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Chapter 24

Gamete Selection for Specific Combining Ability*

Gamete selection as a breeding method was designed for more efficient sampling of open-pollinated varieties. It was suggested by Stadler in 1944. The method was outlined in detail by Stadler (1945) and preliminary data presented. Hayes, Rinke, and Tsiang (1946) proposed that the same technic could be used to select gametes from such sources as synthetic varieties, single or more complex crosses, and inbred lines. They discussed gamete selection in its relation to the improvement of a particular double cross combination.

MATERIALS AND METHODS

In 1945, three double crosses, Minhybrids 602, 607, and 406, were selected for a method study in gamete selection. Single cross performance data shown in Tables 24.1 and 24.2 indicate that A344 is low in combining ability in Minhybrids 602 and 607, and that the same is true for inbreds A25 and A73 in Minhybrid 406.

A344 was crossed to Minnesota #13 (Morris strain) and to 8 inbred lines namely, Oh51A, A97, I234, A315, A348, A367, A396, and Ill. 4226 as sources of gametes. The inbreds were selected because of their diversity of origin and good general combining ability. In addition, A367 had yielded well in specific tests with A357, A385, and A392. A315 and A348 had performed well in crosses with A392. The remaining five inbreds had not been crossed to A357, A385, or A392 in previous years. A25 was crossed with Golden King and A73 with Murdock. In 1946, individual F_1 plants of these crosses were

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selfed and crossed to the *opposing* single cross parent of the double cross. Table 24.3 gives the number and type of test crosses made.

Approximately 60 inbred × variety F_1 plants from each of the three sources were selfed and crossed to the testers. Selection of the better F_1 plants at harvest reduced the number for further study to 35, 32, and 38 as listed in Table 24.3. Experiments 1 and 2 were tested in separate randomized blocks

TABLE 24.1

PERFORMANCE OF A344 AND A334*

Inbreds	Av. of Crosses	
	% Moist.	Bu.
A344×A357, A392, A385.....	28.3	69.8
A334×A357, A392, A385.....	30.1	84.3

* As indicated by average moisture and yield when crossed in non-parental single cross combinations of Minhybrid 602 (A344×A334) (A357×A392) and Minhybrid 607 (A344×A334) (A357×A385).

TABLE 24.2

PERFORMANCE OF A25, A334, A73, AND A375*

Inbreds	Av. of Crosses	
	% Moist.	Bu.
A25 ×A73, A375............	24.6	76.2
A334×A73, A375............	24.7	79.4
A73 ×A25, A334............	24.6	74.8
A375×A25, A334............	24.7	80.8

* As indicated by moisture and yield in non-parental single crosses of Minhybrid 406 (A25×A334) (A73×A375).

using two replicates at each of three locations in central Minnesota. Data from the two testers were averaged to give a total of 12 replicates as a test for each gamete. Experiments 3 and 4 were also grown in randomized blocks with three replicates at each of four locations in southern Minnesota. One location of experiment 3 was discarded and one replicate of experiment 4 was abandoned prior to harvest.

On the basis of yield trial results in 1947, gametes were selected from all varieties and from two inbreds, for use as parents in the development of new lines by straight selfing and by backcrossing to the sampler inbred.

Study of the performance indices and agronomic characters of the test crosses led to the selection of three Golden King gametes and four Murdock gametes as higher in general desirability than the sampler inbred parent. In addition, gametes of low yield potential but of relatively satisfactory agronomic characters were selected from both varieties, three from Golden King and two from Murdock.

F_2 populations were grown in 1948 from the selfed ears of the twelve F_1 plants selected in the above manner. Visual selection was practiced for desirable plant and ear characters, and these individual plants were crossed to the appropriate single cross tester. Remnant seed of the test crosses of the selected F_1 plants was used to make a direct yield comparison in 1949 with the test crosses of the selected F_2 plants. Two randomized block experiments were made at each of three locations in southern Minnesota with three

TABLE 24.3

GAMETE SOURCES, TESTERS USED, AND TEST CROSSES MADE IN SELECTING GAMETES FOR IMPROVEMENT OF INBREDS A344, A25, AND A73

Experiment Number	Inbreds	Gamete Source	Tester	Number of Crosses
1........	A344	Morris 13 gametes	A357×A392	35
	A344	Inbred gametes	A357×A392	8
		A344	A357×A392	1
2........	A344*	Morris 13 gametes	A357×A385	35
	A344	Inbred gametes	A357×A385	8
		A344	A357×A385	1
3........	A25	Golden King gametes	A73×A375	32
		A25	A73×A375	1
4........	A73	Murdock	A25×A334	38
		A73	A25×A334	1

* Same plants as in experiment 1.

replications per location. One experiment consisted of the crosses of 6 F_1 plants (remnant seed) from A25 × Golden King, and 34 F_2 plants by the tester compared with the cross of A25 × tester. The other included test crosses of 6 F_1 and 37 F_2 plants from A73 × Murdock gametes in comparison with A73 × tester.

EXPERIMENTAL RESULTS

The Morris strain of Minnesota 13 has been a very outstanding open-pollinated variety in Central Minnesota for many years. Yield trial data from plants of A344 × Morris 13 crossed with the testers show that a large proportion of Morris 13 gametes have higher yield potential than A344. Table 24.4 gives the distribution of yield and moisture data obtained from thirty-five test crosses of A344 × Morris 13. Sixteen of the thirty-five gametes gave test-cross yields significantly in excess of A344 × tester. Although not higher in yield, five other gametes may be considered superior to A344 because of their significantly lower moisture content at harvest and yields not significantly different in test crosses from A344 × tester.

The eight inbreds tested as possible sources of germ plasm for the improvement of A344 were A97, A315, A348, A367, A396, Oh51A, Ia234, and Ill.4226.

TABLE 24.4

DISTRIBUTION OF PER CENT MOISTURE AND YIELD OF 35 F_1 PLANTS OF A344 × MORRIS 13 CROSSED TO S.C. TESTERS A357 × A392 AND A357 × A385*

% Ear Moisture	Yield −2	Yield −1	Yield +1	Yield +2	Yield +3
+1			3	5	1
−1	2	3	6	6	2
−2		3	2	2	

Horizontal line between +1 and −1 moisture: (Mean A344 × tester). Vertical line between −1 and +1 yield: (Mean A344 × tester).

* Classes separated by one or more than one LSD (5 per cent) from the mean of A344×tester.

TABLE 24.5

DISTRIBUTION OF PER CENT MOISTURE AND YIELD OF TEST CROSSES OF 8 INBRED LINES AS SOURCES OF GAMETES. CROSSES ARE OF THE TYPE (A344 × INBRED) × TESTERS*

% Ear Moisture	Yield −2	Yield −1	Yield +1	Yield +2	Yield +3	Yield +4	Yield +5
+2			1		1		
+1		2	1				1
−1		1		1			

Horizontal line between +1 and −1 moisture: (Mean of A344 × tester). Vertical line between −1 and +1 yield: (Mean of A344 × tester).

* Classes separated by one or more than one LSD (5 per cent) from the mean of A344×tester.

The distribution for yield and moisture of test crosses of A344 × Inbred is given in Table 24.5. Three inbreds, Ia234, A396, and A97, demonstrated yield potential significantly higher than A344.

Golden King and Murdock are old, well-adapted varieties formerly grown extensively in southern Minnesota. Test crosses of thirty-two Golden King gametes × A25 and thirty-eight Murdock gametes × A73 are shown in Tables 24.6 and 24.7, respectively.

No gamete from Golden King exceeded A25 significantly in test-cross yields. However, eight not different in yield were significantly earlier, and are considered superior in yield performance on the basis of maturity. Eight gametes from Murdock demonstrated yield potential greater than A73, as indicated by significantly higher yields in crosses. In addition, fourteen gametes not different from A73 in yield were significantly earlier in maturity.

The proportion of promising gametes extracted from the three varieties and the eight inbreds is summarized in Table 24.8. About 25 per cent of the total number tested were superior to the sampler inbred in yield potential. Another 25 per cent would be considered desirable parents because they had a yield potential equal to and a maturity potential which was significantly earlier than the sampler inbreds.

SELECTION OF GAMETES AS PARENTS AND TESTS OF F_2 PROGENIES

Years of testing at Minnesota have led to the conclusion that, in general, there is a direct relation between yield and moisture content at husking among hybrids of equal genetic desirability. On this basis the combining ability of inbred × gamete plants was determined by considering both yield and moisture percentage at husking. They were effectively placed on a comparable basis by calculation of a performance index using the test cross of the sampler inbred as 100 for both ear moisture and yield. For example, if the moisture percentage of an A25 × Golden King plant (in test cross) was 93.5 as compared with A25 × tester, and its yield was 106.5 per cent, its performance index would be +13. Where the comparative moisture percentage is higher than the yield percentage the index becomes a negative value.

The performance indices for the selected gametes for both 1947 and 1949 trials and similar data for the F_2 plant progeny tests appear in Tables 24.9 and 24.10. The tests of F_2 plants from gametes of both high and low yield potential were made as explained in "Materials and Methods". This wa scarried out by selfing selected F_2 plants and also crossing them with the appropriate tester, and again comparing the results with the crosses of the appropriate inbred with the same tester. Agreement between the two tests of the gametes was very good except for Murdock gametes numbered 12 and 49.

On the average there was good agreement between F_1 and F_2 progeny performance. Tables 24.11 and 24.12 show that there is evidence of segregation for yield factors within almost all of the F_2 families tested.

Mean performance of the F_2 progeny from the high testing gametes was little different from the F_1 for either ear moisture or yield (Table 24.13). However, the F_2 progeny from the gametes of low yield performance exceeded the F_1 parent plant in yield performance on the average. This indicates that visual selection of plants within the F_2 populations was more effective among the progenies arising from the gametes of low yield performance than for those F_2 plants that were selected from high performing F_1 crosses (gamete × inbred).

TABLE 24.6

DISTRIBUTION OF PER CENT MOISTURE AND YIELD OF 32 F_1 PLANTS OF A25 × GOLDEN KING CROSSED TO A73 × A375*

% Ear Moisture	Yield −2	Yield −1	Yield +1	Yield +2
+2		1		
+1		3	2	
−1	2	8	5	
−2	3	5	3	

* Classes separated by one or more LSD (5 per cent) from the mean of A25×tester.

TABLE 24.7

DISTRIBUTION OF PER CENT MOISTURE AND YIELD OF 38 F_1 PLANTS OF A73 × MURDOCK CROSSED TO A25 × A334*

% Ear Moisture	Yield −2	Yield −1	Yield +1	Yield +2
+3	1			
+2				
+1		1	1	
−1		5	7	3
−2	1	2	9	3
−3		2	1	2

* Classes separated by one or more LSD (5 per cent) from the mean of A73×tester.

TABLE 24.8

NUMBER AND SOURCE OF GAMETES SUPERIOR IN PERFORMANCE TO SAMPLER INBREDS

Source of Gametes	Sampler Inbred	Total Gametes Tested	Higher in Yield and as Early or Earlier in Maturity	Not Different in Yield but Earlier
Morris 13......	A344	35	16	5
8 inbreds......	A344	8	2*	0
Golden King...	A25	32	0	8
Murdock......	A73	38	8	14
Total......	....	113	26	27

* An additional gamete higher in yield was also later in maturity.

TABLE 24.9

PERFORMANCE INDICES OF TEST CROSSES OF SELECTED F_1 PLANTS AND F_2 PROGENY FROM A25 × GOLDEN KING

F_1 Plant Number	Performance Index			Number of F_2 Plants
	1947	1949		
	F_1	F_1	F_2	
19 H*....	+11	+19	+25	5
20 H.....	+14	+ 9	+14	7
36 H.....	+ 9	+16	+11	7
5 L.....	−11	− 3	+ 5	7
29 L.....	−11	− 1	− 0	1
46 L.....	− 5	+ 1	+ 2	7

* H = high- and L = low-performing gametes.

TABLE 24.10

PERFORMANCE INDICES OF TEST CROSSES OF SELECTED F_1 PLANTS AND F_2 PROGENY FROM A73 × MURDOCK

F_1 Plant Number	Performance Index			Number of F_2 Plants
	1947	1949		
	F_1	F_1	F_2	
12 H........	+18	− 3	− 6	8
14 H........	+25	+33	+27	5
49 H........	+20	+ 1	+ 5	6
50 H........	+29	+19	+18	7
6 L........	−10	−23	−10	5
35 L........	− 4	−24	− 7	6

TABLE 24.11

FREQUENCY DISTRIBUTION OF PERFORMANCE INDICES OF F_2 PROGENY PLANTS FROM A25 × GOLDEN KING AROUND MEAN PERFORMANCE OF A25 × TESTER

F_1 Plant Number	Indices for F_2 Plants					
	−15	−5	+5	+15	+25	+35
19 H.....				1	2	2
20 H.....			2	3	2	
36 H.....			3	4		
5 L.....		3	2	1	1	
29 L.....		1				
46 L.....	1	1	5			

TABLE 24.12

FREQUENCY DISTRIBUTION OF PERFORMANCE INDICES OF F_2 PROGENY PLANTS FROM A73 × MURDOCK AROUND MEAN PERFORMANCE OF A73 × TESTER

F_1 Plant Number	Indices for F_2 Plants					
	−15	−5	+5	+15	+25	+35
12 H.....	5	1	1		1	
14 H.....				1	2	2
49 H.....		2	2	2		
50 H.....			2	2	2	1
6 L.....	2	2	1			
35 L.....	2	3	1			

TABLE 24.13

COMPARISON OF F_1 PLANTS AND THEIR F_2 PROGENY IN 1949 TEST CROSS PERFORMANCE FOR EAR MOISTURE, YIELD, AND PERFORMANCE INDEX

Parents	No. Plants Tested		Ear Moisture %			Yield in Bu.			Performance Index		
	F_1	F_2	F_1	F_2	Diff.	F_1	F_2	Diff.	F_1	F_2	Diff.
A25×G. King H....	3	19	20.3	20.2	−0.1	54.0	54.5	+0.5	+14.4	+15.8	+ 1.4
A25×G. King L.....	3	15	23.3	23.8	+0.5	52.9	56.3	+3.4**	− 2.1	+ 3.3	+ 5.4
A73×Murdock H....	4	26	21.8	21.1	−0.7*	56.0	55.0	−1.0	+12.5	+ 9.6	− 2.9
A73×Murdock L....	2	11	22.8	22.4	−0.4	41.7	48.7	+7.0**	−23.6	− 8.6	+15.0

* Exceeds 5% point of significance. ** Exceeds 1% point of significance.

DISCUSSION

Almost 50 per cent of the gametes studied showed evidence of having combining ability in excess of the sampler lines. The gametes chosen as parents appear to furnish a desirable source of germ plasm for a selection program designed to improve the yield potential of A344, A25, and A73 in combining ability in specific crosses.

Where a high combining varietal gamete is chosen for an inbred selection program, the F_1 plant of which it is a parent represents a high$\times$low type of cross so far as combining ability is concerned. To the extent that such F_1 plants are comparable to crosses of inbreds, the breeding results should be similar to those from crosses of inbreds differing in combining ability. At Minnesota (Hayes and Johnson, 1939), crosses of high$\times$low combiners have given F_5 lines ranging from high to low, but with a good proportion of high combiners.

Whether selection of gametes should be followed by test controlled selection in the F_2 is an important question. In these studies more than 50 per cent of the F_2 plants from high combining gametes tested at least ten performance index units higher than the sampler inbred. Thus without further test crosses, the chances of choosing high combining F_2 plants would still have been very good. The number of F_2 plants that could be handled in test crosses was quite limited. This may make for greater difficulty in recovering or improving the agronomic type of the sampler lines. It was very evident from field observations that the proportion of agronomically desirable F_3 lines appeared lower than usually found from crosses of highly selected inbreds.

The greater effectiveness of visual selection among the F_2 progenies of the low testing gametes is at this stage only an interesting development. Only a small proportion of the plants arising from the low testing gamete parents exceeded the sampler inbred in performance by a significant amount.

It was not possible to determine by visual examination which F_2 populations were derived from high gametes and which from low gametes, although there were wide differences in plant type between populations.

Gametes from eight inbred lines compared fairly well with varietal gametes from Morris 13, in offering promising sources of germ plasm for the improvement of specific combining ability of A344. Where a breeder has available large numbers of inbred lines of diverse origin the use of test selected inbred parents rather than varietal gamete parents may be the more feasible approach. Selection for characters other than yield would presumably be done more economically. The same advantage can be claimed for the use of complex crosses of inbreds. On the other hand, utilization of varietal gametes in improvement work does not "use up" inbreds so far as their combination in hybrids for commercial use is concerned. Lines recovered from crosses of inbreds may be more restricted than their inbred parents in commercial use because of relationship. It seems probable to the writers that the method of gamete selection is worthy of considerable use for further selection of material from open-pollinated, desirable commercial varieties.

Studies of lines recovered from selected varietal gametes will have to be carried to F_5 or later generations to determine if the large amount of outcross testing is justified economically. The writers would like to emphasize the importance they attach to method studies of the type presented here. New ideas in breeding must be explored constantly if continued progress is to be made in corn improvement.

SUMMARY

Since 1945, a program has been underway at Minnesota to attempt improvement of Minhybrids 602, 607, and 406 by the method of gamete selection. The hybrid pedigrees are respectively: (A344×A334) (A357×A392), (A344×A334) (A357×A385), and (A25×A334) (A73×A375). Detailed studies of the non-parental single crosses among the inbred parents of each hybrid led to the conclusion that A344 in Minhybrids 602 and 607, and A25 and A73 in Minhybrid 406 were low in combining ability.

A344 was crossed to the Morris strain of Minnesota 13 and to eight inbreds of diverse origin. A25 was crossed to the Golden King variety and A73 to Murdock. (Inbred×gamete) (tester) crosses were made using the opposing single cross parents as testers. These were compared with the appropriate cross of inbred×tester. Yield trial performance was obtained from a total of 113 gametes, 35 from Morris 13, 8 inbreds, 32 from Golden King, and 38 from Murdock.

Sixteen gametes from Morris 13, three from the inbreds, and eight from Murdock gave significant increases in yield over the test crosses of the checks A344 and A73. Five gametes from Morris 13, eight from Golden King, and fourteen from Murdock were not significantly different in yield but were significantly earlier so that yield performance could be considered better than the checks on the basis of ear moisture at harvest. These varieties and the three high testing inbreds thus appear to be good sources of gametes for improving the relatively low performing inbreds in specific combining ability for yield.

Both high and low testing varietal gametes were selected for use in a study of the development of new inbreds. From the crosses, A25×Golden King and A73×Murdock, selected F_2 plants×the appropriate tester were compared with the progeny of their F_1 parental plants when crossed on the same tester. While there was excellent agreement, on the average, for combining ability in the F_1 and F_2, there was evidence of segregation for combining ability from almost all of the twelve F_2 families which were studied. Visual plant selection within the F_2 generations appeared to be effective in increasing yield per-

formance of the plants from the low testing gametes, but appeared to have no effect in further increasing the yield performance of the F_2 plants from the high testing gametes.

The economic feasibility of F_2 plant testing in a gamete selection program is questioned.