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COMBINING ABILITY ESTIMATES OF SOME TESTER LINES USED ONTO CYTOPLASMIC MALE STERILE COTTON

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Abstract

Three cytoplasmic male sterile lines of cotton and six hirsutum non-restorer pollinators were used as tester lines onto CMS parents to study the general and specific combining ability parameters for yield of seed-cotton, seed index, lint index, ginning outturn percentage and staple length. Of the tester lines used, K-68/9 was observed to be the best combiner for yield of seedcotton and therefore was considered suitable for converting it into restorer parent to be utilized in hybrid cotton development programme. *Per se* performance of hybrids for yield of seedcotton was correlated with specific combining ability effects but the correlation did not hold good with respect to seed index, lint index, g.o.t.% and staple length. Generally the GCA of a tester line was not correlated with the SCA of a hybrid for all the characters. GCA effects were more pronounced with respect to yield, as compared to SCA effects, and therefore selection has been advocated on the basis of GCA's of the tester lines.

Introduction

The evaluation of the parents desired for using them in the hybridization programme has been advocated on the basis of their general combining ability values after the concept of Sprague & Tatum (1942) who provided an early systematic exposition of such parameters to evaluate maize inbred lines. Plant breeders define combining ability as the breeding value of cultivars/varieties or strains and their offspring with respect to any quantitative character. Sprague & Tatum (1942) used the term General Combining Ability (GCA) for parents and Specific Combining Ability (SCA) for hybrids to designate their respective performances. The essential idea was to consider a systematic set of crosses between a number of parents and enquire to what extent the variation among crosses can be interpreted as due to statistically additive features of the parents and what must be attributed to the residual interactions. The combining ability analyses are being widely exploited in cotton breeding programmes designed to make use of heterosis through hybrids. Though there are considerably extensive cotton research programmes involving inter and intraspecific hybrids, yet early generation testing on the basis of combining ability studies provides information about gene action of a particular character under study and aids in selecting parents for producing desirable combinations and segregating populations.

A tester line as defined by Rawlings & Thompson (1962) is the one that classifies correctly the relative performance of lines and discriminates efficiently among lines under test. Allison & Curnow (1966) defined the best tester as one that maximizes the expected mean yield of the population produced from random mating of selected genotype. Hallauer (1975) pointed out that, in general, a suitable tester should include simplicity in use, provide information that correctly classifies the relative merit of lines and maximize genetic gain. Either early or late generation testing, the ultimate breeding objective is the choice of a tester line to evaluate combining ability. When aimed at replacing a parental line on the basis of its performance from a specific combination, SCA is of prime importance and the most appropriate tester would be the opposite inbred line parent of a single cross or the opposite single-cross parent of a double cross (Matzinger, 1953). Selecting for GCA, the only apparent requirement is that the tester parent be genetically heterozygous i.e. have a broad genetic base. The GCA of a line, however, is not a fixed property of that line but depends on the genetic composition of the population with which it has been crossed (Kempthorne & Curnow, 1961).

In cytoplasmic male sterility (CMS), genome of one species if transferred into cytoplasm of other species results in male sterility but the same genome in its own cytoplasm is fully fertile. Cytoplasmic male sterile cotton has paved a way in developing hybrid cotton as it completely escapes emasculation. Comprehensive review of utilizing cytoplasmic and genetic male sterility to develop hybrid cotton has been presented by Soomro (1984). In the present studies, six locally developed hirsutum varieties have been used as male tester lines onto four cytoplasmic male sterile hirsutum cultivars to study the performance of former with respect to general and specific combining ability estimates for seedcotton yield and its components. The purpose of the studies was to isolate the best F_1 combinations and forward them to further filial generations through pedigreed selection procedure on the basis of their SCA values and to isolate the best tester line (male parent) on the basis of GCA estimates so that it could conveniently be converted into restorer parent and extensively used in the hybrid cotton development programme.

Materials and Methods

Four cytoplasmic male sterile (CMS) hirsutum cotton varieties viz., CMS Deshams-16, CMS Tamcot-778, CMS Deltapine-55 and CMS Coker-304 (all USA introductions) were used as female parents and six hirsutum tester lines viz., K-68/9 (evolved at Cotton Research Station, Ghotki), CRIS-6/86, CRIS-9/86 (developed at Cotton Research Institute, Sakrand), Qalandri (evolved at Cotton Research Section, Tandojam) and CIM-109 and ST-3 (developed at Cotton Research Institute, Multan) were used as male parents in the combining ability studies programme. In the crossing block, extensive pollen shedding was manually done onto CMS varieties to effect CMS F_1 hybrids.

Every two rows of a CMS parent were flanked by two rows of a non-restorer pollinator tester in the crossing block at Cotton Research Institute, Sakrand, during May 1987. The rows were 15.25 m long and 75 cms apart. The seeds were hand dibbled at a distance of 30 cms hole to hole putting 3 seeds per dibble and then leaving one plant per hole to maturity. Recommended doze of fertilizer @ 75 lbs/ac P_2O_5 in the form of DAP, all at soaking doze, and 100 lbs/ac N in the form of urea (in two equal splits, one with first irrigation and the other at peak flowering) were given.

Bolls, set after pollinators manually brushed onto CMS parents, were collected at maturity. Observations, per 100 bolls sample, were recorded on weight of seedcotton per boll in g, seed index (weight of 100 seeds), lint index (lint weight of 100 seeds), ginning outturn percent and staple length (mm). Obviously, the F_1 seed obtained from these bolls would be CMS, but on the basis of GCA estimates of the pollinator testers, the best performing tester was converted into restorer line and then used for hybrid cotton programme. Similarly, on the basis of SCA estimates of the CMS hybrids, a particular hybrid was exploited with the best tester converted into restorer.

The estimates of GCA and SCA were determined as explained by Simmonds (1979) where two different groups of parents (in the present case CMS as female parents group and hirsutum pollinator testers as males) were mated and combining abilities measured from their general mean. Within group mating (crossing) was not covered in these formulae. The characteristics feature of the GCA values is that since they are estimated from general mean, the sum of GCA's of each group of parents adds to zero. The analysis of variance of the data for all the characters under study was also done following Simmonds (1979) where the proportion of variance between the crosses accounted for by the GCA is identical with coefficient of determination (r^2) which itself explains the variation in the particular character (Sokal & Rholf, 1981).

Results and Discussion

Generally, the success of intraspecific cotton hybrids depends upon the extent of level of heterosis within the parental species involved. The level of heterosis, especially with respect to seedcotton yield per acre, is more or less related to the geographical area in which the cultivars and hybrids are being grown. Therefore the selection of parents plays pivotal role in hybridization programme. The evaluation of tester lines in the present studies was also based on the estimates of GCA of individual line for a particular character under study. The performance of the hybrids obtained by pollinating 4 CMS hirsutum parents (A-lines) with 6 hirsutum non-restorer B-line testers for 5 characters is given in Table 1.

In the *per se* hybrid performance, hybrids CMS Coker-304 x K-68/9 and CMS Tamcot-778 x K-68/9 were the best yielding hybrids and therefore could be predicted to give the highest specific combining ability. This type of interpretation has been found in the reports of Srinivasan & Gururajan (1973), Julka *et al* (1979), Khan *et al* (1981). Similarly for seed index, hybrid CMS Coker-304 x CRIS-6/86 and CMS Coker-304 x K-68/9

Table 1. Average performance of hybrids obtained from pollinating hirsutum CMS lines at CRI-Sakrand during 1987.

CMS line and pollinator	Seed-cotton per boll (gms)	Seed index (gms)	Lint index (gms)	g.o.t. %	Staple length (mm)
CMS Deshams-16					
K-68/9	2.98	8.73	3.99	33.66	29.54
CRIS-6/86	2.21	8.35	3.90	34.17	29.88
CRIS-9/86	3.00	8.89	4.19	32.21	27.80
ST-3	3.11	8.32	3.99	33.22	26.82
CIM-109	2.41	8.99	3.98	30.99	27.23
Qalandri	3.14	7.80	3.85	33.15	28.35
CMS Tamcot-778					
K-68/9	4.23	8.88	4.21	32.31	29.70
CRIS-6/86	3.28	8.72	4.10	33.52	30.06
CRIS-9/86	2.05	8.61	4.18	34.12	27.41
ST-3	3.02	8.62	4.01	33.92	26.79
CIM-109	2.55	8.99	4.04	33.71	27.58
Qalandri	2.08	7.94	3.86	33.91	27.83
CMS Deltapine-55					
K-68/9	3.22	9.05	4.23	32.07	29.68
CRIS-6/86	3.25	8.74	4.04	33.71	30.62
CRIS-9/86	2.70	9.29	4.11	34.17	27.49
ST-3	2.18	8.29	3.84	34.41	26.88
CIM-109	2.60	9.04	4.09	32.92	29.50
Qalandri	2.22	7.96	3.95	33.30	28.02
CMS-Coker-304					
K-68/9	4.25	9.50	4.27	33.59	29.79
CRIS-6/86	3.23	9.65	4.17	32.38	30.08
CRIS-9/86	2.42	8.63	4.15	34.27	27.43
ST-3	2.21	7.28	3.99	32.68	26.84
CIM-109	2.72	9.06	4.14	33.71	27.56
Qalandri	2.34	7.83	3.88	33.23	29.81

were the best by giving bold and sound seeds. In the ginning outturn, CMS Deltapine-55 x ST-3 gave the highest g.o.t.%. On the other hand, there are numerous reports where best performance of an individual hybrid should not be correlated with predicting specific

Table 2. Mean squares from the Anova of the data from Table 1 for five characters.

Source of variation	D.F.	Seedcotton per boll	Seed index	Lint index	g.o.t.	Staple length
CMS parents	3	0.0387	0.048	0.014	0.515	0.320
Pollinator testers	5	0.8542*	0.989 **	0.051 **	0.499	6.498 **
Remainder	15	0.2674	0.164	0.006	0.817	0.338
Fraction of total SS attributable to parents		0.522	0.675	0.772	0.248	0.868

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

combining ability estimates because the highest SCA scoring hybrids have given the poorest *per se* performance with respect to a particular character (Khan *et al,* 1980; Khan *et al,* 1980a; Azhar *et al,* 1983; Shahani & Chang, 1985). Anova of the data in Table 1 (after Simmonds, 1979) duly partitioned into CMS and pollinator parents, is given in Table 2.

The difference between CMS parents for any of the character under study was non-significant while the non-restorer pollinator parents greatly differed from each other for seedcotton yield, seed index, lint index and staple length. The fraction of total sum of squares attributable to parents accounts for the variation in the data that could be explained by parents for the particular character. It would correspond to coefficient of determination for explaining the variability (Simmonds, 1979).

Table 3. General combining ability estimates of CMS A-lines and pollinator non-restorer B-lines for five quantitative characters.

Parent	Seedcotton yield	Seed index	Lint index	g.o.t.	Staple length
CMS Deshams-16	0.00033	-0.117	-0.064	-0.406	-0.175
CMS Tamcot-778	0.0603	-0.004	0.018	0.275	-0.216
CMS Deltapine-55	-0.113	0.097	-0.004	0.129	0.253
CMS Coker-304	0.053	0.027	0.052	0.004	0.140
B-line K-68/9	0.862	0.409	0.127	-0.398	1.232
B-line CRIS-6/86	0.184	0.234	0.004	0.139	1.715
B-line CRIS-9/86	-0.265	0.224	0.109	0.386	-0.912
B-line ST-3	-0.177	-0.503	-0.090	0.251	-0.612
B-line CIM-109	-0.238	0.389	0.014	-0.473	-0.477
B-line Qalandri	-0.363	-0.748	-0.163	0.099	0.057

Table 4. Estimates of specific combining ability of the hybrids obtained from CMS lines of cotton at Cotton Research Institute, Sakrand during 1987.

Combination	Seedcotton yield	Seed index	Lint index	g.o.t. %	Staple length
CMS Deshams-16					
K-68/9	-0.69	-0.194	-0.121	1.157	0.038
CRIS-6/86	-0.782	-0.399	-0.088	1.13	-0.105
CRIS-9/86	0.457	0.151	0.097	-1.077	0.442
ST-3	0.479	0.308	0.096	0.068	0.162
CIM-109	-0.160	0.086	-0.018	1.438	-0.563
Qalandri	0.695	0.033	0.029	0.15	0.023
CMS Tamcot-778					
K-68/9	0.499	-0.157	0.017	-0.874	0.239
CRIS-6/86	0.228	-0.142	0.03	-0.201	0.116
CRIS-9/86	-0.553	-0.242	0.005	0.152	0.093
ST-3	0.329	0.495	-0.034	0.087	0.173
CIM-109	-0.080	-0.027	-0.04	0.601	-0.172
Qalandri	-0.425	0.06	-0.043	0.224	-0.456
CMS Deltapine-55					
K-68/9	-0.337	-0.088	0.059	0.968	-0.25
CRIS-6/86	0.371	-0.223	-0.008	0.135	0.207
CRIS-9/86	0.270	-0.337	-0.043	0.348	-0.296
ST-3	-0.338	0.064	-0.114	0.723	-0.206
CIM-109	0.143	-0.078	0.032	-0.043	1.249
Qalandri	-0.112	-0.021	0.069	-0.205	-0.735
CMS Coker-304					
K-68/9	0.527	0.432	0.043	0.552	-0.00
CRIS-6/86	0.185	0.757	0.066	-1.195	-0.00
CRIS-9/86	-0.176	-0.253	-0.059	0.448	-0.243
ST-3	-0.474	-0.876	-0.02	1.007	-0.133
CIM-109	0.097	0.747	0.026	0.747	-0.548
Qalandri	-0.158	-0.081	-0.057	-0.305	1.268

The performance of CMS parents and pollinator B-lines, with respect to GCA estimates, is given in Table 3 and SCA estimates in Table 4. Combining ability of inbred lines is the ultimate factor determining future usefulness of the lines for their hybrids. Initially, it was a general concept considered collectively for classifying an inbred line relative to its cross performance. Sprague & Tatum (1942) refined the concept of combining ability and the two expressions of GCA and SCA have had a significant impact on inbred line evaluation and population improvement in any crop breeding programme. They defined GCA as the average performance of a line in hybrid combinations and SCA as those instances in which certain hybrid combinations are either better or poorer than would be expected on the average performance of the parent inbred lines included. They also emphasized that estimates of GCA and SCA are relative to and independent on the particular set of inbred lines included in the hybrids under test.

In the present studies, the SCA estimates were calculated as the difference of observed minus expected value of a particular cross combination where expected value was considered as sum total of GCA of ♀ parent, GCA of ♂ parent and grand mean (as explained by Simmonds, 1979). The regression of observed values on the expected ones has a slope of unity in which more scatters about the line indicate larger contribution of SCA. If the scatters are minimum, GCA contribution will be higher and of importance. Accordingly the results of GCA estimates suggest that variety K-68/9 is the best combiner for yield of seedcotton and therefore a suitable tester line with highest GCA value and can be converted into restorer line to advance hybrid cotton breeding programme. The next in the order was CRIS-6/86 while rest of the B-line testers had negative GCA values. Similar interpretations can also be made with respect to seed index and lint index. For g.o.t. % and staple length, CRIS-9/86 and CRIS-6/86 respectively scored the highest GCA values and thus the best pollinator tester lines. None of the CMS lines were effectively good to score high GCA values indicating that these CMS lines may not prove desirable to be included in further hybrid cotton breeding programme. Soomro *et al* (1982) also reported similar results while evaluating nine hirsutum non-restorer pollinators onto two CMS lines Deshams-16 and Tamcot-778.

For specific combining ability results, hybrid CMS Coker-304 x K-68/9 for seedcotton yield, CMS Coker-304 x CRIS-6/86 for seed index, Deshams-16 x CRIS-9/86 for lint index, Deshams-16 x CIM-109 for g.o.t.% and CMS Coker-304 x Qalandri for staple length respectively, gave the highest SCA values. On the basis of SCA scores, these hybrids are expected to perform better among all hybrid combinations. A review of Table-1 shows that hybrid CMS Coker-304 x K-68/9 did give the expected yield of seedcotton per boll and therefore the opinion of Srinivasan & Gururajan (1973), Julka *et al* (1979), Khan *et al* (1980) and Kalsy *et al* (1981) supports the present results. On the other hand for seed index, lint index, g.o.t.% and staple length, the present results suggest that *per se* hybrid performance may not necessarily give positive correlation with SCA value of that hybrid for a particular character.

The lowest SCA scoring hybrids were CMS Deshams-16 x CRIS-6/86 for seedcotton yield, CMS Coker-304 x ST-3 for seed index, CMS Deshams-16 x K-68/9 for lint index, CMS Coker-304 x CRIS-6/86 for g.o.t.% and CMS Deltapine-55 x Qalandri for staple

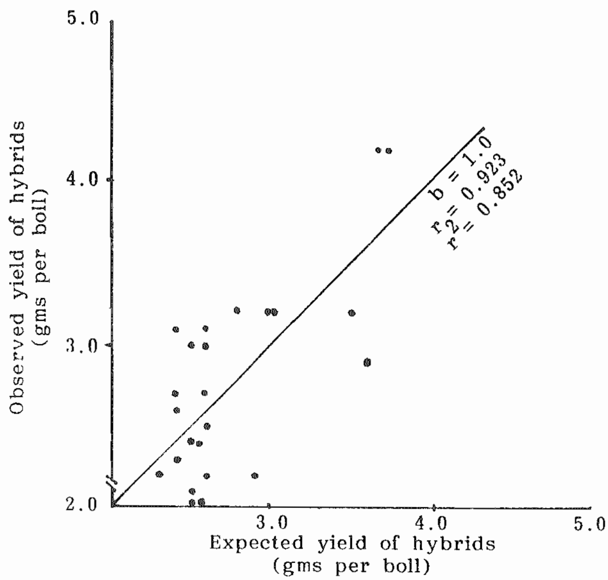

Fig. 1. Regression of observed seedcotton yield on expected yield of CMS hybrids to ascertain relative importance of general and specific combining ability in cotton.

length. In these lowest SCA scoring hybrids, one of the parents involved has scored the highest GCA value for that character which means that the highest GCA scoring parent may not be expected to give hybrid with highest SCA for the particular character. This conclusion is also supported by the reports of Khan *et al* (1980, 1980a), Azhar *et al* (1983), Soomro (1984), Shahani & Chang (1985) and Khan *et al* (1985). Thus from the present combining ability analyses, it can be concluded that, of the pollinator parents used in these studies as non-restorer B-lines, K-68/9 is over all a 'suitable' tester and may be converted into restorer 'R' line for its profitable exploitation in hybrid cotton breeding programme. Next in the order falls CRIS-6/86 and CRIS-9/86, the newly developed varieties of Cotton Research Institute, Sakrand, which may also be converted into restorer 'R' lines and be utilized in the programme if desired for staple length and g.o.t.% respectively.

In order to ascertain the relative importance of GCA and SCA for yield of seedcotton, the regression of observed yield values has been plotted against expected yields predicted from parental GCA's (Simmonds, 1979). Deviations of points from the regression line vertically or horizontally correspond to the SCA effects. The negative effects are on the right and positive effects to the left of the regression line (Fig. 1). Correlation coefficient of observed *versus* expected yield values of hybrids is $r = 0.923$ with r^2 0.852 which is the coefficient of determination and accounts for the portion of variability explained by yield due to specific combining ability effects. In the graph, since larger number of hybrids have minimum deviations from the regression line, the GCA effects are more pronounced and important as compared to SCA effects. Had there been more hybrids with larger deviations from the regression line, the SCA effects would have been more important. In the present case, since GCA effects are more pronounced, selection should be based on the GCA values of the tester lines for yield of seedcotton.

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