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COMBINING ABILITY ANALYSIS FOR SEED YIELD AND ITS CONTRIBUTING TRAITS IN LINSEED (*Linum usitatissimum* L.)

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ABSTRACT
A field experiment was conducted at Crop Research Centre (Chirodi), Sardar Vallabhbhai Patel University of Agriculture & Technology, Meerut (U.P.), during *Rabi* 2012-13 and 2013-14 to estimate combining ability (GCA and SCA) of seed yield and its components of linseed. The experimental material comprised of ten parents and their 45_s F2. The hybrids F2 were evaluated along with their parents in randomized complete block design with three replications. It revealed highly significant variances for GCA and SCA for all the characters. Combining ability studies revealed that the lines Shekhar, Kiran, T-397 and Mukta, which were showed high general combining ability effects in desirable direction for seed yield and yield components. Moreover,. Among the specific cross combinations, the crosses for seed yield per plant viz., Kiran × T-397, Shubhra × Hira, Neelam × Hira, T-397 × Neelam and T-397 × Hira exhibited good specific combining ability effects for seed yield and its contributing traits.

INTRODUCTION

Linseed *(Linum usitatissimum* L.) is an ancient plant, which is also known as flax. Linseed (2n = 30) is one of the first crops domesticated by man. Every part of the linseed plant is utilized commercially either directly or after processing. India is the third largest producer in the world (Kiran *et.al*. 2012). In India, the crop is mainly cultivated in the states like Madhya Pradesh, Chhattisgarh, Uttar Pradesh, Maharashtra, Rajasthan, West Bengal, Karnataka, Orissa and Bihar. Chhattisgarh is one of the important linseed growing states of India, which account 112.52 thousand hectare area and 34.20 thousand metric tons production (Deepak Gauraha *et.al*.2011). However, in the world it covers 2270.35 thousand hectare area with production of 2238.94 thousand tons having productivity of 986.16 kg per hectare, where as in India it covers 338 thousand hectares area and a production of 147 thousand tons with the productivity of 434.91 kg per hectare, (Anonymous, 2013). Linseeds, particularly in their ground form are a great vegetarian source of the Omega 3 essential fatty acid, Alpha-Linolenic Acid (ALA). Linseed oil is an edible oil in demand as a nutritional supplement as a source of á-Linolenic acid (an omega-3 fatty acid) (Simopoulos 2002 and Hassanein M.S. *et.al* 2012). Combining ability is a powerful tool to select good combiners and thus selecting the appropriate parental lines for hybridization programme. In addition, the information on nature of gene action will be helpful to develop efficient crop improvement programme. General combining ability is due to additive and additive × additive gene action and is fixable in nature while specific combining ability is due to non-additive gene action which may be due to dominance or epistasis or both and is non-fixable. The presence of non-additive genetic variance is the primary justification for initiating the hybrid breeding programme (Cockerham, 1961). Several workers like Singh *et al*. (1990), Khorgade *et al*. (1993) and Kumar and Paul (2015) have reported combining ability on seed yield and its attributing traits in linseed.

There are several techniques for the evaluation of varieties or strains in terms of their combining ability especially diallel mating system set excluding reciprocals. This technique was developed by Jinks and Hayman (1953). Keeping in view with the above problem, the present investigation is taken up with the following objectives: To study the general and specific combining ability of parents and crosses for seed yield and yield contributing characters.

MATERIALS AND METHODS

The experiment field was conducted at Crop Research Centre, SardarVallabhbhai Patel University of Agriculture & Technology, Meerut (U.P.), during Rabi 2012-13. The experimental material comprised of ten parents namely, Sweta, Garima, Shekhar, Surbhi, Shubhra, Kiran, T-397, Neelam, Heera and Mukta and their all possible single cross was made under 10 × 10 diallel (Jinks 1953 and Hayman 1953) mating system set excluding reciprocals. The final trial was laid out in Randomized Block Design (RBD) with 45 $F_{1's}$ and ten diversified parents during the year rabi 2013-14 in three replications. The observations were recorded on 5 randomly taken plants per entry and per replication in case of parents and 45 crosses.

Data on the basis of randomly taken competitive plants were recorded on viz., days to 50% flowering, days to maturity, plant height (cm), primary branches per plant, secondary branches per plant, capsules per plant, seeds per capsule, biological yield per plant (g), seed yield per plant (g), harvest index (%), 1000-seed weight (g) and oil content. Oil content of each genotype was determined by Soxhlet procedure (BIS No. 15:548 Part I 1964 and Official and Tentative Methods 1973).

RESULTS AND DISCUSSION

Analysis of variance for combining ability

The combining ability analysis under diallel mating approach was done by the procedure advocated by Griffing (1956), which involves the study of covariances of full sibs and covariances of half sibs to get the estimates of general combining ability and specific combining ability variances and their effects. Analysis of variance for combining ability (Table 1) exhibited the variance due to general combining ability highly significant for all the characters and specific combining ability variance was also observed highly significant for all the traits, indicating involvement of both additive and non-additive types of gene action in the inheritance of these characters. Similar trend of involvement of both additive and non-additive gene action has been earlier reported (Kalia,1972, Patil and Chopde, 1983, Khorgade *et al*., 1993), Popescu *et al*.,1995), Singh *et al*., 2008), Mohammadi *et al*., 2010, Yadav *et al*., 2013, Pali and Mehta, 2014).

The variance components for ó^{2}s values were found higher than estimates values ó^{2}g for all the characters, suggesting major role of additive gene action in expression of these traits. Similar kind of additive gene action for various attributes was reported earlier by Nie *et al*. (1991), Pillai *et al*. (1995), Awasthi and Rao (2005), Singh *et al*. (2008), Goral *et al*. (2008),Yadav *et al*. (2013) and Pali and Mehta (2014).

The proportion of ó2g / ó2s being less than unity for days to 50% flowering, days to maturity, plant height, number of primary branches per plant, number of capsules per plant, number of secondary branches per plant, number of seeds per capsule, 1000 seed weight, biological yield per plant, harvest index, oil content and seed yield per plant suggested that involvement of non-additive kind of gene action for these characters, which indicated that involvement of additive type of gene action for this trait. The similar findings are in conformity with Mishra and Rai (1993), Popescu *et al*. (1995), Tiwari (1999), Awasthi and Rao (2005), Mohammadi *et al*. (2010) and Yadav *et al*. (2013).

The mean degree of dominance (ó^{2}g / ó^{2}s)^{½} was found greater than unity for all the characters, indicating the genetic control of over dominance type of gene effect in them. These types of findings were also reported by Kaushal *et al*. (1974), Rai and Das (1975), Patil and Chopde (1983), Manfroni *et al*. (1989), Khorgade *et al*. (1993), Vishnu *et al*. (2005) and Yadav *et al*. (2013).

General combining ability effects

The estimates of general combining ability effects and *per se* performance of ten parents for all the 12 attributes are presented

Table 1: Analysis of variance for combining ability of yield and its components in linseed(*Linum usitatissimum*L.)

Source of variation	D.F.	Days to 50% flowering	Days to maturity	Plant height (cm)	Number primary branches per plant	Number secondary branches per plant	Number of capsules per plant	Number of seeds per capsule	1000 seed weight (g)	Biological yield per plant (g)	Harvest index (%)	Oil content (%)	Seed yield per plant (g)
GCA	9	56.614**	32.693**	422.033**	2.671**	13.120**	1798.083**	0.658**	3.408**	3.411**	34.818**	5.195**	1.288**
SCA	45	29.149**	18.676**	70.893**	1.685**	5.138**	393.869**	0.901**	2.454**	5.038**	39.736**	2.616**	1.207**
Error	108	0.784	1.222	0.589	0.031	0.209	5.599	0.049	0.062	0.094	2.224	0.570	0.040
Estimated variances due to													
σ^2g		4.653	2.623	35.120	0.220	1.076	149.374	0.051	0.279	0.276	2.716	0.385	1.104
σ^2s		28.365	17.454	70.304	1.654	4.929	388.270	0.852	2.392	4.943	3.512	2.045	1.168
σ^2g/σ^2s		0.164	0.150	0.500	0.133	0.218	0.385	0.060	0.117	0.056	0.072	0.188	0.089
$(\sigma^2s/\sigma^2g)^{1/2}$		2.469	2.579	1.414	2.742	2.140	1.612	4.087	2.928	4.231	3.716	2.305	3.351

Table 2: Estimates of GCA effects and *per se* performance of parents for yield and quality components in linseed (*Linum usitatissimum* L.)

Characters	Days to 50% flowering		Days to maturity		Plant height (cm) branches per plant		Number primary		Number secondary branches per plant		Number of capsules per plant	
Parents	GCA Effect	Mean	GCA Effect	Mean	GCA Effect	Mean	GCA Effect	Mean	GCA Effect	Mean	GCA Effect	Mean
Sweta	-2.638**	89.407	-1.557**	140.610	3.551**	65.317	0.034	3.403	1.276**	16.360	1.823**	124.100
Garima	-3.325**	81.857	-3.445**	127.873	5.138**	53.593	-0.230	4.777	0.838**	16.873	5.623**	121.287
Shekhar	0.538	85.097	-0.691	132.920	1.498**	56.597	0.258	6.890	0.156	17.310	1.918**	170.233
Shubhra	2.75 4**	96.753	-0.699	140.103	2.516**	68.700	-0.073	5.733	-0.989**	12.367	1.54 5*	126.410
Kiran	-0.408	86.980	0.180	133.247	-1.886**	49.967	0.031	5.540	-0.082	18.100	5.007**	116.100
Surbhi	0.562	87.390	1.193**	137.657	5.880**	48.953	-0.127	4.377	0.823**	22.867	10.409**	107.300
T-397	-1.910**	85.177	1.555**	145.010	-4.618**	56.417	1.001**	7.863	1.040**	23.290	26.706**	101.467
Neelam	2.202**	91.953	1.184**	139.393	-3.475**	57.870	0.322	7.250	-0.291	12.800	13.211**	166.210
Mukta	2.712**	93.380	0.307	129.933	1.342**	57.803	1.526**	3.233	-0.747	13.603	15.928**	158.767
Hira	-0.488	97.050	1.973**	142.000	14.085**	92.793	1.691**	3.077	2.024	13.383	5.720**	150.187
SE(gi)	0.549		0.685		0.476		0.109		0.283		0.466	
SE(gi-gj)	0.818		0.021		0.709		0.163		0.423		0.185	

*Significant at 5% probability level; ** Significant at 1% probability level

in (Table 2). The genotypes Garima (-3.325), Sweta (-2.638) and T-397 (-1.910) exhibited significant negative general combining ability effects and were found to be best general combiners for days to 50% flowering. The genotype Garima (-3.445) and Sweta (-1.557) exhibited significant negative general combining ability effects and appeared to be best general combiners for early maturity. In the case of plant height genotypes T-397 (-4.618), Neelam (-3.475) and Kiran (-1.886) were found to be best general combiners for dwarfness and exhibited significant negative general combining ability effects. Out of ten parents, only three genotypes Hira (1.691), Mukta (1.526) and T-397 (1.001) showed significant positive general combining ability effects and appeared to be best general combiners for number of primary branches per plant. The genotypes Sweta (1.276), T-397 (1.040) Garima (0.838) and Surbhi (0.823) emerged as best general combiners for number of secondary branches per plant which revealed significant and positive general combining ability effects. Among the parental lines, the genotypes T-397 (26.706), Mukta (15.928), Neelam (13.211), Surbhi (10.409), Hira (5.720), Garima (5.623), Kiran (5.007), Shekhar (1.918), Sweta (1.823) and Shubhra (1.545) recorded significant and positive general combining ability effects for number of capsules per plant. Out of all parental lines, only three genotypes Surbhi (3.273), Shubhra (1.158) and Shekhar (1.105) revealed significant and positive general combining ability effects and were found to be best general combiners for number of seeds per capsules. The genotypes T-397 (3.745), Neelam (2.358), Shubhra (0.897) and Hira (0.412) exhibited significant positive general combining ability effects and emerged as best general combiners for 1000 seed weight. In the case of biological yield per plant the genotypes, Shekhar (2.128), Mukta (2.241), Kiran (1.554), T-397 (1.375) and Garima (1.031) exhibited significant and positive general combining ability effects and appeared to be good general combiners for biological yield per plant. Significant and positive general combining ability effects was observed for Kiran (3.164), T-397 (2.977), Mukta (2.294), Shekhar (1.894) and Sweta (1.117), which appeared as best general combiners for harvest index. The parents Mukta (5.537) and Sweta (1.278) revealed significant and positive general combining ability effects and were emerged to be best general combiners for high oil content. Out of all parental lines, only four genotypes viz., T-397 (2.272), Shekhar (2.247), Mukta (1.291) and Kiran (1.080) observed significant and positive general combining ability effects and were found to be best general combiner for seed yield per plant. These results are in conformity with Thakur *et al.* (1988), Singh *et al.* (1990), Mishra and Rai (1993), Popescu *et al.* (1995), Tiwari (1999), Bhateria *et al.* (2002), Awasthi and Rao (2005), Goral *et al.*(2008), Yadav *et al.* (2013) and Pali and Mehta (2014).

Specific combining ability effects

The specific combining ability effects and per se performance of crosses is given in (Table-3). To confirm whether the crosses selected on the basis of specific combining ability effects were really the best performance ones, the out of forty five cross combinations, thirteen best cross combinations viz., Kiran × T-397 (11.180), Shubhra × Hira (10.967), Neelam × Hira (10.917), T-397 × Hira (10.613), T-397 × Neelam (10.296), Garima × Hira (9.515), Mukta × Hira (9.183), Sweta × Surbhi

Table 3: Estimation of SCA effects and *per se* performance of crosses for yield components in linseed (*Linum usitatissimum* L.)

Characters	Days to 50% flowering		Days to maturity		Plant height(cm)	
Crosses	SCA Effect	Mean	SCA Effect	Mean	SCA Effect	Mean
Sweta x Garima	4.032**	84.240	0.267	135.593	4.886**	65.580
Sweta x Shekhar	6.796**	90.867	-4.550**	136.807	-0.594	63.740
Sweta x Shubhra	-11.234**	75.053	-10.925**	135.593	-0.188	68.160
Sweta x Kiran	-12.771**	70.353	8.106**	136.807	-6.192**	58.753
Sweta x Surbhi	-3.888**	80.207	2.696*	135.593	4.002**	63.953
Sweta x T-397	-2.190*	79.433	1.604	136.807	3.633**	64.847
Sweta x Neelam	1.899*	87.633	-0.999	135.593	-2.984**	59.373
Sweta x Mukta	-2.778**	83.467	-6.124**	136.807	-8.114**	59.060
Sweta x Hira	3.109**	86.153	-3.894**	135.593	13.683**	93.600
Garima x Shekhar	2.616**	86.000	-1.369	136.807	-0.079	55.567
Garima x Shubhra	-1.067	84.533	-2.421*	135.593	-0.393	59.267
Garima x Kiran	-16.471**	65.967	1.800	136.807	-3.057**	53.200
Garima x Surbhi	4.246**	87.653	-0.530	135.593	-0.730	50.533
Garima x T-397	-3.703**	77.233	0.945	136.807	3.125**	55.650
Garima x Neelam	2.853**	87.900	3.446**	135.593	5.172**	58.840
Garima x Mukta	2.442**	88.000	3.820**	136.807	-0.269	58.217
Garima x Hira	0.382	82.740	-1.856	135.593	-11.831**	59.397
Shekhar x Shubhra	-1.263	88.200	2.622*	136.807	3.844**	67.143
Shekhar x Kiran	2.486**	88.787	-1.487	135.593	-3.080**	56.817
Shekhar x Surbhi	-2.837**	84.433	4.279**	136.807	-0.660	54.243
Shekhar x T-397	-1.849*	82.950	-0.649	135.593	-0.405	55.760
Shekhar x Neelam	-0.377	88.533	-4.738**	136.807	-0.682	56.627
Shekhar x Mukta	2.319**	91.740	7.806**	135.593	-4.759**	57.367
Shekhar x Hira	-3.588**	82.633	3.113**	136.807	11.792**	86.660
Shubhra x Kiran	8.483**	97.000	-1.275	135.593	-6.361**	57.550
Shubhra x Surbhi	0.097	89.583	0.035	136.807	9.476**	68.393
Shubhra x T-397	-0.832	86.183	-0.730	135.593	1.854	62.033
Shubhra x Neelam	-0.573	90.553	-4.313**	136.807	7.218**	68.540
Shubhra x Mukta	0.279	91.917	3.765**	135.593	-7.336**	58.803
Shubhra x Hira	-4.037**	84.400	4.869**	136.807	-10.889**	67.993
Kiran x Surbhi	6.326**	92.650	-0.622	135.593	-6.814**	48.700
Kiran x T-397	2.447**	86.300	0.850	136.807	-0.577	56.200
Kiran x Neelam	3.302**	91.267	-2.586**	135.593	0.600	58.520
Kiran x Mukta	4.458**	92.933	0.495	136.807	28.603**	91.340
Kiran x Hira	-1.508	83.767	3.566**	142.533	17.961**	93.440
Surbhi x T-397	1.477	86.300	-2.363**	137.200	5.987**	57.770
Surbhi x Neelam	-0.207	88.727	2.034**	141.227	3.444**	56.370
Surbhi x Mukta	-3.028**	86.417	2.985**	141.300	-1.199	56.543
Surbhi x Hira	-2.378**	83.867	-5.424**	134.557	-10.372**	60.113
T-397 x Neelam	-0.829	85.633	-1.554	138.000	-3.065**	51.123
T-397 x Mukta	1.936*	88.910	0.330	139.007	-3.318**	55.687
T-397 x Hira	-2.106*	81.667	-7.606**	132.737	-13.978**	57.770
Neelam x Mukta	-2.218**	88.867	3.221**	141.527	-1.508	58.640
Neelam x Hira	-6.608**	81.277	5.068**	145.040	-13.274**	59.617
Mukta x Hira	-6.978**	81.417	-0.317	138.777	12.222**	89.930
S.E.(Sij)	0.644		0.052		1.425	
SE(Sij-Sik)	1.417		0.016		0.095	

Table 3: Cont......

Characters	Number Primary branches per plant		Number secondary branches per plant		Number of capsules per plant	
Crosses	SCA Effect	Mean	SCA Effect	Mean	SCA Effect	Mean
Sweta x Garima	-1.088	3.733	-0.326	18.400	17.101**	123.427
Sweta x Shekhar	0.124	5.433	0.633	18.667	16.089**	120.733
Sweta x Shubhra	1.489	6.467	-0.489	16.400	15.584**	152.033
Sweta x Kiran	1.585**	6.667	0.837	18.633	10.902**	140.800
Sweta x Surbhi	0.376	5.300	1.126	19.827	15.005**	139.500
Sweta x T-397	1.481	7.533	2.722**	21.640	17.901**	126.100
Sweta x Neelam	1.374	6.747	0.879	18.467	-43.216**	104.900
Sweta x Mukta	-0.385	4.140	-1.744	15.387	21.201**	172.033
Sweta x Hira	-1.593	2.767	1.943	17.797	13.776**	154.400

Table 3: Cont.....

Characters	Number Primary branches per plant		Number secondary branches per plant		Number of capsules per plant	
Crosses	SCA Effect	Mean	SCA Effect	Mean	SCA Effect	Mean
Garima x Shekhar	-2.611**	2.433	1.171	18.767	18.442**	162.710
Garima x Shubhra	0.520	5.233	-0.884	15.567	34.075**	177.970
Garima x Kiran	-0.117	4.700	0.529	17.887	40.940**	178.283
Garima x Surbhi	3.507**	8.167	2.937**	21.200	-10.797**	121.143
Garima x T-397	-0.221	5.567	2.113***	16.367	37.882**	153.527
Garima x Neelam	-2.542**	3.567	1.084	18.233	7.855**	147.707
Garima x Mukta	-0.028	4.233	0.767	17.460	18.494**	139.783
Garima x Hira	3.138**	5.233	-0.366	15.050	23.720**	124.350
Shekhar x Shubhra	-0.968	4.233	-1.552	14.217	-11.956**	128.233
Shekhar x Kiran	-0.972	4.333	-0.492	16.183	-16.781**	116.857
Shekhar x Surbhi	2.086**	7.233	0.053	17.633	0.059	102.177
Shekhar x T-397	-1.209	5.067	-4.148**	13.650	0.906	101.033
Shekhar x Neelam	0.703	6.300	0.667	17.133	-1.506	150.350
Shekhar x Mukta	-0.516	4.233	3.723**	17.733	0.171	157.743
Shekhar x Hira	0.650	5.233	1.150	15.883	0.342	146.707
Shubhra x Kiran	-1.440	3.533	1.969	17.500	-16.605**	116.660
Shubhra x Surbhi	-1.483	3.333	-0.135	16.300	-14.229**	113.633
Shubhra x T-397	-0.878	5.067	1.247	17.900	-0.230	108.337
Shubhra x Neelam	-1.032	4.233	2.911**	18.233	13.423**	164.907
Shubhra x Mukta	2.049**	6.467	0.501	15.367	6.270**	160.470
Shubhra x Hira	0.015	4.267	0.945*	14.533	0.481	147.473
Kiran x Surbhi	2.386**	3.533	5.609**	11.733	-0.211	112.100
Kiran x T-397	-0.548	5.500	4.360**	13.200	-1.948	86.067
Kiran x Neelam	-0.836	4.533	1.371	17.600	17.818**	162.750
Kiran x Mukta	0.612	5.133	1.894	17.667	11.619**	159.267
Kiran x Hira	2.177**	6.533	0.538	15.033	1.493	138.933
Surbhi x T-397	-0.357	5.533	2.132**	16.333	1.621	101.233
Surbhi x Neelam	-0.578	4.633	-3.501**	15.633	31.438**	170.967
Surbhi x Mukta	-0.830	3.533	-1.977	14.700	14.355**	156.600
Surbhi x Hira	-0.565	3.633	-2.000**	13.400	15.096**	147.133
T-397 x Neelam	-0.140	6.200	0.715	18.067	-0.966	99.267
T-397 x Mukta	0.441	5.933	0.138	17.033	-0.682	105.267
T-397 x Hira	-0.260	5.067	-1.285	14.333	15.975**	99.767
Neelam x Mukta	-0.280	4.533	2.303**	17.867	0.234	171.100
Neelam x Hira	-0.848	3.800	-1.987	12.300	0.508	158.167
Mukta x Hira	3.400**	4.200	-0.597	13.233	-0.041	155.333
S.E.(Sij)	0.327		0.849		1.393	
SE(Sij-Sik)	0.481		0.249		1.457	

* Significant at 5% probability level; ** Significant at 1% probability level

Table 3: Cont.....

Characters	Number of seeds per capsule		1000 seed weight (g)		Biological yield per plant (g)	
Crosses	SCA Effect	Mean	SCA Effect	Mean	SCA Effect	Mean
Sweta x Garima	0.478	9.433	0.753	8.030	-0.852	14.110
Sweta x Shekhar	-0.922	7.100	-10.800**	7.643	1.897	15.700
Sweta x Shubhra	0.442	8.200	0.382	8.213	-0.339	13.113
Sweta x Kiran	-0.470	7.400	-0.526	8.200	0.971	15.457
Sweta x Surbhi	-1.690	6.500	-1.537	6.877	2.197**	16.123
Sweta x T-397	0.318	8.067	0.148	8.337	-0.163	13.393
Sweta x Neelum	-0.080	7.533	-2.043**	6.533	-1.18	12.733
Sweta x Mukta	-1.147	6.467	2.359**	8.650	3.027**	17.200
Sweta x Hira	0.337	8.600	2.587**	8.933	1.144	15.110
Garima x Shekhar	1.022	8.867	10.683**	8.153	-10.909**	14.787
Garima x Shubhra	3.885**	8.467	10.041	8.900	12.101**	13.243
Garima x Kiran	-0.126	7.567	11.366**	8.120	-0.311	16.067
Garima x Surbhi	0.321	8.333	0.535*	8.977	1.975	17.793
Garima x T-397	-0.238	7.333	-0.087	8.130	-1.049	14.400
Garima x Neelam	5.636**	6.800	0.323	8.927	-0.630	15.183
Garima x Mukta	10.497**	7.933	-0.658	8.660	-3.542**	12.523
Garima x Hira	-0.553	7.533	0.326	9.700	-1.852	14.007
Shekhar x Shubhra	-4.181**	6.467	-0.169	8.857	-0.719	13.467

Table 3: Cont.....

Characters	Number of seeds per capsule		1000 seed weight (g)		Biological yield per plant (g)	
Crosses	SCA Effect	Mean	SCA Effect	Mean	SCA Effect	Mean
Shekhar x Kiran	7.042**	8.800	4.123**	8.043	2.188**	17.407
Shekhar x Surbhi	1.255	9.333	-0.271	7.337	0.787	15.447
Shekhar x T-397	-0.204	7.433	-0.850	6.533	0.034	14.323
Shekhar x Neelam	-1.102	6.400	-0.517	7.253	2.121**	12.533
Shekhar x Mukta	0.331	7.833	-1.601	6.883	2.912**	11.993
Shekhar x Hira	-1.552	6.600	1.070	9.610	1.634**	16.333
Shubhra x Kiran	-1.662	5.833	2.509**	8.817	-0.324	14.543
Shubhra x Surbhi	0.218	8.033	2.397**	8.393	-1.412	12.897
Shubhra x T-397	8.059**	8.433	1.835	8.607	1.682	15.620
Shubhra x Neelam	-0.039	7.200	-1.545	7.613	-0.647	13.657
Shubhra x Mukta	9.028**	8.267	-0.296	8.577	2.799**	17.353
Shubhra x Hira	-0.822	7.067	-0.242	8.687	-1.465	12.883
Kiran x Surbhi	-0.526	7.400	-0.774	7.117	3.485**	18.827
Kiran x T-397	-1.018	6.467	-1.103**	6.563	-1.178	13.793
Kiran x Neelam	0.850	8.200	0.417	8.470	-2.207**	13.130
Kiran x Mukta	0.117	7.467	-2.084**	6.683	-3.108**	12.480
Kiran x Hira	0.033	8.033	11.396**	7.427	-1.515**	13.867
Surbhi x T-397	-1.338	6.467	-0.761	6.593	0.588*	15.000
Surbhi x Neelam	10.797**	8.467	-0.055	7.687	3.111**	11.667
Surbhi x Mukta	11.397**	9.067	10.782	7.673	-0.219	14.810
Surbhi x Hira	-0.553	7.767	-0.614	7.897	-1.619	13.203
T-397 x Neelam	-0.529	6.700	1.533	9.050	-0.338	14.070
T-397 x Mukta	-1.096	6.133	0.339	8.570	-0.065	14.593
T-397 x Hira	0.454	8.333	-1.063	7.223	-0.185	14.267
Neelam x Mukta	0.439	7.533	3.549**	8.167	13.391**	11.633
Neelam x Hira	0.089	7.833	-1.240	7.433	3.073**	17.890
Mukta x Hira	0.223	7.967	2.079**	8.467	0.695	15.763
S.E.(Sij)	0.413		0.461		0.570	
SE(Sij-Sik)	0.607		.678		0.838	

* Significant at 5% probability level; ** Significant at 1% probability level

Table 3: Cont.....

Characters	Harvest index (%)		Oil content (%)		Seed yield per plant (g)	
Crosses	SCA Effect	Mean	SCA Effect	Mean	SCA Effect	Mean
Sweta x Garima	2.125**	56.910	-0.187	41.617	-0.165	8.023
Sweta x Shekhar	4.945**	61.640	0.490	42.333	5.847**	9.677
Sweta x Shubhra	3.385*	56.143	1.374	43.157	0.282	7.333
Sweta x Kiran	4.237**	57.873	-0.696	39.987	6.280**	8.943
Sweta x Surbhi	-0.829	54.203	-1.845	39.833	8.144**	8.723
Sweta x T-397	-1.488	56.290	0.583	42.207	-0.324	7.530
Sweta x Neelum	3.121**	58.387	-0.745	41.647	-0.174	7.403
Sweta x Mukta	-5.210**	47.297	0.114	42.577	0.816	8.107
Sweta x Hira	-10.070**	43.567	0.445	42.227	-0.910	6.583
Garima x Shekhar	-0.761	54.800	1.345	41.790	-0.621	8.100
Garima x Shubhra	-0.098	49.527	-4.541**	35.843	-5.385**	6.557
Garima x Kiran	-4.916**	47.587	1.562	40.847	-0.871	7.683
Garima x Surbhi	-3.892**	50.007	-3.413**	36.867	0.420	8.890
Garima x T-397	-1.801	54.843	0.645	40.870	-0.872	7.873
Garima x Neelam	0.711	54.843	-0.200	40.793	-0.152	8.317
Garima x Mukta	9.607**	60.980	-0.697	40.367	-0.706	7.477
Garima x Hira	-3.460*	49.043	0.377	40.757	9.515**	6.870
Shekhar x Shubhra	4.145**	57.680	0.316	40.740	0.087	7.670
Shekhar x Kiran	-0.417	51.997	1.466	40.790	0.831	9.027
Shekhar x Surbhi	0.708	56.517	0.914	41.233	0.625	8.737
Shekhar x T-397	1.862	60.417	-2.378**	37.887	0.270	8.657
Shekhar x Neelam	3.234*	59.277	0.401	41.433	-0.623	7.487
Shekhar x Mukta	-0.350	52.933	0.096	41.200	6.470**	6.353
Shekhar x Hira	11.550**	42.863	2.799**	37.620	-5.026**	7.000
Shubhra x Kiran	3.026**	53.503	-0.036	39.227	0.364	7.780
Shubhra x Surbhi	13.091**	64.963	2.245**	42.503	1.047	8.380
Shubhra x T-397	13.365**	41.253	1.153	41.357	1.171	6.437
Shubhra x Neelam	6.320**	45.787	1.129	42.100	-1.077**	6.253

Table 3: Cont....

Characters	Harvest index (%)		Oil content (%)		Seed yield per plant (g)	
Crosses	SCA Effect	Mean	SCA Effect	Mean	SCA Effect	Mean
Shubhra x Mukta	0.413	49.760	-0.066	40.977	1.596**	8.640
Shubhra x Hira	-1.790	48.687	-0.318	40.040	10.967**	6.280
Kiran x Surbhi	-9.151**	43.600	-0.885	38.273	-0.191	7.753
Kiran x T-397	-4.457**	51.040	-1.381	37.723	11.180**	7.040
Kiran x Neelam	6.392**	59.377	-2.429**	37.443	-0.149	7.793
Kiran x Mukta	4.191**	54.417	-1.609	38.333	-0.850	6.807
Kiran x Hira	8.565**	59.920	-1.365	37.893	0.457	8.317
Surbhi x T-397	4.755**	61.647	-1.413	38.687	7.127**	9.263
Surbhi x Neelam	2.767*	57.147	-0.274	40.593	1.182	6.677
Surbhi x Mukta	5.083**	56.703	-0.061	40.877	0.837	8.410
Surbhi x Hira	-0.887	51.863	-0.773	39.480	-0.985	6.790
T-397 x Neelam	2.744**	59.870	-1.386	39.427	10.296**	8.430
T-397 x Mukta	-1.113	53.253	0.023	40.907	-0.095	7.753
T-397 x Hira	5.247**	60.743	1.161	41.360	10.613**	8.663
Neelam x Mukta	10.996**	62.850	-0.048	41.603	-0.121	7.450
Neelam x Hira	-4.247**	48.737	0.847	41.813	10.917**	8.690
Mukta x Hira	2.682**	52.907	-0.074	40.963	9.183**	8.670
S.E.(Sij)	2.768		1.402		0.370	
SE(Sij-Sik)	4.069		2.061		0.543	

(8.144), Surbhi×T-397 (7.127), Shekhar×Mukta (6.470), Sweta×Kiran (6.280), Sweta×Shekhar (5.847) and Shubhra×Mukta (1.596) exhibited significant and positive specific combining ability effects with good *per se* performance for seed yield per plant. It clearly suggests that while selecting best cross combinations this evidence needs to be given due consideration.

For instance the crosses Sweta×Shekhar had high and desirable specific combining ability effect for days to maturity, number of capsules per plant, harvest index and seed yield per plant; Sweta×Kiran for number of primary branches per plant, number of capsules per plant, harvest index and seed yield per plant; Sweta×Surbhi fornumber of capsules per plant, biological yield per plant and seed yield per plant; Garima×Hira for number of primary branches per plant, number of capsules per plant and seed yield per plant; Shekhar×Mukta forplant height, number of secondary branches per plant, biological yield per plant and seed yield per plant; Shubhra×Mukta for plant height, number of primary branches per plant, number of capsules per plant,number of seeds per capsule, biological yield per plant and seed yield per plant; Shubhra×Hira for days to flowering, plant height, number of secondary branches per plant and seed yield per plant; Kiran×T-397 for number of secondary branches per plant and seed yield per plant; Surbhi×T-397 for days to maturity, number of secondary branches per plant, biological yield per plant, harvest index and seed yield per plant; T-397×Neelam for harvest index and seed yield per plant; T-397×Hira for number of capsules per plant harvest index and seed yield per plant; Neelam×Hira for days to flowering, plant height, biological yield per plant and seed yield per plant and Mukta×Hira for days to flowering, number of primary branches per plant, 1000 seed weight, harvest index and seed yield per plant. These findings were supported by Kalia (1972), Kaushal *et al.* (1974), Patil and Chopde (1983), Thakur *et al.* (1988), Singh *et al.* (1990), Khorgade *et al.* (1993), Popescu *et al.* (1995), Tiwari (1999), Goral *et al.*(2008), Yadav *et al.* (2013) and Pali and Mehta (2014).

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