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Research Article

Combining ability analysis in intraspecific F_1 diallel cross of upland cotton (*Gossypium hirsutum* L.)

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Abstract
Diallel analysis was carried out by involving nine parents and their 72 cross combinations in upland cotton for assessing their combining ability for yield and its component characters. Variance due to parents and hybrids showed significant differences between all the characters studied except number of bolls, boll weight, single plant yield, lint index and seed index. Significance of variance in parents versus hybrids interaction provides adequacy for comparing the heterotic expression for all the characters except boll weight, ginning per cent, lint index and seed index. The GCA variances were larger than those of SCA for all the traits except number of bolls per plant, indicating the preponderance of additive action. The parents MCU 5 and MCU 7 were proved to be good general combiners for single plant yield and other economic traits and hence need to be included in the yield improvement programmes. The hybrid combinations *viz.,* MCU 5 x MCU 7, Khandwa 2 x Suraj, KC 2 x MCU 5, Anjali x MCU 7 and Anjali x Suraj recorded superior *per se performance* for number of bolls, boll weight and single plant yield and other characters. Among these crosses KC 2 x MCU 5, Anjali x Suraj and Anjali x MCU 7 exhibited additive type gene action with one good general combining ability parent for number of bolls, boll weight and lint index respectively. Hence, selection can be made in these crosses in early generation itself.

Keywords:
Cotton, interspecific, combining ability, diallel

Introduction:

Cotton is an important fibre crop and it plays a vital role as a cash crop in commerce of many countries. Cotton production, processing and doing trade in cotton goods provide employment to about 60 million people in India. It provides fibre for textile industry, cellulose from its lint, oil and protein rich meal from its seed (Kumar *et al.*, 2014). The development of new variety with high yield and fibre quality is the primary objective of all cotton breeders. In any breeding programme, the choice of parents is an important aspect for the process of the crop improvement. Diallel analysis provides a systematic approach for detection of appropriate parents and crosses in terms of investigated traits. Among the several biometrical methods developed to identify superior parents for heterosis breeding, the diallel analysis has received considerable attention (Khan *et al.,* 2009). An investigation was taken up in cotton to study the general and specific combining ability and the gene action determining the yield and its yield components using 9 x 9 F_1 diallel design.

Material and methods

Breeding material and field procedure: The research work pertaining to study the genetic potential of genotypes and combining ability in F_1 hybrids of cotton (*Gossypium hirsutum* L.) was conducted during 2012-14 at the Department of Cotton, Tamil Nadu Agricultural University, Coimbatore. Nine diverse genotypes (Suraj, Surabhi, Khandwa 2, Anjali, KC 2, KC 3, MCU 5, MCU 7 and G.Cot 16) of upland cotton were raised during winter 2012-2013 and were crossed in a complete diallel fashion. During winter 2013-14, the parents and 72 F_1s were raised in a Randomized Block Design with two replications. The package of practices recommended for the cotton cultivation in Tamil Nadu was followed throughout the crop growing period. The diallel analysis was performed as based on the model 1 and method 1 suggested by Griffing (1956).

*Traits measurement and statistical analyses:*The datas were recorded on five randomly selected plants per replication for nine characters namely, days to first boll bursting, plant height at maturity, number of sympodia per plant, number of bolls per plant, boll weight, single plant yield, ginning per cent, lint index and seed index. Statistical analysis was carried out by using the mean values over five sample plants through INDOSTAT package.

Results and Discussion

*Analysis of variance:*Analysis of variance showed highly significant differences due to genotypes for all the traits indicating the presence of sufficient variability in the experimental materials (Table 1). Significance of variance in parents versus hybrids interaction provides adequacy for comparing the heterotic expression for all the characters except boll weight, ginning per cent, lint index and seed index. Parents and hybrids showed significant differences between all the characters studied except number of bolls, boll weight, single plant yield, lint index and seed index. It was also confirmed by the results reported in earlier studies of Jatoi *et al.* (2010) for boll weight and Kumar *et al.* (2014) for single plant yield. GCA and SCA variances are significant for all the characters studied except number of bolls per plant for GCA and number of sympodia per plant and boll weight for SCA. Reciprocals were significantly dissimilar all the traits (Table 2).

*Effects of gene action:*The higher SCA than GCA of a character indicates the preponderance of non-additive gene action. Additive gene action provides fixable effects, and the non-additive gene action results are non-fixable. If GCA variance was greater than SCA for the particular character, it indicates preponderance of additive gene action. The current study, analysis of combining ability revealed that variances for GCA were larger than those of SCA for all the traits except number of bolls per plant, indicating the preponderance of additive action, which could be exploited for the improvement of these traits by mass selection. Similar findings were reported by Jatoi *et al.* (2010) in upland cotton. Preponderance of additive type of gene effects suggested directional selection for isolating better homozygous lines from segregating population for these traits. These observations are in conformity with findings obtained by Yuan *et al.* (2002), Khan *et al.* (2005) and Aguiar *et al.* (2007) in upland cotton. In this present study, additive gene action was determined for all the characters studied except number of bolls per plant. Additive gene action for kapas yield, lint index, seed index and boll weight was reported in earlier studies of Iyanar *et al*. (2005), and non-additive gene action for number of bolls per plant was reported by Imran *et al.* (2012), and have been confirmed by our results.

Choice of parents: The nine parents and their resultant 72 F_1 hybrids varies significantly each other in its yield components. Information on the *per se* performance and nature of general combining ability (*gca*) of characters is necessary for selection of suitable parents for developing hybrids. Therefore, the present study was aimed for their *per se* performance and *gca* effects. The *per se* performance of parents for yield and its component characters are presented in Table 3 and compared with grand mean. Based on *per se*, parent MCU 5 recorded higher mean for single plant yield (87.34 g/plant), boll weight (4.55 g/boll), number of sympodial branches per plant (20.09), number of bolls per plant (24.50) and ginning per cent (34.68%) followed by Anjali which recorded high *per se* for single plant yield, boll weight, number of sympodial branches and number of bolls per plant. The parent KC 3 recorded high *per se* for number of bolls, ginning per cent, lint index and seed index. The parent MCU 7 recorded high *per se* for single plant yield and number of sympodial branches. G.Cot 16 registered higher mean for lint index and seed index. The parent Suraj recorded high *per se* for boll weight and ginning per cent. High mean values remain as a selection index in choice of parents and the parents possessing high *per se* performance will result in superior hybrids. Therefore, these parents can be exploited in hybridization for improving this character through pedigree breeding (Hassan *et al.*, 2000).

The estimates of *gca* effect (Tables 4 to 12) showed that, parent MCU 5 had recorded positive and significant *gca* effect for plant height, number of sympodial branches and single plant yield. The parent Suraj was a good combiner for boll weight, ginning per cent and lint index, while MCU 7 was a good combiner for single plant yield and ginning per cent. Good general combiners for boll weight and seed index were Anjali and G.Cot 16, respectively. KC 3 exhibited positive and significant *gca* effects for ginning per cent. Similar results were reported by Kumar *et al.* (2014) and high *gca* effect in desirable direction for a particular character indicates the presence of additive genes for that character in the parent, it could be expected that when the parents possessing high *gca* effects were combined; larger proportion of progenies would have high *per se* value for the character concerned facilitating easy selection for the character. Based on the high *per se* performance and high *gca* effect, the parent MCU 5 was considered as best general combiner as it had significantly higher values for plant height, sympodial branches and single plant yield. The parent Suraj had recorded high *per se* performance and *gca* effects for boll weight and ginning per cent. The parent Anjali for boll weight, KC 3 and G.Cot 16 for ginning per cent and seed index, respectively, showed better expression for high *per se* and *gca* effects.

In general, identification of parents for breeding programme based on either *per se* performance or *gca* effects alone was misleading in the selection programme. In the present study, considering *gca* effects and *per se* performance together, the parents MCU 5, Anjali, KC 3, MCU 7, Suraj and G.Cot 16 were selected as the best, since these were having high mean values for six, five, four, two, two and two traits respectively and also good combining ability for three, two, one, three, three and one yield component traits, respectively. None of the parents was found to be excellent general combiner for all the traits. Hence, it would be desirable to have multiple crosses and subject them to selection in segregating generations to detect superior genotypes with higher yield.

*Choice of crosses:*The specific combining ability (*sca*) effect alone may not be the appropriate choice for exploitation of heterosis because the hybrid with low mean value may also possess high *sca* effect. Hence, the cross combinations were to be identified based on two criterias *viz., per se* performance and the gene action involved in the crosses for further exploitation. In the present investigation, hybrids MCU 5 x MCU 7, Khandwa 2 x Suraj and KC 2 x MCU 5 recorded high *per se* for number of sympodial branches, number of bolls per plant and single plant yield. Hybrid Anjali x MCU 7 recorded high *per se* effects for single plant yield, ginning per cent and lint index. The hybrid Anjali x Suraj recorded high *per se* for boll weight, single plant yield and lint index. The hybrid KC 3 X G.Cot 16 had shown high *per se* for seed index. Hence based on yield and component characters, the crosses MCU 5 x MCU 7, Khandwa 2 x Suraj, KC 2 x MCU 5, Anjali x MCU 7 and Anjali x Suraj were considered as desirable crosses.

In addition to superior *per se* performance, the nature of gene action is an important criterion to select the crosses for pedigree breeding (Tables 4 to 12). Crosses with additive type of gene action are desirable as this facilitates early generation selection. None of the crosses was found desirable simultaneously for all the characters. Based on *sca* effects, MCU 7 x KC 3 recorded significant *sca* effects for number of bolls per plant, boll weight, single plant yield and lint index. Hybrid MCU 7 x KC 3 for boll weight and single plant yield, with high x low *gca* resulted in non-additive gene interactions in these crosses. In this situation, we could go for recombination breeding, whereas the parents with positive *gca* effects and parents with low negative significant *gca* effects. Similar findings were reported by Muthu *et al.* (2005) and Ahuja and Dhayal (2007). Parents with positive significant *gca* effects involved additive type of gene action that would be easily fixable. For yield contributing characters such as number of bolls per plant, hybrids MCU 5 x MCU 7 and Suraj x Khandwa 2 had possessed significant positive *sca* effects. In case of other three high yielding crosses *viz.*, KC 2 x MCU 5, Anjali x Suraj and Anjali x MCU 7 non significant *sca* was observed for number of bolls, boll weight and lint index, respectively and also for its other component characters. It indicated the presence of additive gene action and hence selection can be effective in these crosses in early generation itself. Additive genetic effects were also observed for most of the yield related traits with enough genetic variability and effective selection (Lukonge *et al.,* 2008).

From the above discussion, it might be concluded that the parent MCU 5 had superior *per se* performance for more number of traits studied. Based on high *per se* performance and high *gca* effect, the parents MCU 5, Anjali, KC 3, MCU 7, Suraj and G.Cot 16 were considered as best general combiners as they had significantly higher values for single plant yield, number of sympodial branches and number of bolls. Most of the high yielding crosses, exhibiting desirable *sca* effects, involved parents with high and low gca effects, indicating the influence of non-additive gene interactions in these crosses. Among the hybrids, MCU 5 x MCU 7, Khardwa 2 x Suraj, KC 2 x MCU 5, Anjali x MCU 7 and Anjali x Suraj exhibited superior *per se* performance and one of the parents with good general combining ability and additive type of gene action. Hence, selection can be made in early generation itself in these crosses. Based on *sca* effects, MCU 7 x KC 3, MCU 5 x MCU 7 recorded significant *sca* effects for number of bolls per plant and single plant yield. An increase in the seed cotton yield along with other traits will be a valuable addition to cotton cultivars.

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Table 1. Analysis of variance showing means square for yield and its component characters in a 9 x 9 F_1 diallel cross of upland cotton

Source	d.f	Days to first boll bursting	Plant height (cm)	Number of sympodial branches per plant	Number of bolls per plant	Boll weight (g)	Single plant yield (g)	Ginning per cent (%)	Lint index	Seed index
Replications	1	0.357	15.223	4.590	13.387	0.072	13.629	0.026	0.243	1.993
Genotypes	80	6.721 **	358.857 **	6.747 **	14.823 **	0.255 **	277.862 **	23.179 **	0.644 **	2.368 **
Parents	8	2.735 **	156.155 **	11.733 **	6.476	0.186	47.231	3.712 **	0.391	1.928
Hybrids	71	7174 **	374.639 **	6.023 *	14.205 **	0.266 **	296.090 **	25.690 **	0.682 **	2.414 **
Parents V_s Hybrids	1	6.435 **	859.956 **	18.257 *	125.434 **	0.015	828.759 **	0.672	0.002	2.660
F_1's	35	2.880 **	320.599 **	6.306 *	14.577 **	0.330 **	350.116 **	23.748 **	0.561 **	2.126 *
Reciprocals	35	11.499 **	405.372 **	5.893 *	14.043 *	0.207	248.219 **	28.337 **	0.798 **	2.711 **
$F_{1\ Vs}$ reciprocals	1	6.126 **	1190.365 **	0.703	6.860	0.093	80.655	1.015	0.853	2.052
Error	80	0.631	14.072	3.554	7.565	0.140	41.255	0.629	0.243	1.151
Total	161	3.655	185.401	5.147	11.207	0.197	158.652	11.830	0.442	1.761

**Significant at 1 % level, *Significant at 5 % level

Table 2. Analysis of variance and genetic contribution of parents, hybrids and reciprocals in a 9 x 9 F_1 diallel cross of upland cotton

Source	d.f	Days to first boll bursting	Plant height (cm)	Number of sympodial branches per plant	Number of bolls per plant	Boll weight (g)	Single plant yield (g)	Ginning per cent (%)	Lint index	Seed index
GCA	8	6.181 **	272.977 **	7.875 **	5.153	0.390 **	243.812 **	13.932 **	0.370 **	1.790 **
SCA	36	2.009 **	145.663 **	2.066	6.023 *	0.071	92.759 **	7.234 ***	0.314 **	1.035 *
Reciprocal	36	4.085 **	192.406 **	3.681 **	9.302 **	0.125 *	161.797 **	15.424 **	0.320 **	1.198 **
Error	80	0.315	7.036	1.777	3.782	0.070	20.628	0.314	0.121	0.576

**Significant at 1 % level, *Significant at 5 % level

Table 3. *Per se* performance of parents for yield and its component characters in a 9 x 9 F_1 diallel cross of upland cotton

Parents	Days to first boll bursting	Plant height (cm)	Number of sympodial branches per plant	Number of bolls per plant	Boll Weight (g)	Single plant yield (g)	Ginning per cent (%)	Lint index	Seed index
Suraj	102.63	95.03	12.50	20.00	4.51	76.60	34.50	5.35	10.14
Surabhi	102.33	103.80	15.50	20.10	4.29	80.06	33.85	4.87	9.46
Khandwa 2	101.90	96.10	12.10	18.50	3.91	75.14	30.76	4.14	9.32
Anjali	105.20	110.53	15.00	22.00	4.47	85.09	34.04	5.26	7.74
KC 2	103.00	93.70	15.63	19.50	4.34	78.70	33.03	5.17	10.47
KC 3	101.40	99.40	14.70	22.40	3.87	81.06	35.31	5.48	10.04
MCU 5	101.20	114.90	20.09	24.50	4.55	87.34	34.68	5.11	9.63
MCU 7	102.20	101.88	17.00	21.60	3.75	84.90	32.49	5.11	10.61
G.Cot 16	102.53	86.07	13.67	20.80	4.01	73.10	33.80	5.70	11.15
Grand mean	102.49	100.16	15.13	21.06	4.19	80.22	33.61	5.13	9.84
CD (P = 0.05)	0.55	2.59	2.39	4.31	0.45	3.62	1.69	1.51	3.45

Table 4. General and specific combining ability effects for days to first boll bursting, plant height, number of symbodial branches per plant, number of bolls per plant and boll weight (g)

	Suraj	Surabhi	Khandwa 2	Anjali	KC 2	KC 3	MCU 5	MCU 7	G.Cot 16
Days to first boll bursting									
Suraj	**-0.227**	-0.453	0.915*	0.422	0.131	-0.548	-0.132	0.116	-0.489
Surabhi	0.313	**-0.184**	0.072	0.328	1.488**	1.159**	-0.175	-0.777*	-1.282**
Khandwa 2	0.400	0.300	**-0.640****	-1.398**	0.493	0.195	0.606	-0.034	-0.977**
Anjali	-2.550**	2.500**	-0.283	**1.404****	-1.950**	0.504	1.388**	-0.415	1.780**
KC 2	1.350**	-1.250**	2.000**	-0.600	**-0.406****	0.331	-0.348	-0.205	-0.698
KC 3	-0.500	0.250	-0.370	-2.517**	0.000	**-0.277***	0.768*	-0.472	-0.839*
MCU 5	0.350	0.650	1.225**	-4.100**	-0.255	1.500**	**0.157**	-0.218	0.277
MCU 7	0.500	-0.050	0.137	-0.400	0.000	0.238	1.150**	**0.059**	2.975**
G.Cot 16	-0.250	-0.500	0.350	-3.850**	-0.512	0.150	-0.100	-2.700**	**0.114**
Plant height (cm)									
Suraj	**-1.770****	3.748*	1.319	-2.304	7.695**	-18.713**	6.596**	-9.758**	6.480**
Surabhi	0.510	**4.143****	0.506	-7.979**	2.900	1.424	4.670**	0.479	-7.623**
Khandwa 2	-1.500	-5.000**	**-1.788****	-6.740**	-2.466	-5.007**	-0.449	-7.428**	14.226**
Anjali	-20.923**	13.210**	3.497	**0.657**	-5.687**	19.880**	-3.944*	-1.611	-7.187**
KC 2	-12.280**	-4.533*	4.000*	-17.225**	**0.316**	11.901**	-3.773*	4.316*	-14.316**
KC 3	1.400	1.950	-7.012**	-8.980**	-15.000**	**0.044**	-17.968**	2.053	0.756
MCU 5	14.650**	-8.963**	3.313	13.673**	4.767*	-5.500**	**6.886****	3.194	4.185*
MCU 7	3.400	1.750	-2.587	-16.375**	-9.260**	4.275*	-15.143**	**-1.611****	-2.702
G.Cot 16	15.873**	-1.482	-13.000**	-12.132**	-0.087	-12.262**	-6.478**	5.950**	**-6.877****
Number of sympodial branches									
Suraj	**-0.742***	0.428	0.110	-0.542	1.080	-1.126	0.549	1.265	0.334
Surabhi	1.950*	**0.183**	1.735*	0.258	-0.645	0.649	0.374	-1.210	-0.641
Khandwa 2	-1.400	-0.850	**-0.349**	-0.035	-0.014	-0.015	0.055	0.208	1.240
Anjali	-2.400*	1.475	1.400	**0.503**	-0.515	1.328	-0.014	0.869	0.738
KC 2	-0.800	-2.000	-0.100	1.250	**-0.119**	2.000*	-0.505	-0.759	-0.427
KC 3	-0.450	2.950**	0.855	-1.550	-1.000	**0.137**	-1.081	0.597	-0.696
MCU 5	1.500	-1.750	2.300*	0.717	2.030*	-1.050	**1.112***	-1.040	-0.121
MCU 7	-0.750	-0.800	-0.212	-0.700	0.950	1.038	1.000	**0.347**	-0.155
G.Cot 16	-0.500	2.350*	-0.400	-0.550	-0.638	0.650	-1.500	-0.500	**-1.073****

Table 4. Contd..

	Suraj	Surabhi	Khandwa 2	Anjali	KC 2	KC 3	MCU 5	MCU 7	G.Cot 16
Number of bolls per plant									
Suraj	**-0.104**	-0.602	3.941**	-1.293	0.258	-0.158	2.143	-1.382	0.418
Surabhi	-1.063	**0.236**	2.151	2.175	1.769	0.553	-1.297	0.628	-1.472
Khandwa 2	-2.950*	0.400	**-0.020**	0.555	0.974	-1.349	-1.209	-0.654	0.584
Anjali	-2.950*	1.407	2.882*	**0.414**	-1.710	1.675	-0.043	1.300	-0.300
KC 2	-3.600*	-0.050	-3.500*	0.150	**-0.587**	1.826	-0.236	-1.349	1.326
KC 3	1.500	1.050	-1.208	-1.250	-0.600	**0.128**	-1.090	0.148	-0.215
MCU 5	-0.800	0.800	-1.532	3.868**	3.563*	2.900*	**0.728**	2.836*	-0.614
MCU 7	0.600	0.850	-1.688	-2.500	0.050	3.438*	0.850	**0.253**	0.911
G.Cot 16	1.000	1.550	-1.750	-1.600	-2.725	1.900	-2.900*	-3.950**	**-1.047***
Boll weight (g)									
Suraj	**0.231****	-0.109	-0.056	0.258	0.210	-0.082	-0.039	-0.183	0.172
Surabhi	0.440*	**-0.021**	-0.077	-0.151	0.082	-0.030	0.087	0.197	-0.116
Khandwa 2	-0.108	-0.165	**-0.166****	-0.108	-0.008	0.005	0.015	0.152	0.054
Anjali	-0.033	0.023	-0.170	**0.154***	0.309	-0.246	0.002	-0.141	0.136
KC 2	0.000	-0.390*	-0.110	0.117	**0.119***	-0.193	-0.386*	0.126	-0.027
KC 3	-0.410*	0.400*	-0.055	-0.275	0.297	**-0.214****	0.050	0.149	0.259
MCU 5	-0.210	-0.050	-0.208	-0.230	-0.207	-0.055	**-0.051**	0.224	-0.391*
MCU 7	0.308	0.085	0.150	-0.278	0.485*	0.410*	-0.023	**0.020**	-0.020
G.Cot 16	0.365	-0.105	-0.005	-0.092	0.030	-0.517**	-0.320	-0.007	**-0.072**

**Significant at 1 % level, *Significant at 5 % level; diagonal values indicate the *gca* effects.

Table 5. General and specific combining ability effects for single plant yield, ginning percentage, lint index and seed index

	Suraj	Surabhi	Khandwa 2	Anjali	KC 2	KC 3	MCU 5	MCU 7	G.Cot 16
Single plant yield (g)									
Suraj	**1.924**	0.757	12.357**	3.662	4.541	-8.446**	3.076	-2.684	0.605
Surabhi	13.498**	**-1.521**	5.147	3.042	-0.141	1.265	-7.523*	-2.654	3.621
Khandwa 2	-1.980	-3.770	**-0.709**	-10.328**	-3.439	0.149	-0.701	-2.206	9.080**
Anjali	-10.768**	12.343**	7.800*	**1.669**	-9.034**	3.519	7.224*	9.291**	-2.512
KC 2	-2.035	-13.347**	-3.603	1.510	**0.237**	9.013**	5.148	6.568*	-4.266
KC 3	1.735	12.500**	-13.683**	-15.880**	-5.252	**-5.036****	-10.259**	-2.894	3.137
MCU 5	2.523	-5.613	3.032	6.785*	11.608**	0.262	**6.020****	11.655**	2.702
MCU 7	-5.313	9.138**	-9.662**	-0.243	-0.957	16.202**	7.877*	**2.835****	-9.688**
G.Cot 16	12.442**	3.697	-11.490**	-8.940**	-5.010	-7.670*	-8.360*	-16.320**	**-5.419****

Table 5. Contd..

	Suraj	Surabhi	Khandwa 2	Anjali	KC 2	KC 3	MCU 5	MCU 7	G.Cot 16
Ginning percentage (%)									
Suraj	**1.041****	-0.296	-0.256	1.937**	-0.170	0.104	0.165	0.976**	-1.456**
Surabhi	-1.485**	**-1.307****	0.020	-1.225**	-0.277	0.177	1.010**	-2.559**	0.112
Khandwa 2	-1.525**	-2.682**	**-0.377****	3.365**	-1.197**	-2.153**	1.175**	0.274	0.685
Anjali	-0.547	0.208	-0.608	**0.418****	-4.599**	0.217	-2.522**	2.291**	0.760*
KC 2	0.280	5.875**	-3.935**	2.038**	**-0.968****	2.908**	-2.427**	3.397**	0.826*
KC 3	-2.455**	-0.290	3.515**	-3.930**	3.010**	**0.673****	2.508**	-0.866*	-3.438**
MCU 5	-0.052	2.265**	-1.600**	-1.052**	0.847*	0.073	**0.250***	-0.899*	0.238
MCU 7	3.135**	3.137**	-2.005**	0.647	-1.452**	2.045**	-3.620**	**1.027****	0.376
G.Cot 16	1.977**	2.818**	-2.615**	-2.870**	0.180	-5.928**	6.610**	-3.030**	**-0.759****
Lint index									
Suraj	**0.243****	-0.174	-0.043	0.288	0.071	-0.070	0.183	0.001	0.007
Surabhi	0.058	**-0.158***	0.108	-0.319	-0.033	0.189	0.793**	-0.393	-0.230
Khandwa 2	-0.130	-0.515*	**-0.161***	0.459*	-0.500*	-0.696**	0.502*	0.742**	0.086
Anjali	-0.482	-0.105	-0.065	**0.061**	-0.407	0.040	-0.282	0.266	-0.063
KC 2	0.057	0.457	-0.617*	0.307	**-0.167***	0.528*	-0.604**	-0.101	0.663**
KC 3	-0.322	-0.045	0.392	-0.825**	-0.115	**0.133**	0.307	0.171	-0.563*
MCU 5	-0.350	0.090	-0.450	-0.082	0.007	-0.245	**0.014**	-0.619**	-0.241
MCU 7	0.495*	0.630*	-0.062	-0.013	-0.148	0.565*	0.065	**-0.030**	-0.110
G.Cot 16	-0.025	0.187	-0.500*	-0.517*	0.070	-0.550*	0.822**	-0.810**	**0.064**
seed index									
Suraj	**0.026**	-0.225	0.064	-0.124	0.125	-0.224	0.215	-0.457	0.740
Surabhi	0.810	**0.318**	0.172	0.163	0.252	0.213	1.125*	0.210	-0.528
Khandwa 2	0.430	0.195	**-0.181**	-0.262	-0.591	-0.452	0.419	1.357**	-0.188
Anjali	-0.595	-0.275	0.090	**-0.318**	1.635**	0.122	0.825	-0.224	-0.309
KC 2	-0.017	-1.947**	0.335	-0.405	**0.181**	-0.270	-0.288	-1.635**	0.865
KC 3	0.483	0.043	-0.722	0.185	-1.513**	**-0.015**	-0.570	0.621	0.691
MCU 5	-0.623	-0.985	-0.125	0.330	-0.385	-0.462	**-0.054**	-0.683	-0.575
MCU 7	-0.390	-0.090	0.848	-0.285	0.263	0.143	1.575**	**-0.490****	-0.577
G.Cot 16	-1.070*	-0.960	0.195	0.288	0.045	1.910**	-1.350*	-0.262	**0.533****

**Significant at 1 % level, *Significant at 5 % level; diagonal values indicate the *gca* effect