GENERAL AND SPECIFIC COMBINING ABILITY IN DIALLEL CROSSES OF 15 INBRED LINES OF CORN[1]

E. H. RINKE and H. K. HAYES[2]

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General and specific combining ability are terms of long standing. General combining ability has been recognized for many years as the relative performance of individuals, in a similar group of organisms, when crossed with a heterogeneous tester. Originally in plant breeding, the term — specific combining ability — was used to refer to the progeny performance resulting from a particular cross as related to the performance of other particular crosses of a similar nature. It was said that a specific parental combination was especially desirable or undesirable and the superiority or inferiority of the cross was a result of high or low specific combining ability.

In 1942 Sprague and Tatum (1) published and used formula provided by W. G. Cochran for the calculation of general and specific combining ability. The specific combining ability values so calculated serve to indicate which lines may be doing relatively better or worse than would be expected on the basis of their average performance.

Whereas such values may be of general interest, we have not found a use for them in our breeding program, and they have not been calculated for for this discussion. The type of specific combining ability referred to in this paper is the type which is determined by the relative size of the actual value for the characteristics concerned, *i. e.* the type which simply indicates that in comparison with other crosses of a similar nature, this is a good or poor cross.

Materials and Methods

The material consisted of 15 elite inbred lines used in breeding studies for the production of double-crosses adapted to South Central and Southern Minne-

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(2) Professor and Emeritus Professor of Agronomy and Plant Genetics, University of Minnesota, U. S. A.

sota. These inbreds were unrelated to each other as far as is known, and therefore had the desirable characteristic of genetic diversity. Five of the inbreds, A73, A302, A305, A334, and A375, were Minnesota lines. Other lines were Wf9 and Fe from Indiana; Oh51A and Oh40B from Ohio; Ia Y82, Ia234, and Os 420 from Iowa; CC25 and CC27 from Wisconsin; and Ill 4226 from Illinois.

The data were obtained from inbred and single cross yield trials. The inbred trials were grown in 3 replications at a single location over a five year period. As not all of the 15 inbreds were grown each year, the data were adjusted through a common check inbred so as to make them comparable for the 3 year period when the majority of the inbreds were tested. On the basis of the inbred data, the inbred lines were classified as superior or inferior for the characters; plant height, ear length, and good ears per plant. They were classified as inferior, medium or superior for general combining ability on the basis of their average yields in the 14 possible diallel crosses.

The 105 diallel single crosses were grown in randomized block designs in each of 2 years with 3 replications at each of 4 locations. They were separated into four or more groups with common double cross entries in each group. Data between groups within years were made comparable, when differences indicated the necessity, by adjustment through a common check double cross. There were highly significant differences between the yields of single crosses and between the average yields of individual inbreds in their 14 possible diallel crosses as determined statistically.

[The] single cross data have been classified according to the parental classification of the parents in terms of whether the parental cross was superior by superior, superior by medium, superior by inferior, etc.

Under Minnesota's growing conditions there is, on the average, a positive relationship between yield and maturity as measured by moisture content of the grain at the time of harvest. Superior hybrids which utilize the complete growing season may be expected to outyield superior hybrids that are earlier in maturity. Therefore, a performance index value which gives a combined evaluation of maturity and yield has been used. This performance index value is expressed as 100 plus the sum of the percentage deviations of moisture and yield from the moisture and yield of the check variety. Percentage deviations due to the moisture content being lower than that of the check variety are given a plus value and those above 100 a negative value. Percentage deviations due to the yield, being greater than that of the check variety are given a plus value and *vice versa.*

The general combining ability estimate for each line was determined as the average value of the 14 single crosses that each inbred line entered into in the complete 15 line diallel set of data,

Experimental Results

The range of each characteristic, as expressed directly in the inbreds and in percent of the double cross check in the F_1 hybrids, is presented in table 1. The differences between the superior and inferior expression of the characteristic in the inbreds ranges from about 1/3 to 1/5 of the maximum expression of the character. In the F_1 hybrids the difference ranges from about 1/4 to 1/2 of the maximum expression of a particular characteristic. Differences of this magnitude readily permit classification of material into rather broad groups.

Table 1. *Range and maximum difference for each characteristic as expressed in actual values in inbreds and in percentage of the double cross check in F_1 hybrids.*

	Inbreds		F_1 Hybrids	
	Range	Difference	Range	Difference
	actual		% of check	
Plant Height (inches)	61—93	32	91—118	27
Ear length (inches)	4.5—7.1	2.6	90—125	35
Good Ears (per plant)	.59—.95	.36	79—120	41
Performance Index	—	—	74—130	56
General Combining Ability (P. I.)	*93—113	20	—	—

* % of check.

All breeders are faced with selecting parental material offering the most promise of success in obtaining elite hybrids. Frequency distributions of the F_1 hybrids which are based upon classification of the same characteristic in the inbred parents as in the F_1 are presented for plant height, ear length, and good ears per plant in tables 2, 3 and 4, respectively.

Table 2. *F_1 hybrid plant height as related to parental inbred height. Inferior inbreds ranged 61—73 inches, and superior 74—93 inches. Mean of I was 67; of S, 81 inches.*

Type of Cross	Class Centers for Plant Height In % of Double Cross										No.	Mean
	91	94	97	100	103	106	109	112	115	118		
I×I	1	1	2	5	7	3	5	4			28	104.0±1 06
I×S	1	0	5	6	11	10	12	7	3	1	56	105.8± .74
S×S				1	3	1	7	7	1	1	21	109.3± .95

Table 3. *F_1 hybrid length of ear as related to parental inbred length. Inferior inbreds ranged from 4.5 to 5.9 inches and superior from 6.2 to 7.5 inches. Mean of I was 5.7; of S, 6.7 inches.*

Type of Cross	Class Centers for Ear Length In % of Double Cross								No.	Mena
	90	95	100	105	110	115	120	125		
I×1	2	10	7	7	1	1			28	99.6±1.12
I×S	1	8	14	12	15	6			56	104.5± .87
S×S			4	5	2	6	1	3	21	111.0±1.85

Table 4. *F_1 hybrid good ears per plant as related to parental inbred good ears per plant. Inferior inbreds ranged from .59 to .80 and superior from .81 to .95. Mean of I was .73; of S, ,88 good ears per plant.*

Type of Cross	Class Centers for Good Ears per Plant In % of Duble Crooss									No.	Mean
	79	84	90	95	100	105	110	115	120		
I×I	2	1			5	8	8	4		28	104.4+1.82
I×S		1	1	2	9	15	16	11	1	56	106.9± .92
S×S				1	1	3	7	6	3	21	111.0±1.41

The ranges are not directly comparable as there were larger numbers in the crosses of S × I than in either I × I or S × S. An examination of the frequency arrays in these three tables indicates that in no cases did inferior × inferior parental crosses give hybrids that were equal to those produced by the better superior × superior parents, and no crosses of S × S were as inferior as some crosses of I × I. For plant height the I × S crosses covered the entire range of both I × I and S × S. For length of ear the I × S crosses had the same range as I × I and for good ears per plant I × S covered all classes except the lowest class of I × I. If the data in the various arrays were to be presented on a percentage basis instead of actual numbers, the greatest frequency of superior hybrids would be found in the S × S combinations in all cases. The pattern of distribution as seen in these tables is believed to be quite typical of the distribution patterns which occur for quantitative characters when one looks at the inheritance of the character from the parent, F_1 progeny relationship.

There was a slight indication of parental phenotypic dominance of I over S as, in general, the means of I × S were somewhat below the respective mean value of I × I and S × S.

The relationship between general combining ability and the occurrence of superior hybrid progeny is presented in table 5. The data are on a performance index basis in order to compensate for maturity yield relationships.

Table 5. *Relation between Performance Index Classes for General Combining Ability and Yield of Specific F_1 Crosses.*

Yield Classes for General Combining Ability	Class for Performance of F_1 Crosses									No.	Mean
	74	81	88	95	102	109	116	123	130		
I×I 93—103	1	1				1				3	88.0±10.7
I×M		1	5	3	5	1	2	1		18	98.9± 2.7
I×S	1	3	1		6	2	5			18	100.8± 3.3
M×M 105—106		1		3	4	3	3	1		15	104.8± 2.8
M×S			1	1	9	10	10	4	1	36	110.4± 1.5
S×S 110—113						3	8	1	3	15	117.9± 1.9

The inbreds were placed into three general combining ability classes. Inbreds in the I group were Os 420, Oh 40B and Fe; in the M group, Wf9, CC27, A334, A302, A375 and Ill 4226; and in the S group, CC25, Ia Y82, Ia 234, Oh 51A, A73 and A395. The inferior class ranges from 93–103, the medium class ranges from 104–106, and the superior class ranges from 110–113. Unfortunately, there were only 3 lines in the I group but the same number of lines in the M group as in the S group. The mean values, of the single cross arrays for the six possible combinations of the three parental classes, gave a range of performance index values from 88.0 to 117.9 and show a positive relationship of increasing values as the general combining ability of the parents increase.

The frequency distribution arrays indicate that superior×superior general combining ability crosses are the ones which give the greatest percentage of superior hybrids. Only one of the medium × superior crosses gave a single cross which was equivalent in performance index to the best of the superior × superior. As in the case of other characters, the I × S mean was somewhat below the average of I × I and S × S.

Discussion

The 15 inbreds were selected on the basis that they did not have close genetic relationship of origin. Heterosis for yield as expressed in F_1's was inherited in the same pattern as were the other quantitative characters. Therefore, if one expects to get a maximum frequency of high yielding single crosses, it appears that one should cross parents which are superior in general combining ability.

The fact that genetic diversity seems to lead to maximum heterosis has been known for a long time and has been recognized widely but perhaps has not been utilized always as efficiently as is possible in breeding programs involving hybridization in the final product. Different and diverse germ plasm sources must be used and are being used to introduce into elite genetic complexes now in existence additional increments of morphological and physiological characteristics for yield. Through the use of such materials and through diligent careful work and selection procedures, it is anticipated by the writers that corn yields can be obtained that will greatly excel our today's hybrids.

Using information and materials similar to that presented in this study, heterozygous and heterogeneous parental combinations such as unrelated synthetics A and B could be produced that would be known to have high combining ability in their cross. Different desirable domestic and exotic breeding germ plasm could be introduced at will into either A or B, or both, that was known to be different in origin and the heterotic advantages of genetic diversity maintained. Synthetics of this nature should make excellent base material for reciprocal recurrent selection, a procedure which seems of such great promise as to deserve wider use than now appears to be the case.

Conclusion

The inbred material used in the studies was selected on the basis of diversity of origin. Yield heterosis for general combining ability was transmitted to its F_1 progeny in about the same manner as for other quantitative characcters studied. The greatest possibility of obtaining a high frequency of high yielding single crosses results from crossing together genetically diverse inbred lines which are high in general combining ability.

Literature Cited

(1) SPRAGUE, G. F., and L. A. TATUM. General vs. Specific Combining Ability in Single Crosses of Corn. Agron. J. 34: 923-32, 1942.