollen parents for crossing with three pistillate lines *viz*., M-574, IPC-21, SKP-84 in a line x tester design (**Table 3**). Morphological characters indicated that all the selected monoecious lines have red stem color, double bloom and spiny capsules except ICS-139 which has green stem color.

Four male lines *viz*., ICS-121, ICS-150, ICS-127 and ICS-139 were earlier than the earliest maturing check, DCS-9 based on the node number to Primary (12.1), secondary one and two (5.8 and 4.9). Based on the DUS guidelines, six male lines viz., ICS-127, ICS-138, ICS-141, ICS-126, ICS-137, ICS-142 were significantly shorter than the very tall type checks, 48-1 and DCS-107 (>85 cm) while ICS-144 (69.3 cm) and ICS-139 (67.5 cm) were significantly the shortest. The line ICS-121 (57.5 cm) was on par with the medium statured check, DCS-9 (59.7 cm) (Chakrabarty *et al.,* 2009).

The analysis of variance of combining ability for pick-wise yield, total seed yield and its components indicated highly significant mean squares due to genotypes for all the eleven characters (**Table 4**). The study indicated presence of genetic variation for all the 11 characters among 25 genotypes. Lines and testers mean sum of squares were also significant for all the characters except for oil content and effective spike length in case of testers. A similar trend was observed in case of mean sum of squares of line x testers also. The ratio of GCA and SCA variance was low or close to unity for all the characters except for 100-seed weight indicating predominance of non-additive gene action. Several researchers have reported similar results in castor on general and specific combining for majority of the characters (Lavanya *et al*., 2006, Madariya *et al*., 2008, Liv *et al*.,2012, Lavanya *et al*.,2018, Ramya *et al*., 2018, Lavanya and Mukta, 2020).

The estimates of general combining ability of lines and testers indicated that SKP-84 is the good combiner for majority of the characters *viz*., total seed yield, pick-wise seed yield at 90 DAS and 150 DAS, tall plant height, higher node number and 100-seed weight. DPC-21 is a good combiner for pick-wise seed yield at 120 DAS, short plant height, lower node number while M-574 is a good combiner for number of capsules per primary spike. Both M-574 and SKP-84, dwarf pistillate lines are good combiners for tall plant height (**Table 5**). Among testers, ICS-139 is a good combiner for seed yield and all the yield components except total primary spike length and oil content. Another tester, ICS-127 is a good combiner for pick-wise seed yield at 150 DAS, short plant height, lower node number and early flowering to primary spike. None of the lines and testers were good combiners for total primary spike length and oil content except ICS-141 and ICS-128 respectively.

Among the 15 crosses, the top five crosses for per se performance along with their sca effects are given in **Table 5**. Three high yielding crosses *viz*., M-574 x ICS-139, SKP-84 x ICS-128, SKP-84 x ICS-127 recorded

Table 3. Analysis of variance for combining ability of eight parents for 12 characters in a L x T design of castor

Source of variation	**DF**	**Days to 50 % flowering**	**Final seed yield (g/pl)**	**Pick-wise seed yield (g/pl) at**			**Total primary spike length (cm)**	**Effective primary spike length (cm)**	**Number of capsules /primary spike**	**Hundred seed weight (g)**	**Plant height up to primary spike (cm)**	**Number of nodes to primary**	**Oil content (%)**
				90 DAS	120 DAS	150 DAS							
Replications	2	24.304ns	139.3 ^{ns}	54.8 ^{ns}	10.9 ^{ns}	2.8 ^{ns}	4.8 ^{ns}	49.8 **	146.2**	1.5 ^{ns}	28.1 ^{ns}	1.8 ^{ns}	12.4 **
Genotypes	22	65.105**	3933.4 **	950.4 **	330.4 **	1332.1 **	136.6 **	130.2**	837.9 **	42.1 **	2400 **	16.5 **	12.4 **
Parents	7	86.47**	5474.9 **	211.6 ^{ns}	382.553**	3210.891**	277.595**	296.833**	1305.565**	49.15**	2485.828**	35.308**	23.813**
P vs C	1	69.567**	6864.786	7737.314	0.017	26.977	7.548	39.239	293.536	323.478	26126.59	0.674	86.401
Crosses	14	0.111ns	2953.266**	835.083**	327.877**	485.976**	75.27**	53.381**	642.994**	18.494**	663.047**	8.178**	1.354ns
Lines (L)	4	326.803**	7757.582**	2169.2**	704.236**	433.028**	166.056**	124.667**	1581.478**	48.21**	1165.32**	11.604**	2.099 ns
Testers (T)	2	58.975**	1373.253**	407.23*	48.961**	641.864**	6.689*	28.467ns	256.689**	20.559**	851.414**	24.088**	0.005ns
L x T	8	1.383	946.111**	274.987**	209.427**	473.478**	47.022**	23.967*	270.328**	3.12*	364.819**	2.488**	1.318ns
Error	44	16.198	86.256	44.459	3.65	27.408	5.493	9.204	14.327	1.787	58.686	0.556	1.058
σ2 GCA		5.32	301.61	84.44	13.93	5.33	3.28	4.38	54.06	2.61	53.63	1.28	-0.02
σ2 sCA		2.248	288.19	75.12	68.73	152.74	13.89	5.28	84.91	0.61	100.58	0.69	0.03
σ2 GCA/ σ2 SCA		2.37	1.05	1.12	0.20	0.03	0.24	0.83	0.64	4.28	0.53	1.87	-0.71

*, ** significant at 5 % and 1 % level of probability respectively

Table 4. *Per se* performance and GCA effects of eight parents for 12 characters in a L x T design of castor

Genotype	Final seed yield (g/pl)		Seed yield at 90 das (g/pl)		Seed yield at 120 das (g/pl)		Seed yield at 150 das (g/pl)		Plant height up to primary spike (cm)	
	Mean	GCA	Mean	GCA	Mean	GCA	Mean	GCA	Mean	GCA
Lines										
M-574	94.967	-3.218	47.667	-0.078	10.767	0.673	36.533	-3.807**	59.267	4.067**
DPC-21	178.4	-7.544**	54.5	-5.171**	13.267	1.373**	110.6	-3.747**	112.933	-8.693**
SKP-84	79.267	10.762**	45.667	5.249**	12.733	-2.047**	20.867	7.553**	67	4.627**
Testers										
ICS-127	125.2	-3.118	53.267	-1.327	25.8	-4.298**	46.133	2.493*	63.867	-7.249**
ICS-128	130.7	-0.551	46.667	-5.593**	35.3	-0.142	48.7	5.204**	122.933	8.418**
ICS-134	96.633	-11.296**	59.133	-1.427	18	-3.964**	19.5	-5.918**	126.8	2.773
ICS-139	169.467	47.471**	56.733	25.318**	39.1	15.236**	73.633	6.938**	88.6	11.796**
ICS-141	56.367	-32.507**	32.667	-16.971**	11.2	-6.831**	12.467	-8.718**	63.433	-15.738**

Genotype	Number of nodes to primary		Total primary spike length (cm)		Effective primary spike length (cm)		No. of capsules/primary		Hundred seed weight (g)		Oil content (%)		Days to 50% flowering	
	Mean	GCA	Mean	GCA	Mean	GCA	Mean	GCA	Mean	GCA	Mean	GCA	Mean	GCA
Lines														
M-574	16.067	0.044	52.333	-0.756	52.333	-1.533*	67.333	4.644**	27.133	-1.24**	42.867	0.004	54.333	0.711
DPC-21	16.667	-1.289**	55.667	0.244	55.667	0.4	93.333	-3.289**	27.433	0.153	43.067	-0.029	54	-0.222
SKP-84	21.8	1.244**	56	0.511	56	1.133	52.333	-1.356	22.133	1.087**	37.3	0.024	54.333	-0.489
Testers														
ICS-127	10.333	-0.556**	39	-0.889	38.333	-1.222	52.667	-7.511**	21.8	-2.811**	46.033	0.107	44	-2.644*
ICS-128	13.6	0.556**	48.333	-3.444**	43.667	-1.889*	98.333	4.933**	24.2	-1.556**	44.233	0.762*	49	2.244*
ICS-134	14.133	-0.267	32	-3.222**	30.333	-4.333**	58	-8.289**	34.4	3.078**	46.367	-0.06	52	3.244**
ICS-139	14.267	1.622**	35	0.444	35	2.333**	96.667	21.156**	27.933	1.278**	43.467	-0.482	48.333	3.356**
ICS-141	12.3	-1.356**	38.333	7.111**	37.333	5.111**	54.333	-10.289**	24.733	0.011	42.0	-0.327	39.667	-6.2**

*, ** significant at 5 % and 1 % level of probability respectively

Table 5. Top five crosses with high sca and *per se* performance for seed yield and components

Seed yield (g/pl)	Mean	SCA	Effective primary spike length (cm)	Mean	SCA
SKP-84 x ICS-139	203	7.216	DPC-21 x ICS-141	51.0	3.489*
M-574 x ICS-139	195	13.762**	SKP-84 x ICS-141	47.3	-0.911
SKP-84 x ICS-128	159	11.338**	DPC-21 x ICS-139	44.7	-0.067
DPC-21 x ICS-139	156	-20.978**	SKP-84 x ICS-139	44.7	-0.8
SKP-84 x ICS-127	153	8.271*	M-574 x ICS-139	43.7	0.867
Days to 50 % flowering	**Mean**	**SCA**	**Number of capsules/primary spike**	**Mean**	**SCA**
SKP-84 x ICS-141	40	-3.067	M-574 x ICS-139	108	5.911**
DPC-21 x ICS-127	43	-3.889*	SKP-84 x ICS-139	95	-1.089
DPC-21 x ICS-141	45	1.333	DPC-21 x ICS-139	89	g
M-574 x ICS-141	46	1.733	M-574 x ICS-134	85	12.356**
SKP-84 x ICS-127	48	1.711	M-574 x ICS-128	84	-1.533
Node number	**Mean**	**SCA**	**Hundred seed weight (g)**	**Mean**	**SCA**
DPC-21 x ICS-141	11.3	-0.711*	SKP-84 x ICS-134	35.3	0.336
M-574 x ICS-127	13.0	-1.178**	SKP-84 x ICS-139	33.8	0.669
DPC-21 x ICS-127	13.3	0.489	DPC-21 x ICS-134	33.5	-0.531
DPC-21 x ICS-128	13.7	-0.289	DPC-21 x ICS-139	32.9	0.669
M-574 x ICS-134	13.9	-0.6*	M-574 x ICS-134	32.8	0.196
Plant height (cm)	**Mean**	**SCA**	**Oil content (%)**	**Mean**	**SCA**
DPC-21 x ICS-141	109	4.604	M-574 x ICS-128	46.9	0.618
SKP-84 x ICS-141	110	-7.849*	DPC-21 x ICS-128	46.1	-0.149
DPC-21 x ICS-128	116	-12.684**	DPC-21 x ICS-127	46.1	0.473
M-574 x ICS-127	117	-8.578*	DPC-21 x ICS-134	46.0	0.573
M-574 x ICS-141	121	3.244	SKP-84 x ICS-141	46.0	0.787
Total primary spike length (cm)	**Mean**	**SCA**			
DPC-21 x ICS-141	56.3	5.089**			
SKP-84 x ICS-141	48.7	-2.844*			
M-574 x ICS-141	48.0	-2.244*			
M-574 x ICS-134	45.3	5.422**			
DPC-21 x ICS-139	44.7	0.089			

*, ** Significant at 5 % and 1 % level of probability respectively

significant sca effects for seed yield. None of the top five high yielding crosses showed significant sca effects for other characters except M-574 X ICS-139 for the number of capsules per primary. The cross DPC-21 x ICS-141 with higher per se performance for early flowering (45 DAS), lower node number (11.3), lower plant height to primary spike (109 cm), total and effective primary spike length (56.3 cm, 51 cm) showed significant SCA effect for node number, total and effective primary spike length. The cross involving the two best combiners, SKP-84 and ICS-139 recorded maximum seed yield (203 g/pl) but with non-significant sca effects. Manivel *et al.* (1998) in their study on combining ability for earliness indicated that there was no correlation of *per se* performance with either gca of parents or sca of hybrids.

Among the 5 crosses with significant sca effects, two crosses involved high (SKP-84) x medium (ICS-127, ICS-128) combiners while two other crosses involved medium (M-574) x high (ICS-139) or medium (M-574) x poor (ICS-134) combiners for seed yield. High sca effects in these four crosses may be due to combination of favorable additive effects of good (high) general combiner parents (SKP-84, ICS-139) and epistatic effects of medium or poor combiner parents (M-574, ICS-127, ICS-128, ICS-134) with its favorable plant attribute. The cross DPC-21 x ICS-141 involved both poor combiners for seed yield indicating over dominance due to dominance x dominance type of non-allelic gene interaction. Majority of the superior cross combinations involved either low x low or high x low general combiners. In a 4 x 9 line x tester analysis, Mohan *et al*. (2006) reported that per se performance of the hybrids is not correlated with sca effects and involved combination of parents with high x high, high x low or low x low *gca* effects for yield and yield components. Similar results were reported by Chandramohan *et al*. (2006), Patel *et al*. (2007) and Kavani *et al*. (2010).

The present study indicated that SKP-84 and ICS-139 are good combiners for seed yield and majority of the yield components and can be used for development of high yielding castor hybrids. Among the top five high seed yielding crosses, the two crosses *viz*., M-574 x ICS-139, SKP-84 x ICS-128 with high seed yield and significant *sca* effects can further be confirmed for their yield superiority in large scale plots. Further, DPC-21 a desirable pistillate line for its good GCA for short plant type need to be further exploited for heterosis breeding by crossing with large number of diverse male lines.

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