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Research Article

GENETIC STUDIES FOR THE EXPLOITATION OF HYBRID VIGOUR FOR SEED YIELD AND COMPONENT CHARACTERS IN CASTOR (*Ricinus communis* L.)

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Abstract- Forty five hybrids which were developed through half diallel mating design (ten inbred lines) were evaluated along with their parents to study heterosis for seed yield and its related traits in castor. The analysis of variance revealed that the mean square values due to genotypes, parents and crosses were significant, which suggested differences among themselves for all the characters under study. Among parental genotypes, inbreds namely ANDCI 8, ANDCI 10-04, ANDCI 10-1, ANDCI 9 and JI 360 yielded superior heterotic crosses for seed yield and its component characters. The cross combinations *viz*., ANDCI 8 x ANDCI 10-04,ANDCI 8 x ANDCI 10-3 and ANDCI 8 x ANDCI 10-12exhibited significant and positive heteros is over the standard check for seed yield per plant. Among the crosses, cross combinations, JI 360 x ANDCI 10-1 and ANDCI 8 x ANDCI 10-04 also exhibited significant and desirable heterotic effects (RH and HB) for number of effective branches per plant and number of secondary spikes per plant. The heterosis for seed yield per plant appeared because of high manifestation of heterosis for component traits, *viz*., primary raceme length, effective raceme length, number of capsules per primary raceme, kernel, length and volume weight. In consideration to dominance effect, all the characters except number of nodes up to primary raceme and kernel width revealed that increasing alleles had dominant effects; thereby more number of parents contributed dominant genes causing increasing effect. For days to 50% flowering as well as maturity of primary raceme exhibited that genes responsible for lateness were dominant; while, the characters plant height up to primary raceme and oil content suggested that both increasing and decreasing genes showed dominance effect and different parents contributed accordingly. Hence, selection of crosses on the basis of per se performance with observed heterosis for important seed yield contributing traits would be more desirable to exploit heterosis on commercial scale in castor.

Keywords- Diallel analysis, Heterosis, Dominance effect and Castor.

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Introduction

Oilseed crops are next to cereals in production of agricultural commodities in India, which occupy a place of prime importance in Indian economy. Among the oilseed crops, castor (*Ricinus communis* L., 2n = 2x = 20) is one of the most important non-edible oilseed crops widely cultivated in the arid and semi-arid regions of the world [1]. The genus Ricinus is monotypic and *R. communis* is the only species with the most polymorphic forms known. In castor, its monoecious nature favours cross pollination, and it is up to the extent of 50 per cent. Castor is believed to have most probably originated in Ethiopian-East African region. It is grown in tropical, sub-tropical and temperate regions of the world. It is cultivated in about 30 countries on commercial scale. Among those, India, Brazil, China, Russia, Thailand and Philippines are the principle castor growing countries. In India, It is known from very early days and is referred in Susruta Samhita written over 2,000 years ago [2]. Castor seed contains 47 to 55 per cent oil. Due to its unique chemical and physical properties, the oil from castor seed is used as raw material for numerous and varied industrial applications, such as for manufactures of polymers, coatings, lubricants for aircrafts, cosmetics etc. and for the production of biodiesel [3]. Being the largest producer, India is also largest exporter of castor seed oil. Total area under castor crop in India for the year 2014-15 is 10.14 lakh hectares with production 17.33 lakh tones and average yield is 1666 kg/ha. The major castor growing states in India are Gujarat, Andhra Pradesh, Rajasthan, TamilNadu, Karnataka and Orissa. Gujarat is leading castor growing state, where the crop was grown in around 7.15 lakh ha with 14.56 lakh tones production and productivity of 2036 kg/ha during 2014-15 [4]. In Gujarat, Banaskantha, Mehsana and Sabarkantha are major castor growing districts. The phenomenon of heterosis has proved to be the most important genetic tool in enhancing the yield of self as well as cross pollinated crop species in general and castor in particular. The exploitation of heterosis on commercial scale in castor is regarded as one of the major breakthrough in the improvement of productivity of castor. Castor is highly cross pollinated crop and with the availability of pistillate lines, heterosis has been successfully exploited on commercial scale. In order to achieve high-yielding cross combinations, it is essential to evaluate available promising diverse lines and their hybrid combinations for yield and its attributes. Hence, the proposed investigation in castor was undertaken using 10 x 10 diallel excluding reciprocals among inbreds (monoecious lines) to study the extent of heterosis, heterobeltiosis and standard heterosis for seed yield and related traits to identify best heterotic cross combinations for commercial exploitation..

MaterialsandMethods

The experimental material comprised of ten parents (Inbreds), their 45 crosses and one standard check hybrid (GCH-7) was evaluated in Randomized Complete Block Design with three replications during kharif season of the year 2012-2013 at Regional Research Station, Anand Agricultural University, Anand, Gujarat. Each test genotypes was grown in a single row of 10 plants as an experimental unit by adopting 120 x 60 cm spacing. All the recommended agronomic practices followed time to time to raise a good crop. Data were recorded on five randomly selected plants from each net plot of parents and F1s in all the three replications. Mean value on per plant basis were recorded for various characters *viz*., days to 50 % flowering as well as maturity of primary raceme, plant height up to primary raceme (cm), number of nodes up to primary raceme, number of effective branches per plant, length of primary raceme (cm), effective length of primary raceme (cm), number of capsules on primary raceme, number of secondary as well as tertiary spikes per plant, total number of capsules per plant, shelling out turn (g), test weight of 100 kernels (g), kernel length (mm), kernel width (mm), volume weight (g), seed yield per plant (g) and oil content (%).The observations on days to 50% flowering and days to maturity of primary raceme were recorded on plot basis. The oil content of kernels was measured by Nuclear Magnetic Resonance (NMR) technique. For which, a random sample of 15 grams kernels was taken from the bulk sample of representative plants of each experimental unit. Analysis of variance technique suggested by [5] and reviewed by [6] for Randomized Complete Block Design was followed to test the differences among the genotypes for the characters under study. Heterosis expressed as per cent increase or decrease in the mean value of F1 hybrid over mid parent i.e, relative heterosis [7], over better parent i.e., heterobeltiosis [8] and over standard check (GCH 7) i.e., standard heterosis [9] were computed for each character.

Results and Discussion

The results obtained under the present investigation are presented in [Table-1] to 3]. The analysis of variance revealed that the mean square values due to genotypes, parent and crosses were significant which suggested differences among themselves for all the characters under study [Table-1]. The perusal of results of heterotic effects over mid parent (RH), better parent (HB) and over check hybrid (SH) for various characters revealed that the magnitude and extent of various heterotic effects varied with cross combinations and characters, which indicated that parents differed for contributing increasing and decreasing genes causing dominance effect. Among the hybrids, hybrid ANDCI 10-12 x ANDCI 10-11 (P6 x P8) took the least days for 50 % flowering (36.33) as well as 50 % maturity (103.67) of primary raceme. The said hybrid also flowered earlier than check hybrid GCH-7 (52.66 days).The highest mean value was observed with parent ANDCI 10-12 (219.17g) for seed yield per plant followed by ANDCI 8 (211.39g), while, hybrid ANDCI 8 x ANDCI 10-04 (P3 x P4) had the highest seed yield per plant (251.93g). The estimates of standard heterosis over check hybrid GCH-7 varied from -31.01 (ANDCI 10-12 x ANDCI 10-11) to 2.53 (SKI 215 x ANDCI 10-1) per cent. A comparative performance of the most five heterotic crosses for seed yield per plant and its component characters is presented in [Table-2]. The perusal of results revealed that for seed yield per plant, cross ANDCI 8 x ANDCI 10-04 (P3 x P4) depicted high estimates for all types of heterotic effects and the crosses ANDCI 10-1 x ANDCI 9 (P7 x P9) and JI 360 x ANDCI 10-1 (P2 x P7) registered high estimates of both relative heterosis and heterobeltiosis. In addition to above crosses, crosses ANDCI 10-12 x ANDCI 10-11 (P6 x P8) and ANDCI 8 x ANDCI 10-3 (P3 x P5) also depicted high estimates of RH and SH, respectively. All these crosses also recorded higher seed yield, cross ANDCI 8 x ANDCI 10-04 (P3 x P4) had the highest seed yield followed by crosses ANDCI 8 x ANDCI 10-3 (P3 x P5), ANDCI 8 x ANDCI 10-12 (P3 x P6) and JI 360 x ANDCI 10-12 (P2 x P6). The cross ANDCI 10-1 x ANDCI 9 (P7 x P9) exhibited significant and desirable heterotic effects (RH and HB) for days to 50 % flowering of primary raceme, number of nodes up to primary raceme, number of secondary spikes per plant, number of tertiary spikes per plant, total number of capsules per plant, days to 50 % maturity of primary raceme and volume weight. While the crosses JI 360 x ANDCI 10-1 (P2 x P7) and ANDCI 8 x ANDCI 10-04 (P3 x P4) exhibited significant and desirable heterotic effects (RH and HB) for number of effective branches per plant and number of secondary spikes per plant. The top ranking cross ANDCI 8 x ANDCI 10-04 (P3 x P4) also depicted significant and desired RH and HB for plant height up to primary raceme, number of effective branches per plant, number of secondary spikes per plant, number of tertiary spikes per plant and kernel length.

The persual of the above findings revealed that the crosses, which had higher estimates of RH for seed yield also had positive effects for component characters *viz.,* number of effective branches per plant, number of secondary spikes per plant, number of tertiary spikes per plant, total number of capsules per plant and volume weight. Therefore, heterotic effect for seed yield per plant could be outcome of direct effect of these attributes, and could be outcome of indirect effects of other yield contributing attributes like number of effective branches per plant and total number of capsules per plant. Hence, heterotic effects for seed yield per plant could be a result of combinational heterosis. However, positive and negative estimates of heterosis for rest of the component characters could have checked each other for outcome of net heterotic effects for seed yield. Thus, to obtain maximum heterotic effects for seed yield, desired level of heterosis of each component character need to be worked out. Among parental genotypes, inbreds ANDCI 8 (P3), ANDCI 10-04 (P4), ANDCI 10-1 (P7), ANDCI 9 (P9) and JI 360 (P2) yielded the superior heterotic crosses for seed yield and its component characters.

In present study the magnitude of RH was positive with low to moderate estimates; while, magnitude of HB was negative with moderate estimates. The results are in agreement with the reports of [10-12] for RH and with the findings of [12-15] While the present findings differed from the reports of [10,15, 11] for HB as they reported positive magnitude. The estimates of dominance effect [Table-3] ranged from -0.67 (ANDCI 10-11 x ANDCI 1) to 22.00 (ANDCI 10-3 x ANDCI 1). Out of 45 hybrids; only 6 hybrids showed negative estimates, whereas 39 hybrids exhibited positive estimates. In consideration to dominance effect, the characters *viz*. number of effective branches per plant, length of primary raceme, effective length of primary raceme, total number of capsules on primary raceme, number of secondary spikes per plant, number of tertiary spikes per plant, total number of capsules per plant, shelling out turn, test weight of 100 kernels, kernel length, volume weight and kernel yield per plant revealed that increasing alleles had dominant effects, thereby more number of parents contributed dominant genes causing increasing effect. While, the characters *viz.* number of nodes up to primary raceme and kernel width resulted that the large number of decreasing genes causing dominant effect. For days to 50% flowering as well as maturity of primary raceme exhibited that genes responsible for lateness were dominant while, the characters plant height up to primary raceme and oil content suggested that both increasing and decreasing genes showed dominance effect and different parents contributed accordingly.

Conclusion

Based on per se performance and effect of heterosis five hybrid *viz.*, ANDCI 8 x ANDCI 10-04 (P3 x P4), ANDCI 8 x ANDCI 10-3 (P3 x P5), ANDCI 8 x ANDCI 10-12 (P3 x P6), JI 360 x ANDCI 10-112 (P2 x P6) and SKI 215 x ANDCI 10-04 (P1 xP2) were selected, which significantly out yielded the check GCH 7 and could be exploited through heterosis breeding programme. Further the cross ANDCI08 x ANDCI 10-04 also exhibited desirable heterosis over the mid-parent, better parent and standard check for earliness and its related traits, days to flowering, days to maturity and number of nodes up to primary spike. Hence, such crosses could be handled to drive high yielding and short duration castor hybrids.

Conflict of Interest: None declared

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Table-1 *Analysis of variance for various characters of castor*

Source of variation	d.f.	Mean Square values																	
		Days to 50 % flowering of primary raceme	Plant height up to primary raceme	Number of nodes up to primary raceme	Number of effective branches per plant	Length of primary raceme	Effective length of primary raceme	Number of capsules on primary raceme	Number of secondary spikes per plant	Number of tertiary spikes per plant	Total number of capsules per plant	Days to 50 % maturity of primary raceme	Shelling out turn	Test weight of 100 kernels	Kernel length	Kernel width	Volume weight	Seed yield per plant	Oil content
Replications	2	6.29	68.11	0.97	1.09	47.26	51.23	67.13	0.68	0.55	99.45	15.97	7.23	0.64	0.23	0.071	74.28	215.19	0.42
Genotypes	55	47.97**	675.21**	7.04**	32.17**	221.37**	254.65**	595.36**	6.43**	9.21**	2501.30**	171.40**	6.76**	21.59**	0.46**	0.44**	1456.26**	2230.09**	8.77**
Parents	9	62.74**	1533.13**	11.61**	78.95**	454.29**	484.80**	1006.13**	11.00**	20.52**	3067.40**	315.11**	10.83**	24.15**	0.53**	0.67**	3353.09**	2797.03**	21.43**
Hybrids	44	41.90**	506.21**	6.20**	22.58**	146.02**	188.81**	494.08**	5.33**	6.76**	2313.93**	130.72**	5.87**	21.55**	0.44**	0.41**	955.20**	2045.64**	6.46**
Parents Vs Hybrids	1	168.29**	183.58*	0.87	2.14	1434.09**	1065.12**	1263.55**	9.50**	15.30**	6720.95**	389.09**	9.13	5.86**	0.95**	0.029	7862.26**	5823.07**	0.001
Check Vs Hybrids	1	74.89**	828.16**	9.46**	61.68**	160.83**	205.40**	571.81**	9.06**	7.29**	1063.09*	502.21**	5.89	14.85**	0.005	0.072	112.64	1278.07	5.30**
Error	110	2.38	31.26	0.32	2.32	16.49	16.82	35.50	0.34	0.44	211.45	7.59	2.71	0.59	0.109	0.026	101.28	397.80	0.29

*,** Significant at 5 % and 1 % levels, respectively.

Table-2 *Manifestation of Relative Heterosis (RH), Heterobeltiosis (HB) and Standard Heterosis for other characters in five top ranking crosses for seed yield per plant.*

Crosses	*Per se* performance for seed yield per plant (g)	Estimates of heterotic effects for seed yield per plant	Heterotic effects for other characters								
			Days to 50 % flowering of primary raceme	Plant height up to primary raceme	Number of nodes up to primary raceme	Number of effective branches per plant	Length of primary raceme	Effective length of primary raceme	Number of capsules on primary raceme	Number of secondary spikes per plant	Number of tertiary spikes per plant
		Relative Heterosis									
P_7 x P_9	229.31	33.80**	-6.58**	2.73	-10.97**	9.83**	6.74**	4.89**	-1.63	25.53**	16.48**
P_6 x P_8	216.66	28.91**	-17.11**	-17.56**	-5.32**	38.71**	35.78**	36.56**	41.33**	44.52**	52.76**
P_3 x P_8	203.20	23.77**	-6.32**	11.56**	1.55	49.71**	30.43**	24.57**	15.32**	19.48**	72.37**
P_3 x P_4	251.93	21.53**	-1.61*	-8.38**	-1.65*	25.00**	0.75	-0.33	3.61**	20.59**	43.56**
P_2 x P_7	205.08	19.54**	-8.44**	7.48**	-2.78**	23.35**	23.98**	11.69**	-3.42*	36.59**	9.62**
Heterobeltiosis											
P_7 x P_9	229.31	31.39**	-5.69**	22.92**	-9.61**	-8.06**	2.30	0.76	-4.11*	10.28**	8.57**
P_3 x P_4	251.93	19.18**	-1.29	-5.52**	-0.83	15.56**	-7.28**	-8.51**	-2.02	6.03**	27.17**
P_3 x P_5	247.91	17.28**	-1.30	9.68**	0.89	-16.13**	0.97	0.86	0.64	-3.91*	-5.96**
P_2 x P_7	205.08	17.26**	-4.08**	26.88**	7.14**	16.27**	16.72**	6.88**	-5.96**	34.94**	-5.79**
P_9 x P_{10}	204.40	14.89**	-1.32	6.89**	-5.58**	2.90	-10.22**	-6.80**	11.66**	6.92**	5.16**
Standard Heterosis											
P_3 x P_4	251.93	13.26**	-3.79**	-9.62**	-2.46**	-19.75**	-1.80	-2.29	3.99**	-12.46**	-25.24**
P_3 x P_5	247.91	11.45**	-4.43**	-9.42**	-6.97**	-19.75**	6.94**	7.71**	6.81**	-12.96**	-9.27**
P_3 x P_6	238.65	7.29**	-10.13**	-14.70**	-2.46**	-51.23**	3.00*	3.12*	4.97**	-28.83**	-34.19**
P_2 x P_6	234.07	5.23*	-10.76**	-18.22**	-5.33**	-21.60**	-3.86**	-4.59**	3.13*	-21.00**	-20.13**
P_1 x P_4	233.28	4.87*	-3.16**	-6.91**	-2.87**	-8.02**	-9.08**	-9.45**	-10.95**	-8.90**	-0.96

Table-2 *Continue……..*

Crosses	Heteротic effects for other characters							
	Total number of capsules per plant	Days to 50 % maturity of primary raceme	Shelling out turn	Test weight of 100 kernels	Kernel length	Kernel width	Volume weight	Oil content
Relative Heterosis								
P_7 x P_9	34.55**	-6.40**	-4.19**	-0.25	0.24	-1.79**	2.72**	-1.20**
P_6 x P_8	17.36**	-6.75**	2.85**	3.41**	0.97	-0.52	12.46**	4.82**
P_3 x P_8	36.97**	-5.29**	2.09**	11.93**	4.56**	0.95*	3..39**	0.97**
P_3 x P_4	10.34**	-3.94**	1.01	-0.37	2.27**	-1.60**	1.89**	-0.95**
P_2 x P_7	11.09*	-4.84**	0.81	7.02**	1.82**	0.95*	6.36**	2.76**
Heterobeltiosis								
P_7 x P_9	24.19**	-3.12**	-5.83**	-3.33**	-1.80*	-3.29**	1.30**	-1.41**
P_3 x P_4	2.35	0.27	-1.25*	-5.85**	2.05**	-5.39**	0.67	-4.95**
P_3 x P_5	14.18**	-0.82	-3.96**	9.58**	0.12	5.15**	-4.23**	-5.58**
P_2 x P_7	3.53	-2.54**	0.79	-1.23*	-0.37	-0.97	5.63**	0.00
P_9 x P_{10}	6.78*	8.38**	1.07	-9.34**	-2.24**	-2.74**	-0.29	-2.23**
Standard Heterosis								
P_3 x P_4	6.45**	-8.96**	-1.91**	-13.52**	4.15**	-7.93**	5.63**	-2.41**
P_3 x P_5	4.13	-9.70**	-4.60**	0.65	1.74*	2.33**	0.49	-3.06**
P_3 x P_6	16.74**	-20.59**	-1.09	-8.54**	6.21**	-3.98**	1.68**	-10.00**
P_2 x P_6	-2.75	-7.46**	-0.23	1.54*	0.45	0.73	3.71**	-2.35**
P_1 x P_4	-2.02	-1.74*	-2.68**	-5.50**	-0.57	-2.44**	-1.72**	-1.10**

Table-3 *Estimation of dominance effects for different eighteen characters in castor*

Crosses	Code	Characters								
		Days to 50 % flowering of primary raceme	Plant height up to primary raceme	Number of nodes up to primary raceme	Number of effective branches per plant	Length of primary raceme	Effective length of primary raceme	Number of capsules on primary raceme	Number of secondary spikes per plant	Number of tertiary spikes per plant
SKI 215 X JI 360	$P_1 \times P_2$	0.56	-0.26	-1.10	-0.81	18.00	1.22	3.58	-0.40	-0.66
SKI 215 X ANDCI 8	$P_1 \times P_3$	2.09	0.44	-1.00	-0.25	0.40	0.48	-0.54	0.64	0.17
SKI 215 X ANDCI 10-04	$P_1 \times P_4$	1.40	14.26	1.33	-0.16	1.27	1.16	0.57	-0.45	0.24
SKI 215 X ANDCI 10-3	$P_1 \times P_5$	1.67	-0.79	-0.54	-1.16	9.18	11.80	0.84	-0.31	-0.77
SKI 215 X ANDCI 10-12	$P_1 \times P_6$	0.65	0.03	-5.25	-0.34	1.73	0.95	-0.17	-0.21	-0.39
SKI 215 X ANDCI 10-1	$P_1 \times P_7$	0.50	0.00	-2.00	-0.02	1.58	1.21	0.24	0.75	-0.62
SKI 215 X ANDCI 10-11	$P_1 \times P_8$	-0.44	0.07	0.30	-0.19	0.99	1.02	0.42	-0.06	-0.29
SKI 215 X ANDCI 9	$P_1 \times P_9$	1.86	-0.58	-1.44	-0.51	4.38	2.86	2.67	-0.32	-0.04
SKI 215 X ANDCI 1	$P_1 \times P_{10}$	1.29	-0.38	2.13	-1.15	1.58	0.57	5.32	-0.80	-0.79
JI 360 X ANDCI 8	$P_2 \times P_3$	1.86	0.77	-0.59	19.33	0.60	0.31	-1.00	19.40	6.50
JI 360 X ANDCI 10-04	$P_2 \times P_4$	2.00	0.62	0.21	-0.45	2.13	1.41	0.35	-0.64	5.40
JI 360 X ANDCI 10-3	$P_2 \times P_5$	7.00	0.32	-0.45	0.06	11.27	199.00	1.16	0.96	0.22
JI 360 X ANDCI 10-12	$P_2 \times P_6$	13.00	0.45	-1.06	2.83	3.49	2.56	1.54	8.33	1.45
JI 360 X ANDCI 10-1	$P_2 \times P_7$	1.86	-0.49	0.30	3.83	3.85	2.59	-1.26	30.00	0.59
JI 360 X ANDCI 10-11	$P_2 \times P_8$	-0.62	-0.86	-0.76	0.29	1.05	1.05	0.30	-1.82	3.33
JI 360 X ANDCI 9	$P_2 \times P_9$	1.36	-12.20	-0.09	0.73	4.76	17.00	51.67	2.17	1.57
JI 360 X ANDCI 1	$P_2 \times P_{10}$	12.00	-1.27	0.58	0.39	0.21	1.22	1.80	-0.02	1.15
ANDCI 8 X ANDCI 10-04	$P_3 \times P_4$	5.00	2.77	2.00	3.06	0.09	-0.04	0.63	1.50	3.38
ANDCI 8 X ANDCI 10-3	$P_3 \times P_5$	5.00	-0.22	0.73	0.16	1.08	1.06	1.11	0.75	0.78
ANDCI 8 X ANDCI 10-12	$P_3 \times P_6$	3.00	2.79	-0.60	-3.20	0.72	0.62	0.74	23.00	0.36
ANDCI 8 X ANDCI 10-1	$P_3 \times P_7$	3.29	0.01	1.00	1.11	0.59	0.35	-0.32	7.00	0.48
ANDCI 8 X ANDCI 10-11	$P_3 \times P_8$	0.44	-0.26	-0.06	4.25	0.73	0.51	0.46	1.36	11.00
ANDCI 8 X ANDCI 9	$P_3 \times P_9$	3.50	-1.56	0.64	0.33	0.13	0.40	-0.10	1.63	1.41
ANDCI 8 X ANDCI 1	$P_3 \times P_{10}$	9.00	-1.44	0.36	0.41	0.45	0.53	0.41	0.05	0.67
ANDCI 10-04 X ANDCI 10-3	$P_4 \times P_5$	4.00	0.64	1.11	0.93	1.43	0.84	13.10	1.33	1.34
ANDCI 10-04 X ANDCI 10-12	$P_4 \times P_6$	0.43	-0.16	-0.43	6.00	4.52	8.73	5.10	1.15	0.46

Table-3 *Continue...............*

Crosses	Code	Characters								
		Days to 50 % flowering of primary raceme	Plant height up to primary raceme	Number of nodes up to primary raceme	Number of effective branches per plant	Length of primary raceme	Effective length of primary raceme	Number of capsules on primary raceme	Number of secondary spikes per plant	Number of tertiary spikesper plant
ANDCI 10-04 X ANDCI 10-1	P_4 x P_7	2.67	-0.36	0.25	10.38	8.00	4.86	0.84	1.40	3.55
ANDCI 10-04 X ANDCI 10-11	P_4 x P_8	0.75	-0.31	0.02	0.62	1.04	1.01	0.49	0.44	-0.09
ANDCI 10-04 X ANDCI 9	P_4 x P_9	1.67	-0.96	1.13	0.14	0.95	1.00	1.54	5.89	0.25
ANDCI 10-04 X ANDCI 1	P_4 x P_{10}	7.00	-0.36	0.17	-0.07	25.25	5.85	1.23	1.29	-0.08
ANDCI 10-3 X ANDCI 10-12	P_5 x P_6	7.80	0.06	-0.60	-0.37	6.37	4.07	7.55	0.79	-0.88
ANDCI 10-3 X ANDCI 10-1	P_5 x P_7	1.50	-1.01	0.09	0.25	2.70	3.15	0.04	1.00	0.80
ANDCI 10-3 X ANDCI 10-11	P_5 x P_8	0.63	0.05	-0.04	0.46	1.06	0.99	0.11	0.90	0.80
ANDCI 10-3 X ANDCI 9	P_5 x P_9	5.40	-0.97	4.50	0.00	73.67	27.44	-0.29	0.43	0.27
ANDCI 10-3 X ANDCI 1	P_5 x P_{10}	22.00	-2.35	1.20	-27.00	1.73	2.78	0.36	-9.00	-2.50
ANDCI 10-12 X ANDCI 10-1	P_6 x P_7	-0.08	-0.12	4.67	-0.67	12.80	1.34	0.11	-2.00	-5.67
ANDCI 10-12 X ANDCI 10-11	P_6 x P_8	1.36	0.35	0.24	2.06	1.13	0.92	1.40	3.00	2.84
ANDCI 10-12 X ANDCI 9	P_6 x P_9	-0.20	-0.45	-3.00	-0.64	2.64	1.75	1.39	0.33	-0.64
ANDCI 10-12 X ANDCI 1	P_6 x P_{10}	7.00	0.20	1.40	-0.28	1.93	5.32	0.57	-0.71	0.89
ANDCI 10-1 X ANDCI 10-11	P_7 x P_8	-0.04	-2.17	0.18	-1.48	0.37	0.51	1.07	-1.53	-1.05
ANDCI 10-1 X ANDCI 9	P_7 x P_9	7.00	-0.17	7.29	0.50	1.55	1.19	-0.63	1.85	2.26
ANDCI 10-1 X ANDCI 1	P_7 x P_{10}	2.20	-0.32	2.81	-1.06	-7.00	-46.60	0.76	-1.08	-1.29
ANDCI 10-11 X ANDCI 9	P_8 x P_9	0.67	-0.48	-0.01	0.32	1.12	1.01	0.86	0.90	1.68
ANDCI 10-11 X ANDCI 1	P_8 x P_{10}	-0.67	-0.23	0.65	0.17	0.09	-0.45	1.20	0.13	0.00
ANDCI 9 X ANDCI 1	P_9 x P_{10}	1.57	-2.57	2.71	7.00	-0.63	-0.54	2.46	1.78	2.07
Range	Min.	-0.67	-12.20	-5.25	-27.00	-7.00	-46.60	-1.26	-9.00	-5.67
	Max.	22.00	14.26	7.29	19.33	73.67	199.00	51.67	30.00	11.00
No. of positive crosses		39	17	27	26	43	41	37	30	30
No. of negative crosses		6	28	18	19	2	4	8	15	15
Average dominance effect		3.33	-0.21	0.42	0.57	4.69	6.11	2.44	2.24	0.89

Table-3 *Continue……….*

Crosses	Code	Characters								
		Total number of capsules per plant	Days to 50 % maturity of primary raceme	Shelling out turn	Test weight of 100 kernels	Kernel length	Kernel width	Volume weight	Seed yield per plant	Oil content
SKI 215 X JI 360	$P_1 \times P_2$	0.79	0.57	-0.80	0.56	4.84	3.19	0.65	0.79	0.15
SKI 215 X ANDCI 8	$P_1 \times P_3$	-2.65	1.63	1.52	2.27	1.29	-0.09	-0.04	-27.61	-10.55
SKI 215 X ANDCI 10-04	$P_1 \times P_4$	0.49	-0.18	0.93	0.64	-0.06	0.04	-0.19	7.74	0.02
SKI 215 X ANDCI 10-3	$P_1 \times P_5$	2.65	0.60	1.79	0.16	0.80	-0.05	0.75	9.49	-1.51
SKI 215 X ANDCI 10-12	$P_1 \times P_6$	0.32	0.37	1.68	4.60	0.08	-0.93	3.52	-2.84	0.06
SKI 215 X ANDCI 10-1	$P_1 \times P_7$	-1.20	4.50	-0.75	2.30	0.20	2.05	0.80	0.02	-3.60
SKI 215 X ANDCI 10-11	$P_1 \times P_8$	-0.16	0.55	1.65	0.34	1.01	-0.18	1.16	-0.10	0.04
SKI 215 X ANDCI 9	$P_1 \times P_9$	1.96	0.61	5.00	1.48	5.46	0.29	1.39	1.48	-1.37
SKI 215 X ANDCI 1	$P_1 \times P_{10}$	1.74	0.66	2.78	24.53	2.80	1.67	1.15	0.96	-0.01
JI 360 X ANDCI 8	$P_2 \times P_3$	0.98	18.50	1.61	0.66	1.67	0.17	-0.81	0.85	0.07
JI 360 X ANDCI 10-04	$P_2 \times P_4$	0.42	1.00	0.73	0.56	0.76	0.68	0.72	2.09	3.68
JI 360 X ANDCI 10-3	$P_2 \times P_5$	2.01	1.30	-0.03	-0.15	1.01	-0.03	0.08	1.49	-1.23
JI 360 X ANDCI 10-12	$P_2 \times P_6$	0.75	-0.36	0.52	-0.02	0.28	-0.94	2.87	1.67	1.68
JI 360 X ANDCI 10-1	$P_2 \times P_7$	1.52	2.05	40.53	0.84	0.83	0.49	9.23	10.05	1.00
JI 360 X ANDCI 10-11	$P_2 \times P_8$	1.06	0.13	0.58	0.10	-0.51	0.98	-0.29	0.18	0.30
JI 360 X ANDCI 9	$P_2 \times P_9$	-0.04	7.50	0.75	-0.43	7.81	-0.85	0.70	-13.11	0.44
JI 360 X ANDCI 1	$P_2 \times P_{10}$	1.47	0.83	1.48	-0.62	0.53	-0.72	0.54	14.76	5.23
ANDCI 8 X ANDCI 10-04	$P_3 \times P_4$	1.33	0.94	0.44	-0.06	10.58	-0.40	1.56	10.91	-0.22
ANDCI 8 X ANDCI 10-3	$P_3 \times P_5$	12.50	1.19	-5.33	2.77	1.02	2.25	-1.48	12.84	-1.77
ANDCI 8 X ANDCI 10-12	$P_3 \times P_6$	3.24	1.26	-0.14	-1.31	5.87	-1.80	0.57	6.01	-1.36
ANDCI 8 X ANDCI 10-1	$P_3 \times P_7$	0.59	6.47	2.56	39.62	8.51	0.41	0.90	1.16	-10.19
ANDCI 8 X ANDCI 10-11	$P_3 \times P_8$	1.49	0.68	0.57	2.05	3.38	1.63	0.36	0.83	0.10
ANDCI 8 X ANDCI 9	$P_3 \times P_9$	12.02	5.67	-1.59	-2.27	2.23	-5.14	0.26	0.19	-20.15
ANDCI 8 X ANDCI 1	$P_3 \times P_{10}$	2.49	0.92	0.36	0.08	0.08	-0.55	1.36	0.91	-0.44
ANDCI 10-04 X ANDCI 10-3	$P_4 \times P_5$	0.71	-13.00	2.05	61.06	0.69	16.72	-0.48	15.59	0.65
ANDCI 10-04 X ANDCI 10-12	$P_4 \times P_6$	1.98	-1.42	-0.72	-0.21	-2.56	-0.58	0.72	0.32	1.23

Table-3 *Continue………*

Crosses	Code	Characters								
		Total number of capsules per plant	Days to 50 % maturity of primary raceme	Shelling out turn	Test weight of 100 kernels	Kernel length	Kernel width	Volume weight	Seed yield per plant	Oil content
ANDCI 10-04 X ANDCI 10-1	P_4 x P_7	1.46	0.87	0.32	0.37	-4.00	-0.48	2.49	1.01	-0.41
ANDCI 10-04 X ANDCI 10-11	P_4 x P_8	-0.40	2.52	0.46	0.00	0.74	-0.02	-0.18	0.11	-0.94
ANDCI 10-04 X ANDCI 9	P_4 x P_9	0.80	1.80	0.27	-1.37	0.86	-0.40	0.79	0.76	-0.46
ANDCI 10-04 X ANDCI 1	P_4 x P_{10}	0.37	1.95	2.58	-0.14	-0.68	-0.13	7.60	1.00	13.88
ANDCI 10-3 X ANDCI 10-12	P_5 x P_6	3.98	-0.33	-12.18	-1.81	-0.02	-0.14	0.99	1.29	-0.34
ANDCI 10-3 X ANDCI 10-1	P_5 x P_7	0.20	0.17	2.30	-0.79	0.20	-0.01	0.66	0.03	0.19
ANDCI 10-3 X ANDCI 10-11	P_5 x P_8	1.19	0.46	0.16	-8.69	-0.18	-0.11	1.06	0.40	0.21
ANDCI 10-3 X ANDCI 9	P_5 x P_9	0.17	1.84	-1.62	-3.64	-0.03	-0.64	15.96	-1.13	0.00
ANDCI 10-3 X ANDCI 1	P_5 x P_{10}	2.19	0.50	1.12	0.19	1.41	-0.18	-13.20	0.57	0.60
ANDCI 10-12 X ANDCI 10-1	P_6 x P_7	0.64	0.36	0.73	7.15	1.83	-1.63	2.08	1.13	0.24
ANDCI 10-12 X ANDCI 10-11	P_6 x P_8	0.56	3.46	0.87	0.48	0.48	-0.23	6.93	0.95	1.17
ANDCI 10-12 X ANDCI 9	P_6 x P_9	0.17	-0.86	-3.34	-1.00	0.19	-6.88	1.09	0.90	-0.36
ANDCI 10-12 X ANDCI 1	P_6 x P_{10}	-0.79	-2.58	0.44	1.33	3.98	-2.15	1.17	-0.32	0.96
ANDCI 10-1 X ANDCI 10-11	P_7 x P_8	1.28	-0.22	-0.18	0.03	-4.29	-1.22	1.10	0.52	0.22
ANDCI 10-1 X ANDCI 9	P_7 x P_9	4.14	1.89	-2.41	-0.08	0.11	-1.15	1.94	18.36	-5.50
ANDCI 10-1 X ANDCI 1	P_7 x P_{10}	1.29	0.70	0.08	-1.83	-11.90	-1.79	2.00	-2.16	-0.38
ANDCI 10-11 X ANDCI 9	P_8 x P_9	-0.13	1.00	1.95	3.07	3.64	-0.48	1.41	0.06	0.25
ANDCI 10-11 X ANDCI 1	P_8 x P_{10}	0.55	-9.67	6.60	-0.03	-4.18	-0.89	1.22	0.19	1.99
ANDCI 9 X ANDCI 1	P_9 x P_{10}	2.27	-0.49	1.77	-0.56	-0.06	-4.20	0.31	16.65	0.37
Range	Min.	-2.65	-13.00	-12.18	-8.69	-11.90	-6.88	-13.20	-27.61	-20.15
	Max.	12.50	18.50	40.53	61.06	10.58	16.72	15.96	18.36	13.88
No. of positive crosses		38	35	33	26	33	13	37	38	26
No. of negative crosses		7	10	12	19	12	32	8	7	19
Average dominance effect		1.52	1.03	1.29	2.94	1.04	-0.10	1.37	2.15	-0.58