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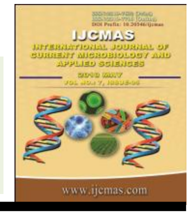

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Genetics Analysis of Yield and Quality Characters in Chickpea (*Cicer arietinum* L.) under Rice Based Cropping System

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A B S T R A C T

Analysis of variance for combining ability revealed that the variance due to gca were highly significant for all the characters in all the environments except for days to maturity in $E_{1,}$ plant height and primary branches plant^{-1} in $E_{1,}$ E_2 and E_3, secondary branches, seed yield and harvest index in E_2 and $E_{3,}$ pods plant^{-1} in E_1 and $E_{2,}$ biological yield plant^{-1} in E_2 and protein content in E_1. Similarly variance due to sca were highly significant for all the characters in all the environments except days to maturity in $E_{1,}$ plat height, primary branches plant^{-1} and secondary branches plant^{-1} in $E_{3,}$ seed yield plant^{-1} in E_2 indicated the importance of both additive and non additive gene effect in their expression. The parent JG 14 and JG 16 appeared to be good general combiners for the trait seed yield plant^{-1} in all the three environments. JG 14 and JG 130 for pods plant^{-1} in E_1 and $E_{2,}$ JG 16 and JG 130 in E_3. For the trait harvest index, JG 14 and JG 16 in E_1 and $E_{2,}$ JG 14 and ICCV 96029 in environments $E_{3.}$ The parents Vaibhav and JG 11 also appeared to be good general combiners for the traits protein content in all three environments. For high seed yield plant^{-1} the cross JG 130 x JG 97, JG 14 x JG 97, JG 315 x JG 97, JG 315 x ICCV 96029 were found as better specific combiners in all the three environments. whereas, Indira Chana-1 x JG 97 in E_1 and E_2, JG 11 x JG 97 in E_1, Vaibhav x ICCV 96029 in E_1 found as better specific combiners for the characters.

Introduction

Chickpea [*Cicer arietinum* (L.) 2*n* = 2*x* = 16] belongs to genus *Cicer*, tribe Cicereae, family Fabaceae, and subfamily Papilionaceae. It is commonly called gram, bengal gram or garbanzo bean, is the most important cool season food grain legume in the world after common bean (*Phaseolus vulgaris* L.) and pea (*Pisum sativum* L.). Chickpea is the world's third most important food legume crop grown as rainfed in cool and dry climate in semi-arid regions. During the last few decades, due to increasing demand of the food for world's growing population depend to a large extent on the conservation and use of world's remaining plant genetic resources. Chickpea covers about 11.7 million ha area and 9.3 million tones production in over 45 countries of the world. India is the largest chickpea producer accounting a share of about 67% in global chickpea production with about 9.93 million ha area, 9.53million tones production and productivity of 960 kg/ha. Distribution of chickpea in six states *viz*., Madhya Pradesh, Rajasthan, Maharashtra, Uttar Pradesh, Karnataka and Andhra Pradesh together contribute 90.2% of the production and 90.8 % of the area of the country. Chhattisgarh covers 0.276million ha area with production 0.213million tones and productivity of 771kg ha^{-1}. (Project Coordinators Report, 2014-15). A parent which transmits genes for lesser number of days to flowering and maturity to its progeny is regarded as a desirable combiner. Thus parental strains with significant and negative gca effects have been consider as desirable combiners.

Materials and Methods

The experimental material comprised *viz.* seven lines *viz.*, Vaibhav, Indira Chana-1, JG 315, JG 11, JG 14, JG 16, JG 130 of agronomic base and three testers JG 97, ICCV 96029 and ICCV 96030 for early maturity were crossed as per Line x Tester mating design fashion (Kempthorn, 1957) to develop 21 F_1 during 2014-15. These F_1 along with their parents were evaluated with two replication in one row plot during 2015-16. Under following three rice based cropping systems *viz.* E_1: Cropping System I: after harvest of early rice variety (Danteshwari) CS-I, E_2: Cropping System II: after harvest of medium rice variety (Mahamaya). CS-II, E_3: Cropping System III: after harvest of late rice variety (Dubraj) CS-III. The row to row and plant to plant spacing 30 x 10 cm maintained at Research cum Instructional farm, Department of Plant Breeding and Genetics, Indira Gandhi Agricultural University, Raipur The recommended packages of practices were adopted to raise the normal crops. Observations on metric traits where recorded on single plant basis on five randomly selected competitive plant of each genotypes from each replication in each cropping system were as observation on days to 50% flowering, days to maturity, plant height (cm), number of primary branches $plant^{-1}$, pods $plant^{-1}$, Biological yield $plant^{-1}$ (g), harvest index (%), 100 seed weight (g), Seed yield $plant^{-1}$ (g), seed volume (ml $seed^{-1}$), hydration capacity $seed^{-1}$ (g), hydration index, swelling index and protein content (%) were recorded on plot basis as per the chickpea descriptor developed by ICRISAT-IBPGR- ICARDA (1993). Sprague and Tatum (1942) were the first to develop the concept of combining ability in terms of genetic variation in Maize. Their results confirmed that the general combing ability (GCA) was primarily due to additive effect of genes and specific combining ability (SCA) was due to combined effects of dominance deviations and epiststic interactions. Rojas and Sprague (1952) concluded that the information on the SCA would often be lower in predictive value than the information on the gca. Griffing (1956) applied the concept of GCA and SCA in relation to diallel crossing system while Kempthorne (1957) proposed this concept in line × tester analysis.

Results and Discussion

Analysis of variance

The analysis of variance for line x tester analysis for the traits under study has been presented in Table 1). The mean sums of square due the genotypes significant of the mean square for parents *vs.* hybrid are taken to indicate presence of heterosis. Although this method is statistically valid, conclusion regarding heterosis may not be reliable and useful. It is a comparison of mean of the parents as a group with the mean of crosses as group. Significant could result even when mean of crosses as a group is smaller than mean of parental line as a group.

Moreover, when there is significance, it is quite likely that many crosses do not show heterosis but significant is caused by only a few highly heterotic crosses. The mean squares due to genotypes were highly significant for all the traits in E_1, E_2 and E_3.The mean squares due to parents were highly significant for all the characters in all the environments except plant height and primary branches plant^{-1} in E_1 and E_3, pods plant^{-1} in E_1 and $E_{2,}$ harvest index and seed yield plant^{-1} in $E_2$and E_3, protein content in $E_1$and swelling index in $E_{2.}$

The highly significant variance due to parent *vs* crosses recorded for all the characters in all three environments except days to 50 % flowering in E_1, days to 50 % flowering, harvest index and seed yield plant^{-1} in $E_{2,}$ days to 50 % flowering, plant height and secondary branches plant^{-1} in $E_{3.}$

Mean square due to line and tester were found to be significant for all the traits in all the environments except days to maturity in all the environments. Primary branches plant^{-1} in E_1 and $E_{3,}$ secondary branches plant^{-1} and yield plant^{-1}in $E_2$and protein content in $E_{3.}$ Hence, its indicated that line does not appear to behave consistently over different tester in the respective environments.

Analysis of variance for combining ability

Analysis of variance for combining ability (Table 2) revealed that the variance due to gca were highly significant for all the characters in all the environment except for days to maturity in $E_{1,}$ plant height and primary branches plant^{-1} in $E_{1,}$ E_2 and E_3, secondary branches, seed yield and harvest index in E_2 and $E_{3,}$ pods plant^{-1} in E_1 and $E_{2,}$ biological yield plant^{-1} in E_2 and protein content in $E_{1.}$ Similarly variance due to sca were highly significant for all the characters in all the environments except days to maturity in $E_{1,}$ plant height, primary branches plant^{-1} and secondary branches plant^{-1} in $E_{3,}$ seed yield plant^{-1} in E_2 indicating importance of both additive and non-additive gene effect in their expression.

Result of the analysis revealed that the variance due to gca was lower than sca variance for all most all the characters in all the environments except protein content in E_2, primary branches plant^{-1} and secondary branches plant^{-1} in $E_{3,}$ suggesting the predominance of non-additive gene action controlling these characters. Dominance genetic variance was larger than additive genetic variance for the characters, these result are supported by ratio of variance to general to specific combining ability (σ^2gca/ σ^2sca) which was smaller than unity and by the degree of dominance (σ^2D/ σ^2A) which take values greater than unity. Therefore, it applied that the inheritance of these traits was controlling by a preponderance of non-additive gene effect. Such types of gene action clearly indicated that selection of superior plant for these characters should be postponed to latter generation where these characters can be improved by making selection among the recombinants which the segregating population. As the ratio of gca: sca variance more than unit recorded for protein content in $E_{2,}$ primary branches plant^{-1} and secondary branches plant^{-1} in E_3 further supported by finding degree of dominance and heritability indicated the role of additive genetic variance in their expression. Hence, direct selection for the characters would be advantageous in isolating chickpea genotypes of more protein content and more primary branches and secondary branches. These finding are in general agreement with the finding of Verma and Waldiya (2010), Monpara and Dhamelia (2013). High estimate of heritability in narrow sense were observed for secondary branches plant^{-1} in $E_{1,}$ E_2 and $E_{3,}$ days to 50 % flowering in $E_{1,}$ primary branches plant^{-1} in E_2 and $E_{3,}$ harvest index in E_2 and $E_{3,}$ swelling index in E_1 E_2 and E_3 and protein content in E_2 (Table 3–5).

Table.1 Analysis of variance for L x T for yield, its attributes and quality characters under E_1, E_2 and E_3 in chickpea

Source of variation	D.F.	Mean sum of squares														
		Days to 50% flowering	Days to maturity	Plant height (cm)	Primary branches plant^{-1}	Secondary branches plant^{-1}	Pods plant^{-1}	Biological yield plant^{-1} (g)	Harvest index (%)	100-seed weight (g)	Seed yield plant^{-1} (g)	Seed volume (ml seed^{-1})	Hydration capacity seed^{-1} (g)	Hydration index	Swelling index	Protein content (%)
E_1: After harvest of early rice variety of 90-110 days																
Genotypes	30	26.55**	12.190**	40.370**	6.140**	376.02**	9197.4**	881.57**	341.26**	20.60**	301.12**	0.02**	0.0213**	0.0032**	3.920**	2.160**
Parents	9	58.56**	29.50**	24.97	0.254	5.17**	162.47	151.15**	342.80**	13.445**	26.87*	0.0018**	0.022342**	0.000198**	1.6848**	1.09499
hybrids	20	13.48**	2.25	46.68**	2.371**	172.56**	3560.1**	177.62**	231.13**	13.07**	269.77**	0.0019**	0.02035**	0.000391**	4.45436**	2.1739**
Par Vs Hyb	1	0.035	59.32**	52.81**	134.59**	7783.4**	20325.8**	21530.8**	2530.08**	235.67**	3398.34**	0.0091**	0.03172**	0.000009**	13.5610**	11.6757**
Line	6	30.43*	5.300**	46.31	1.431	342.98**	3832.58**	150.4*	367.58**	23.59**	355.410**	0.0032**	0.03488**	0.00065**	8.1970**	4.2395*
Tester	2	4.22	0.863	33.34	2.301	205.75**	4563.94**	127.22	93.15	2.984**	86.820**	0.0036**	0.000343*	0.000026**	2.3092	0.2188
Line x Tester	12	6.57**	0.960	49.10*	2.853	81.82**	3256.67**	199.63**	185.89**	9.5**	257.440**	0.0011**	0.0160**	0.000317**	2.9404**	1.467*
Error	30	1.00	1.35	16.33	0.510	0.1448	366.95	35.064	51.041	0.3535	9.55	0.00008	0.00006	0.000001	0.08136	0.77683
E_2: After harvest of medium rice variety of 111-135 days																
Genotypes	30	32.79**	27.66**	102.14**	4.037**	310.01**	6475.9**	731.99**	239.4**	22.18**	317.15**	0.023**	0.209**	0.0032**	3.45**	1.898**
Parents	9	78.2721**	73.755**	20.9032	0.11912	0.9205	65.1731	16.2659	54.7656	134.488**	4.076253	0.00186**	0.022556**	0.000198**	2.123	1.386*
hybrids	20	13.795**	2.2312*	51.1851**	2.83924**	176.833**	3915.12**	193.9875**	333.513**	13.0775**	254.3312	0.00168**	0.019547**	0.00039**	3.65876**	1.692**
Par Vs Hyb	1	3.4257	121.51**	1852.51**	63.26703**	5755.24**	115389.4**	17933.6**	21.6914	283.045**	4391.305	0.0174**	0.033053**	0.000003*	11.2353**	10.679**
Line	6	30.484**	4.493*	49.540	5.271*	495.255**	5097.094	223.300	367.1	23.595*	341.309	0.0024	0.03327	0.000659	7.3596**	1.386*
Tester	2	5.453	0.170	33.810	2.366	68.437	2439.246	46.908	45.441	2.983	56.443	0.0031	0.00054	0.000027	3.0566	1.691**
Line x Tester	12	6.8411**	1.443	54.900**	1.702*	35.688	3570.089**	203.84**	364.728**	9.500**	243.823**	0.00103	0.01558**	0.000317**	1.9086**	10.679**
Error	30	0.88064	0.96505	14.5232	0.43312	17.9776	526.3379	57.3844	56.8828	0.36509	12.31574	0.000078	0.000094	0.000001	0.16528	0.549
E_3: After harvest of late rice variety of above 135 days																
Genotypes	30	32.09**	26.587**	60.40**	1.993**	262.75**	684.75**	462.16**	255.53*	23.07**	163.47**	0.019**	0.206**	0.0031**	3.124**	2.385**
Parents	9	74.7999**	70.1163**	10.6922	0.254	2.8315432	310.1801**	26.998**	88.2691	13.45041**	5.358101	0.001545**	0.02236**	0.000199**	1.819**	1.365*
hybrids	20	15.0953**	2.49531**	64.3968	2.371	170.12143	479.5344**	198.412**	326.8023**	13.07754**	103.991**	0.0018431**	0.0193**	0.000387**	3.294**	2.175**
Par Vs Hyb	1	0.44140	91.7343**	428.097	134.59**	4454.602	8160.025**	9653.697**	335.781**	309.6514**	2776.236**	0.00773**	0.0333**	0.000012**	11.492**	15.754**
Line	6	31.151*	5.429**	154.37**	2.831**	475.26**	391.651	387.821**	335.262	23.595*	164.049	0.00291*	0.0331	0.000634	5.978*	4.241*
Tester	2	1.2388	0.667	24.300	1.340	8.588	47.012	170.346	647.832	2.984	14.553	0.00363**	0.00026	0.000027	2.435	0.222
Line x Tester	12	9.3768**	1.333	26.092*	0.651	44.469*	595.562**	108.385**	269.067**	9.500**	88.860**	0.0010**	0.0154**	0.000325**	2.0942**	1.466
Error	30	0.73334	0.72311	9.77124	0.458789	11.83804	83.76560	21.69353	120.4268	0.364980	9.886743	0.000074	0.000134	0.000001	0.367	0.588

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

Table.2 Combining ability and genetic components for seed yield, its attributes and quality characters under E_1, E_2 and E_3 in chickpea

Source of variation	D.F.	Days to 50% flowering	Days to maturity	Plant height (cm)	Primary branches plant^{-1}	Secondary branches plant^{-1}	Pods plant^{-1}	Biological yield plant^{-1} (g)	Harvest index (%)	100-seed weight (g)	Seed yield plant^{-1}(g)	Seed volume (ml seed^{-1})	Hydration capacity seed^{-1} (g)	Hydration index	Swelling index	Protein content (%)
E_1: CSI																
GCA	9	58.56**	29.50**	24.97	0.254	5.17**	162.47	151.15**	342.80**	13.445**	26.87*	0.0018**	0.022342**	0.000198**	1.6848**	1.09499
SCA	20	13.48**	2.25	46.68**	2.371**	172.56**	3560.1**	177.62**	231.13**	13.07**	269.77**	0.0019**	0.02035**	0.000391**	4.45436**	2.1739**
Error	30	1.00	1.35	16.33	0.510	0.1448	366.95	35.064	51.041	0.3535	9.55	0.00008	0.00006	0.000001	0.08136	0.77683
Genetic components																
σ^2gca		1.065	0.211	-0.927	-0.099	19.254	94.158	-6.082	4.447	0.378	-3.632	0.0002	0.0001	0.0000025	0.2312	0.0762
σ^2sca		2.777	-0.256	15.274	1.0774	30.703	1395.5	75.11	77.453	4.554	124	0.0005	0.0082	0.000158	10874	0.3786
σ^2gca/ σ^2sca		0.384	-0.824	-0.061	-0.092	0.627	0.067	-0.081	0.057	0.083	-0.029	0.400	0.012	0.016	0.000	0.201
σ2A		4.260	0.844	-3.708	-0.396	77.016	376.632	-24.328	17.788	1.512	-14.528	0.001	0.000	0.000	0.925	0.305
σ2D		11.108	-1.024	61.096	4.310	122.812	5582.000	300.440	309.812	18.216	496.000	0.002	0.033	0.001	43496.000	1.514
h2(ns)		30.926	12.467	-13.079	-11.910	40.948	7.876	-5.308	9.069	14.432	-9.353	7.968	3.745	0.625	46.224	20.757
E_2: CS-II																
GCA	9	78.2721**	73.755**	20.9032	0.11912	0.9205	65.1731	16.2659	54.7656	134.488**	4.076253	0.00186**	0.022556**	0.000198**	2.123	1.386*
SCA	20	13.795**	2.2312*	51.1851**	2.83924**	176.833**	3915.12**	193.9875**	333.513**	13.0775**	254.3312	0.00168**	0.019547**	0.00039**	3.65876**	1.692**
Error	30	0.88064	0.96505	14.5232	0.43312	17.9776	526.3379	57.3844	56.8828	0.36509	12.31574	0.000078	0.000094	0.000001	0.16528	0.549
Genetic components																
σ^2gca		1.112	0.0887	-1.322	0.211	24.615	19.808	-6.874	15.845	0.3788	4.494	0.0002	0.0001	0.0000025	0.3299	0.1341
σ^2sca		2.888	0.2476	20.422	0.564	5.446	1457.8	75.26	95.77	4.5525	96.691	0.0005	0.0079	0.0001583	0.8313	0.125
σ^2gca/ σ^2sca		0.385	0.358	-0.065	0.374	4.520	0.014	-0.091	0.165	0.083	0.046	0.400	0.013	0.016	0.397	1.073
σ2A		4.448	0.355	-5.288	0.844	98.460	79.232	-27.496	63.380	1.515	17.976	0.001	0.000	0.000	1.320	0.536
σ2D		11.552	0.990	81.688	2.256	21.784	5831.20	301.04	383.080	18.210	386.764	0.002	0.032	0.001	3.325	0.500
h2(ns)		26.421	2.479	-9.065	37.762	60.039	2.263	-6.967	42.783	13.442	10.912	6.933	0.383	0.625	73.001	43.841
E_3: CS-III																
GCA	9	74.7999**	70.1163**	10.6922	0.254	2.8315432	310.1801**	26.998**	88.2691	13.45041**	5.358101	0.001545**	0.02236**	0.000199**	1.819**	1.365*
SCA	20	15.0953**	2.49531**	64.3968	2.371	170.12143	479.5344**	198.412**	326.8023**	13.07754**	103.991**	0.0018431**	0.0193**	0.000387**	3.294**	2.175**
Error	30	0.73334	0.72311	9.77124	0.458789	11.83804	83.76560	21.69353	120.4268	0.364980	9.886743	0.000074	0.000134	0.000001	0.367	0.588
Genetic components																
σ^2gca		0.681	0.171	6.324	0.1434	19.74	-37.62	17.069	22.248	0.3789	0.0435	0.0002	0.0001	0.0000005	0.2112	0.0763
σ^2sca		4.242	0.284	7.579	0.0422	14.91	268.65	51.521	110.23	4.5525	38.96	0.0005	0.0077	0.000161	0.8125	0.3792
σ^2gca/ σ^2sca		0.161	0.602	0.834	3.398	1.324	-0.140	0.331	0.202	0.083	0.001	0.400	0.013	0.003	0.260	0.201
σ2A		2.724	0.684	25.296	0.574	78.960	-150.480	68.276	88.992	1.516	0.174	0.001	0.000	0.000	0.845	0.305
σ2D		16.968	1.136	30.316	0.169	59.640	1074.600	206.084	440.920	18.210	155.840	0.002	0.031	0.001	3.250	1.517
h2(ns)		16.598	5.009	72.098	46.790	57.512	-39.161	28.222	47.342	12.935	0.201	8.388	0.388	0.129	48.399	20.531

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

Table.3 Estimation of General Combing Ability (GCA) effect for yield, its attributing and quality characters in chickpea

Characters	E	Lines							Testers			SE of GCA Female	SE of GCA Male
		Vaibhav	**IC-1**	**JG 315**	**JG 11**	**JG 14**	**JG 16**	**JG 130**	**JG 97**	**ICCV 96029**	**ICCV 96030**		
1	E_1	-1.600**	0.570	0.070	2.900**	-4.100**	1.240**	0.900*	0.620**	-0.310	-0.310	0.310	0.180
	E_2	-1.620**	0.550	0.210	0.880*	-4.120**	1.210**	0.880*	0.690**	-0.520*	-0.170	0.320	0.190
	E_3	-2.550**	0.790*	0.120	2.450**	-3.710**	1.450**	1.450**	0.330	-0.240	-0.100	0.290	0.170
2	E_1	-0.310	0.360	1.020	0.520	0.860*	-1.140**	-1.310**	-0.140	-0.140	0.290	0.380	0.220
	E_2	-0.430	0.570	0.740*	0.400	0.900*	-0.930**	-1.260**	-0.100	-0.020	0.120	0.300	0.170
	E_3	-0.450	0.550	0.550	0.710*	1.050**	-0.950**	-1.450**	-0.240	0.190	0.050	0.270	0.160
3	E_1	-0.090	1.010	4.710**	0.450	-0.650	0.750	-4.190**	-0.690	1.340	0.340	1.340	0.770
	E_2	-1.700	1.070	4.770**	0.500	-0.60	0.630	-4.670**	-1.490	1.610*	-0.120	1.170	0.670
	E_3	-1.380	-2.410*	-0.450	-1.320	-2.80**	-2.970*	11.320**	1.230	0.160	-1.390	1.030	0.590
4	E_1	-0.500	-0.350	-0.550	0.120	0.75*	0.420	0.090	0.380*	-0.430*	0.050	0.260	0.150
	E_2	-0.360	-0.760*	-0.950**	-0.800*	1.17**	1.170**	0.540	0.450*	-0.110	-0.350	0.240	0.140
	E_3	-0.500	-0.890**	-0.590*	0.010	0.350	0.930**	0.680*	0.340	-0.270	-0.070	0.230	0.140
5	E_1	-8.360**	-8.500**	1.400	-0.160	1.570	13.640**	2.400	4.340**	-1.430	-2.910**	1.410	0.810
	E_2	-6.560*	-8.690**	-5.120*	-4.860*	0.210	15.140**	9.880**	2.480*	-0.720	-1.760	1.550	0.890
	E_3	-7.150**	-8.950**	-5.05**	-5.780**	3.620**	12.190**	11.120**	0.580	0.310	-0.890	1.190	0.690
6	E_1	-18.610**	-0.810	-12.58	-32.510**	37.220**	-2.350	29.650**	18.770**	-1.530	-17.240**	6.710	3.880
	E_2	-16.730	-9.270	-25.53**	-34.970**	41.270**	14.530	30.70**	12.250*	1.730	-13.980**	7.960	4.590
	E_3	0.240	3.480	-17.36**	0.510	0.680	6.530*	5.910*	2.050	-1.480	-0.570	2.370	1.370
7	E_1	-5.910*	-0.430	-4.560	-3.660	2.590	4.790	7.170**	-1.420	3.460*	-2.050	2.190	1.260
	E_2	-9.050**	2.410	-5.820*	-3.190	2.650	6.680*	6.310*	-1.780	1.880	-0.100	2.270	1.310
	E_3	-9.600**	-2.38**	4.22**	-7.820**	-4.120**	10.080**	9.620**	0.400	-3.670*	3.270**	0.720	0.420
8	E_1	-5.980**	2.630	-5.70**	-9.090**	11.060**	9.130**	-2.040	-2.700*	0.270	2.430*	1.730	1.000
	E_2	-4.90*	0.520	-5.160**	-8.220**	12.390**	9.040**	-3.660	-1.930	1.650	0.280	2.212	1.220
	E_3	-0.310	2.480	-7.140**	-6.250**	14.340**	2.210	-5.330**	-0.130	6.870**	-6.730**	2.170	1.250
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9	E_1	0.490*	-0.400	-1.800**	0.110	-1.350**	4.100**	-1.150**	-0.220	0.530	-0.310*	0.200	0.110
	E_2	0.490*	-0.400	-1.800**	0.110	-1.350**	4.100**	-1.150*	-0.220	0.530**	-0.310	0.200	0.110
	E_3	0.490*	-0.400	-1.800**	0.110	-1.350**	4.100**	-1.150**	-0.220	0.530**	-0.310*	0.200	0.110
10	E_1	-7.300**	1.340	-6.300**	-8.430**	10.400**	8.920**	1.370	-2.870	1.600*	1.270*	0.950	0.550
	E_2	-7.420**	1.550	-6.580**	-6.880**	10.620**	8.970**	-0.250	-2.230	1.670*	0.550	1.180	0.680
	E_3	-5.490**	0.150	-2.650*	-6.620**	4.210**	7.560**	2.850	0.420	0.750	-1.160	1.030	0.590
11	E_1	-0.026**	0.005	0.008	-0.038**	-0.027**	0.096**	-0.018**	0.148**	-0.155**	0.007	0.004	0.004
	E_2	-0.025**	0.005*	0.008	-0.035**	-0.027**	0.095**	-0.022**	0.149**	-0.156**	0.006	0.004	0.004
	E_3	-0.025**	0.003*	0.008	-0.037**	-0.026**	0.093**	-0.017	0.149	-0.154**	0.006	0.002	0.003
12	E_1	-0.017**	0.038**	0.015	-0.006	-0.029**	0.00	-0.002	-0.097**	0.045**	0.052**	0.003	0.005
	E_2	-0.011	0.037**	0.015	-0.004	-0.030**	-0.003	-0.003	-0.095**	0.039**	0.056**	0.005	0.004
	E_3	-0.016**	0.039**	0.012	-0.006	-0.025**	-0.003	-0.001	-0.096**	0.042**	0.053**	0.004	0.005
13	E_1	-0.041	0.038	0.030	0.022	-0.066	0.001	0.017	-0.003	0.135	-0.132	0.003	0.002
	E_2	-0.043**	0.037	0.028	0.020	-0.064**	0.004	0.019	-0.007	0.138**	-0.131**	0.003	0.004
	E_3	-0.039**	0.038**	0.031**	0.025	-0.063**	-0.005	0.015	-0.004	0.133**	-0.129**	0.004	0.004
14	E_1	-0.890**	0.090	1.120**	-0.210	0.360	-1.940**	1.480**	-0.190*	0.470**	-0.270**	0.110	0.060
	E_2	-0.940**	-0.050	0.790**	0.130	0.440*	-1.860**	1.480**	-0.130	0.520	-0.390	0.150	0.090
	E_3	-0.890**	0.000	0.890**	-0.040	0.380	-1.620**	1.270**	-0.230	0.480**	-0.250	0.210	0.120
15	E_1	1.130**	-0.900**	-0.880**	0.770*	-0.270	-0.530	0.660*	-0.130	0.010	0.120	0.260	0.150
	E_2	0.940**	-0.760**	-0.730**	0.920**	-0.290	-0.720*	0.640*	-0.110	-0.110	0.210	0.230	0.140
	E_3	1.130**	-0.900**	-0.870**	0.780*	-0.270	-0.530	0.670*	-0.130	0.010	0.120	0.260	0.150

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

1. Days to 50% flowering	**4. Primary branches plant^{-1}**	**7. Biological yield (g)**	**10. Seed yield plant^{-1}**	**13. Hydration index**
2. Days to maturity	5. Secondary branches plant^{-1}	8. Harvest index (%)	11. Seed volume (ml)	14. Swelling index
3. Plant height (cm)	6. Pods plant^{-1}	9. 100-seed weight (g)	12. Hydration capacity seed^{-1}	15. Protein content (%)

Table.4 Specific Combing ability effects (SCA) of hybrids for seed yield, its attributing and quality characters in chickpea

Hybrids	E	Days to 50% flowering	Days to maturity	Plant height (cm)	Primary branches plant^{-1}	Secondary branches plant^{-1}	Pods plant^{-1}	Biological yield (g)	Harvest index (%)	100-seed weight (g)	Seed yield plant^{-1}
VAIBHAV x JG 97	E_1	-1.120*	-0.690	-1.510	0.950*	1.490	-1.670	-1.280	4.650	-0.110	2.970*
	E_2	-1.020*	-1.070*	-1.040	0.980**	-0.810	6.520	0.280	2.050	-0.110	1.660
	E_3	-3.170**	-0.760	-0.470	0.360	-1.080	8.890*	-3.830**	3.190	-0.110	-0.980
VAIBHAV x ICCV 96029	E_1	-0.290	0.140	-1.910	0.550	-0.380	-41.270**	-8.220**	0.100	1.700**	-3.560*
	E_2	-0.190	-0.070	-2.110	-0.520	1.820	-46.750**	-5.780	-2.490	1.700**	-4.210*
	E_3	0.000	0.240	-3.560**	-0.410	2.220	-8.700*	-2.000	-4.560	1.700**	-3.520
VAIBHAV x ICCV 96030	E_1	1.710**	0.480	-4.210*	-1.450**	-8.380**	49.700**	-5.580	-2.220	-2.400**	-3.030*
	E_2	1.640**	-0.240	-4.410*	-0.640	-4.850**	11.720	-4.950	-3.800	-2.400**	-3.170
	E_3	2.170**	0.740	3.420**	-0.860*	-1.280	-10.220**	4.200**	-2.460	-2.400**	2.180
INDIRA CHANA-1xJG-97	E_1	-0.120	-1.020	-3.750	-0.510	4.490**	-7.470	12.220**	0.260	2.740**	5.200*
	E_2	-0.020	-0.900*	-3.940*	0.410	0.690	-12.950	16.010**	0.680	2.740**	7.230*
	E_3	0.083	-0.930*	0.590	0.590	4.250**	27.710**	-1.960	6.450**	2.740**	1.250
INDIRA CH-1x ICCV 96029	E_1	-1.620**	0.640	0.750	-1.050*	-0.040	-50.200**	-11.330**	-7.180**	-2.900**	-12.230**
	E_2	-1.520**	0.600	0.560	-1.450**	1.320	-44.180**	-12.820**	-3.070	-2.900**	-10.370**
	E_3	-1.500**	-0.260	2.870**	-0.390	-2.950	-28.850**	-2.860*	-12.170**	-2.900**	-7.180**
INDIRA CH-1x ICCV 96030	E_1	-0.950*	0.640	6.750**	1.390**	-7.310**	28.860**	4.620	-1.870	1.700**	0.950
	E_2	-1.360**	1.430*	6.720**	1.150**	-6.310**	62.050**	5.750	-4.300	1.700**	0.480
	E_3	-0.670	0.740	-4.960**	0.280	-3.210	11.500**	6.640**	-3.720	1.700**	1.170
JG 315 x JG 97	E_1	2.380**	-0.190	3.890	0.120	10.120**	22.060**	9.580**	6.260**	-0.750*	9.700**
	E_2	2.480**	0.260	4.220**	0.080	8.150**	23.590**	1.510	10.920**	-0.750*	8.390**
	E_3	2.330**	0.240	2.110**	0.430	2.050	-0.430	-0.200	13.280**	-0.750*	7.080**
JG 315 x ICCV 96029	E_1	-1.690**	0.310	0.960	-0.690	-5.740**	18.930	5.090	1.620	-0.090	3.300**
	E_2	-1.810**	0.860	0.360	-1.060**	-0.610	22.330	-1.980	7.550*	-0.090	3.560**
	E_3	-0.600	0.810	-0.700	-0.230	1.690	-13.840**	3.690**	6.700*	-0.090	4.490**
JG 315 x ICCV 96030	E_1	-0.360	0.140	-0.640	-0.040	2.100	28.430**	-2.250	3.950	-1.600**	1.960
	E_2	-0.480	0.360	-0.910	0.140	0.720	25.170	0.760	1.860	-1.600**	1.890
	E_3	-0.430	-0.190*	-1.140**	0.050	1.190	2.880	-3.130**	-4.510	-1.600**	-3.850*
JG 11 x JG 97	E_1	-0.360	-0.020	-4.640*	0.360	3.600	-12.800	9.240*	1.380	-0.200	4.800**
	E_2	-0.140	0.190	-4.910**	0.180	1.550	5.430	13.890**	-5.730	-0.200	2.730
	E_3	-0.260	-1.190	-1.710**	0.300	1.690	15.910**	-11.130**	15.020**	-0.200	1.650
JG 11 x ICCV 96029	E_1	0.310	0.480	6.020**	-1.110**	-2.240	-14.170	-7.860**	-0.550	-1.060**	-3.270
	E_2	0.190	0.520	5.760**	-0.420	-0.110	-11.430	-9.240**	-1.810	-1.060**	-4.670
	E_3	-1.100*	0.140	-1.600	-0.800*	-1.980	-11.860**	6.000**	-13.190**	-1.060**	-2.080

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Hybrids	E	Days to 50% flowering	Days to maturity	Plant height (cm)	Primary branches plant^{-1}	Secondary branches plant^{-1}	Pods plant^{-1}	Biological yield (g)	Harvest index (%)	100-seed weight (g)	Seed yield plant^{-1}
JG 11 x ICCV 96030	E_1	0.810	0.140	-0.280	1.260**	0.530	-23.100**	-4.310	-13.540**	1.050**	-13.200
	E_2	0.690	0.020	-0.540	1.110**	-1.180	-26.870**	-0.780	-17.830**	1.050**	-13.270
	E_3	1.070*	0.310	0.490	0.470	7.120**	6.480	-5.200**	2.120	1.050**	-4.010
JG 14 x JG 97	E_1	0.480	-0.360	-1.280	-0.710	8.760**	-8.740	1.690	12.610**	1.300**	11.280**
	E_2	0.860	-1.140*	-1.380	-0.690*	3.190	-25.330**	-0.510	23.400**	1.300**	12.880**
	E_3	0.400	-0.690	6.500**	-0.070	-2.140	-2.320	3.700**	7.240**	1.300**	7.140**
JG 14 x ICCV 96029	E_1	0.810	-0.690	-0.140	0.930*	-7.000**	11.460	-1.600	-5.470	0.600	-4.870**
	E_2	0.690	-0.810	1.620	0.740*	-3.550	10.700	3.860	-7.430**	0.600	-3.110
	E_3	0.900*	0.810	-1.830**	0.280	-7.580**	2.750	6.070**	-13.400	0.600	-3.350*
JG 14 x ICCV 96030	E_1	2.810**	0.380	0.560	-0.260	4.250**	-17.260	-3.800	-6.280*	0.200	-6.270**
	E_2	2.830**	0.210	0.690	0.080	1.430	-28.850**	1.700	-9.600**	0.200	-5.220**
	E_3	3.760**	-0.050	1.170**	-0.130	-0.610	4.850	0.140	-9.890**	0.200	-3.500*
JG 16 x JG 97	E_1	0.640	-0.290	2.560	-0.510	-1.720	12.840	10.460**	-4.050	-0.110	1.600
	E_2	0.670	-0.290	3.020	0.380	-2.540	21.580	5.030	0.630	-0.110	2.310
	E_3	0.430	-0.050	4.700**	0.360	-3.410	5.820	5.130**	9.060**	-0.110	7.360**
JG 16 x ICCV 96029	E_1	-1.360**	-0.450	8.860**	1.090**	4.780	-36.890**	-3.650	0.840	2.590**	-1.770
	E_2	-1.500**	0.050	9.320**	0.460	3.300	-17.150	-8.940**	9.530**	2.590**	0.450
	E_3	-1.900**	0.450	-1.710**	0.560	-0.410	-5.700	6.930**	-12.560**	2.590**	-3.840**
JG 16 x ICCV 96030	E_1	-0.190	0.550	-2.280	1.620**	-2.250	21.640**	-4.350	0.300	-1.670**	-1.930
	E_2	-0.170	0.380	-1.810	0.010	-0.570	24.380**	-6.770**	1.140	-1.670**	-2.550
	E_3	0.260	0.790	1.010*	0.210	-2.280	-15.860**	-4.040**	6.740*	-1.670**	0.830
JG 130 x JG 97	E_1	0.810	-0.790	-0.480	-0.210	-0.490	73.310**	15.650**	20.720**	1.860**	25.430**
	E_2	0.830	-0.620	-0.010	0.350	-0.140*	71.050**	13.600**	20.900**	1.860**	23.650**
	E_3	0.430	-0.050	-3.360**	-0.080	-4.180*	22.370**	8.060**	10.040**	1.860**	11.200**
JG 130 x ICCV 96029	E_1	0.480	-0.290	-5.480**	-0.680	-1.450	-20.120**	-6.300	-10.740**	-3.010**	-12.230**
	E_2	0.500	-0.290	-5.350	-0.450	3.130	-36.720	0.760	-19.100**	-3.010**	-13.350**
	E_3	0.260	-0.050	-1.540	-0.210	5.360	-9.180	-10.340**	-3.520	-3.010**	-8.300**
JG 130 x ICCV 96030	E_1	-3.190	0.880	-3.740	-1.050	-3.120	-33.520	-7.990**	-0.790	0.140	-4.830**
	E_2	-3.170	0.550	-5.850	-0.820	-4.600	-34.290	-5.370	-3.490	0.140	-5.290**
	E_3	-3.240	-1.050	-0.280	-0.710	5.520	-2.310	-5.870**	0.120	0.140	-3.740*
SE of SCA	E_1	0.450	0.540	1.890	0.370	1.990	9.490	3.090	2.450	0.280	1.350
SE of SCA	E_2	0.450	0.430	1.650	0.330	2.190	11.250	3.210	3.000	0.280	1.670
SE of SCA	E_3	0.420	0.390	0.330	0.330	1.680	3.360	1.020	3.070	0.280	1.460

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

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Hybrids	E	Seed volume (ml)	Hydration capacity seed^{-1}	Hydration index	Swelling index	Protein content (%)
VAIBHAV x JG 97	E_1	-0.048**	0.017**	0.074**	0.130	-0.660
	E_2	-0.046**	0.011	0.071	0.050	-0.690*
	E_3	-0.048**	0.016	0.074**	0.040	-0.660
VAIBHAV x ICCV 96029	E_1	0.019**	-0.010	-0.100	0.220	-0.010
	E_2	0.018**	-0.007	-0.099	-2.280*	0.130
	E_3	0.018**	-0.007	-0.097**	0.200	-0.020
VAIBHAV x ICCV 96030	E_1	0.028**	-0.007	0.026**	-0.260	-0.550
	E_2	0.028	-0.004**	0.028	0.000	-0.410
	E_3	0.030	-0.008	0.023**	0.040	-0.550
INDIRA CHANA-1xJG-97	E_1	-0.029*	-0.038**	-0.025**	-1.010**	0.680
	E_2	-0.031**	-0.037**	-0.028	-0.410	0.320
	E_3	-0.027**	-0.039**	-0.032**	-0.910**	0.680
INDIRA CHANA-1x ICCV 96029	E_1	-0.007	-0.025**	0.066**	0.900**	1.060**
	E_2	-0.007	-0.026**	0.067	0.770**	0.870**
	E_3	-0.005	-0.023**	0.072**	0.770*	1.060**
INDIRA CHANA-1x ICCV 96030	E_1	0.037**	0.063**	-0.041**	0.230	0.270
	E_2	0.038**	0.062**	-0.039	0.120	0.240
	E_3	0.032**	0.061**	-0.040**	-0.040	0.270
JG 315 x JG 97	E_1	0.028**	-0.010	-0.002	-0.200	-0.770
	E_2	0.027**	-0.011**	-0.004	-0.250	-0.470
	E_3	0.024**	-0.008	-0.005	-0.110	-0.780*
JG 315 x ICCV 96029	E_1	-0.012	0.049**	0.035**	-0.550*	0.620
	E_2	-0.012	0.051	0.036	-0.440	0.740*
	E_3	-0.011	0.044**	0.039**	-0.620	0.620
JG 315 x ICCV 96030	E_1	-0.016**	-0.038**	-0.033**	0.430*	-0.120
	E_2	-0.015**	-0.041**	-0.031	0.510*	-0.330
	E_3	-0.013**	-0.036**	-0.034**	0.030	-0.120
JG 11 x JG 97	E_1	-0.033**	0.007	0.031	-1.970**	0.100
	E_2	-0.033	0.005	0.028	-1.690**	-0.110
	E_3	-0.034**	0.006**	0.031**	-1.620**	0.100
JG 11 x ICCV 96029	E_1	0.028	-0.010	0.002	1.880**	0.810
	E_2	0.025	-0.014	0.003	1.490**	0.600
	E_3	0.027	-0.008	0.005	1.830**	0.810
JG 11 x ICCV 96030	E_1	0.005	0.003	-0.033	0.170	-1.320**
	E_2	0.008	0.009	-0.032	0.050	-0.870**
	E_3	0.007	0.001	-0.036**	0.110	-1.320**

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Hybrids	E	Seed volume (ml)	Hydration capacity seed^{-1}	Hydration index	Swelling index	Protein content (%)
JG 14 x JG 97	E_1	-0.052	0.028	0.029**	-0.240	-0.210
	E_2	-0.053	0.029	0.028	-0.170	-0.090
	E_3	-0.053**	0.023**	0.029**	-0.090	-0.210
JG 14 x ICCV 96029	E_1	0.033	0.037	-0.085	0.280	0.130
	E_2	0.033	0.037	-0.082	0.240	0.080
	E_3	0.032**	0.036**	-0.082	0.360	0.130
JG 14 x ICCV 96030	E_1	0.019	-0.065	0.056**	0.420*	0.050
	E_2	0.020	-0.066	0.054	0.390	-0.050
	E_3	0.021**	-0.060**	0.053**	0.580	0.050
JG 16 x JG 97	E_1	0.146	-0.009	-0.048**	-0.650**	0.140
	E_2	0.144	-0.006	-0.040	-0.230	0.210
	E_3	0.148**	-0.004	-0.039**	-0.230	0.130
JG 16 x ICCV 96029	E_1	-0.072	-0.017	0.034**	2.230**	0.450
	E_2	-0.072	-0.016	0.030	1.690**	0.520
	E_3	-0.070**	-0.020**	0.019	1.580**	0.450
JG 16 x ICCV 96030	E_1	-0.073	0.026	0.014	-0.870**	-1.490**
	E_2	-0.072	0.022	0.011	-1.080**	-0.920**
	E_3	-0.078**	0.024*	0.020	-0.930**	-1.490**
JG 130 x JG 97	E_1	-0.011	0.006	-0.059**	-1.070**	0.270
	E_2	-0.009	0.008	-0.055	-0.830**	0.000
	E_3	-0.011*	0.005	-0.059	-0.880**	0.270
JG 130 x ICCV 96029	E_1	0.010	-0.025	0.047**	0.010	-0.050
	E_2	0.014	-0.025	0.045**	0.050	-0.150
	E_3	0.009	-0.022**	0.045	0.130	-0.050
JG 130 x ICCV 96030	E_1	0.000	0.018	0.012**	-0.080	0.650
	E_2	-0.005	0.018	0.010**	0.010	0.380
	E_3	0.002	0.017**	0.014**	-0.250	0.640
SE of SCA	E_1	0.004	0.004	0.004	0.150	0.370
SE of SCA	E_2	0.004	0.004	0.004	0.220	0.330
SE of SCA	E_3	0.004	0.004	0.005	0.300	0.370

* Significant at 5%; ** Significant at 1% level of probability E_1= CS-I; E_2= CS-II; E_3= CS-III

Table.5 Best general and specific combiners for seed yield and its attributing and quality characters in chickpea under different environment

Characters	ENV.	Best general combiners	Best specific combiners
Days to 50 % flowering	E_1	JG 14 and Vaibhav	JG 315 x ICCV 96029 and Indira Chana-1 x ICCV 96029
	E_2	JG 14 and Vaibhav	JG 315 x ICCV 96029 and JG 16 x ICCV 96029
	E_3	JG 14 and Vaibhav	Vaibhav x JG 97 and Indira Chana-1 x ICCV 96029
Days to maturity	E_1	JG 130 and JG 16	-
	E_2	JG 130 and JG 16	JG 11 x ICCV 96029 and Vaibhav x JG 97
	E_3	JG 130 and JG 16	Indira Chana-1 x JG 97 and JG 315 x ICCV 96030
Plant height (cm)	E_1	JG 315	JG 16 x ICCV 96029 and Indira Chana-1 x ICCV 96030
	E_2	JG 315	JG 16 x ICCV 96029 and Indira Chana-1 x ICCV 96030
	E_3	JG 130	JG 14 x JG 97 and JG 16 x JG 96
Primary branches plant^{-1}	E_1	JG 14 and JG 97	JG 16 x ICCV 96030 and Indira Chana-1 x ICCV 96030
	E_2	JG 16 and JG 14	Indira Chana-1 x ICCV 96030 and JG 11 x ICCV 96030
	E_3	JG 16 and JG 130	-
Secondary branches plant^{-1}	E_1	JG 16 and JG 97	JG 315 x JG 97 and JG 14 x JG 97
	E_2	JG 16 and JG 130	JG 315 x JG 97
	E_3	JG 16 and JG 130	JG 11 x ICCV 96030 and Indira Chana-1 x JG 97
Pods plant^{-1}	E_1	JG 14 and JG 130	JG 130 x JG 97 and Vaibhav x ICCV 96030
	E_2	JG 14 and JG 130	JG 130 x JG 97 and Indira Chana-1 x ICCV 96030
	E_3	JG 16 and JG 130	Indira Chana-1 x JG 97 and JG 130 x JG 97
Biological yield plant^{-1} (g)	E_1	JG 130 and JG 16	Indira Chana-1 x ICCV 96029 and Vaibhav x ICCV 96029
	E_2	JG 16 and JG 130	Indira Chana-1 x ICCV 96029and JG 11 x ICCV 96029
	E_3	JG 16 and JG 130	JG 11 x JG 97and JG 130 x ICCV 96029
Harvest index (%)	E_1	JG 14 and JG 16	JG 130 x JG 97 and JG 14 x JG 97
	E_2	JG 14 and JG 16	JG 14 x JG 97 and JG 130 x JG 97
	E_3	JG 14 and ICCV 96029	JG 11 x JG 97 and JG 315 x JG 97

Conti…….

Characters	ENV.	Best general combiners	Best specific combiners
100-seed weight (g)	E_1	JG 16 and Vaibhav	Indira Chana-1 x JG 97 and JG 16 x ICCV 96029
	E_2	JG 16 and ICCV 96029	Indira Chana-1 x JG 97 and JG 16 x ICCV 96029
	E_3	JG 16 and ICCV 96029	Indira Chana-1 x JG 97 and JG 16 x ICCV 96029
Seed yield plant^{-1} (g)	E_1	JG 14 and JG 16	JG 315 x JG 97 and Indira Chana-1 x JG 97
	E_2	JG 14 and JG 16	JG 315 x JG 97 and Indira Chana-1 x JG 97
	E_3	JG 14 and JG 16	JG 315 x JG 97 and JG 315 x ICCV 96029
Seed volume (ml seed^{-1})	E_1	JG 97 and JG 16	Indira Chana-1 x ICCV 96030 and JG 315 x JG 97
	E_2	JG 97 and JG 16	Indira Chana-1 x ICCV 96030 and JG 315 x JG 97
	E_3	JG 16 and Indira Chana-1	Indira Chana-1 x ICCV 96030 and JG 315 x JG 97
Hydration capacity seed^{-1} (g)	E_1	ICCV 96030 and ICCV 96029	Indira Chana-1 x ICCV 96030 and JG 315 x ICCV 96029
	E_2	ICCV 96030 and ICCV 96029	Indira Chana-1 x ICCV 96030 and JG 315 x ICCV 96029
	E_3	ICCV 96030 and ICCV 96029	Indira Chana-1 x ICCV 96030 and JG 315 x ICCV 96029
Hydration index	E_1	-	Vaibhav x JG 97 and Indira Chana-1 x ICCV 96029
	E_2	ICCV 96029	Vaibhav x JG 97 and Indira Chana-1 x ICCV 96029
	E_3	ICCV 96029 and Indira Chana-1	Vaibhav x JG 97 and Indira Chana-1 x ICCV 96029
Swelling index	E_1	JG 130 and JG 315	JG 16 x ICCV 96029 and JG 11 x ICCV 96029
	E_2	JG 130 and JG 315	JG 16 x ICCV 96029 and JG 11 x ICCV 96029
	E_3	JG 130 and JG 315	JG 11 x ICCV 96029 and JG 11 x ICCV 96029
Protein content (%)	E_1	Vaibhav and JG 11	JG 16 x ICCV 96030 and JG 11 x ICCV 96030
	E_2	Vaibhav and JG 11	JG 16 x ICCV 96030 and JG 11 x ICCV 96030
	E_3	Vaibhav and JG 11	JG 16 x ICCV 96030 and JG 11 x ICCV 96030

* E_1: CS-I (Environment 1) E_2: CS-II (Environment 2) and E_3: CS-III (Environment 3)

This supported the involvement of both additive and non-additive gene effects. Rest of the character showed moderates to low narrow sense heritability over the environments. Similar finding were reported by Khan *et al.*, (2006), Gupta *et al.*, (2007), Verma and Waldiya (2010), Bhatt *et al.*, (2013) and Monpara and Gaikwad (2014).

General combining ability

Yield and contributing characters

For the Characters primary branches plant^{-1} parent JG 14 and JG 97 in E_1 andE_2 JG 16 in E_2 and E_3 JG 130 for E_3 have sown desirable positive gca effects for the traits and among them JG 14 in E_1 JG 16 in E_1 E_2, and E_3 have been considered as the best combiners for the traits. For the traits JG 16 in all three environments, JG 130 in $E_2$and$E_3$and JG 97 in $E_1$and E_2 have sown desirable positive gca effects for the traits and among them JG 16has been considered as the best general combiners as it shown the maximum gca effects for the traits. For Pods plant^{-1} the parents JG 14 and JG 97 in $E_1$and E_2 and JG 130 in all the environment *i.e.* E_1, E_2 and E_3 have exhibited desirable gca and among these JG 14 in $E_1$and E_2 positive gca effects for the traits JG 130 in E_3 have considered as the best general combiners for the traits. For Biological yield plant^{-1} the parents JG 14 and ICCV 96030 in E_3, JG 16 in E_2 and E_3, JG 130 in all the environments and ICCV 96029 in E1 have exhibited the desirable positive gca among them JG 130 in E_1 and JG 16 in E_2 and E_3 have considered as the best general combiners for the traits. For Harvest Index the traits significant positive gca was observed for JG 14 in E_1, E_2 and E_3, JG 16 in E_1 and E_2, ICCV 96029 in E_3 and ICCV 96030 in E_1, JG 14 has been identified as the best combiner for the traits in all the environments. For 100 seed weight the trait parent Vaibhav, JG 16 and ICCV 96029 have exhibited the desirable positive gca and among them JG 16 has been found as the best general combiner for seed index in all the three environments and Seed yield plant^{-1} the parents JG 14 and JG 16 in all the three environments. ICCV 96029 in E_1 and E_2 and ICCV 96030 in E_1 exhibited the desirable gca for the traits parents JG 14 in E_1 and E_2 and JG 16 in E_3 have been considered as the best general combiners.

Quality characters

The quality characters like Seed volume the trait parents JG 16 in all the three environments, Indira Chana-1 in E_2 and E_3 and JG 97 in E_1 and E_2 exhibited the positive desirable gca and JG 97 in E_1 and E_2 and JG 16 in E_3 have identified as the best general combiners for the trait. For Hydration capacity the trait positive desirable gca was observed for Indira Chana-1, ICCV 96029 and ICCV 96030 in all the environments and ICCV 96030 has been identified as the best general combiner for the hydration capacity. For Hydration index the trait parents Indira Chana-1 and JG 315 in E_3 and ICCV 96030 in E_2 and E_3 have exhibited positive desirable gca effects. While in E_1 none of the parent has shown significant positive gca. The parent ICCV 96029 has been identified as the best general combiner for hydration index. For Swelling index the trait parents JG 315 and JG 130 in all the three environments have sown positive gca. Similarly, JG 14 in E_2 and ICCV 96029 in E_1 and E_3 exhibited positive desirable gca for the trait. The parent JG 130 in all the three environments possessed the highest general combining ability effects consider as the best general combiner for the traits in the three environments. For Protein content the positive significant desirable gca has been consider for the parents Vaibhav, JG 11 and JG 16 in all the three environments. Among these parents Vaibhav exhibited the maximum gca and considered as the best general combiner for the trait. Similar results were reported by Katiyar *et al.,* (1993), Kamatar *et al.,* (1994), Chaturvedi *et al.,* (1997), Sorde *et al.,* (2000), Jeena and Arora (2001), Bhadouria and Chaturvedi (2003), Kulkarni *et al.,* (2004), Bhatnagar and Singh (2005), Mali *et al.,* (2006), Bhardwaj *et al.,* (2009), Bhardwaj *et al.,* (2010), Bhatt *et al.,* (2013), Mishra *et al.,* (2013), Amdabade *et al.,* (2014) and Monpara and Gaikwad (2014).

Specific combing ability

Even though SCA effect does not contribute tangibly in the improvement of self-pollinated crops, except in situations where exploration of heterosis is feasible, best crosses are expected to generate transgrasive segregants which could be selected as potent homozygous lines.

Result of sca analysis revealed that some exhibited significant desirable sca estimates in all the environment for one or more characters whereas, for other trait they shared significant SCA in one or two environment. Hence, in order to draw some valid conclusions result of the crosses exhibited significant sca for the traits under all the environments have discussed. The hybrid Vaibhav x JG 97 exhibited desirable negative SCA for days to 50 % flowering in all the three environments. The hybrid Vaibhav x ICCV 96029 exhibited desirable positive SCA in all the environments for 100 seed weight and seed volume. The hybrid Indira chana-1 x ICCV 96029 exhibited desirable negative SCA for days to 50 % flowering and desirable positive SCA for swelling index and protein content in all the environments. The hybrid Indira Chana-1 x ICCV 96030 exhibited desirable positive SCA for pods plant^{-1}, 100 seed weight, seed volume and hydration capacity seed^{-1} in all the three environments. The hybrid JG 315 x JG 97 exhibited significant positive SCA for harvest index seed yield plant^{-1} and seed volume in all the three environments. The hybrid JG 315 x ICCV 96029 showed positive desirable SCA for seed yield plant^{-1} in all the three environments *i.e.*, E_1, E_2 and E_3. The hybrid JG 11 x ICCV 96029 exhibited desirable positive SCA for swelling index in all the three environments. The hybrid JG 11 x ICCV 96030 exhibited desirable positive SCA for 100 seed weight in all the three environments. The hybrid JG 14 x JG 97 exhibited positive significant desirable SCA for harvest index, 100 seed weight, seed yield plant^{-1} and hydration index in all the three environments. The hybrid JG 16 x ICCV 96029 exhibited desirable negative SCA for days to 50 % flowering whereas, it had desirable positive SCA for plant height, 100 seed weight and swelling index in all the environments. The hybrid JG 130 x JG 97 exhibited desirable positive SCA for pods plant^{-1}, biological yield, harvest index, 100 seed weight and seed yield plant^{-1}in all the three environments. The hybrid JG 130 x ICCV 96030 exhibited significant positive desirable SCA for hydration index in all the three environments. Similar finding were reported by Khan *et al.,* (2006), Gupta *et al.,* (2007) and Bhatt *et al.,* (2013) for days to maturity. Jayalakshmi *et al.,* (2009) and Naveed *et al.,* (2012) for plant height. Sewak *et al.,* (2012), Gadekar and Dodiya (2013) and Mishra *et al.,* (2013) for primary branches plant^{-1} and Secondary branches plant^{-1}. Bhardwaj *et al.,* (2010) for pods plant^{-1}, Biological yields, and harvest index, 100 seed weight and seed yield plant^{-1}. Naveed *et al.,* (2012)for harvest index, Sidramappa *et al.,* (2008), Malik *et al.,* (2011) and Mishra *et al.,* (2013) for 100 seed weight and seed yield plant^{-1}.

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