THE VALUE OF HYBRIDS AND SYNTHETICS IN SUNFLOWER SEED PRODUCTION[1]

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ABSTRACT

Highly significant correlations, in excess of +.7, occurred between the percentage of hybrids in the seed for planting and the yielding ability of two single-cross sunflowers, Advance and Advent. The percentage of hybrids approached or reached 100 when the hybrids were produced by hand-pollination without emasculation and varied down to only 16 per cent when produced commercially by natural pollination in 2 × 2 crossing blocks. Seed from a 50-50 mixture of the two parents of Advance contained less hybrids than seed of the female from crossing blocks and was lower yielding. Quantity of pollen transferred to the female parent greatly affected percentage of hybrids. Yields of four synthetics, each composed of four inbred lines, indicated that synthetics are a better means of using inbred lines in sunflowers than hybrids such as Advance. Double crosses produced by natural pollination were not superior to synthetics made from the same lines.

INTRODUCTION

The value of double-cross hybrids in corn production is well known. Synthetics (2, 4) also show promise as a means of using inbred lines in corn. In oilseed sunflowers, the hybrid Advance has been important in Manitoba. Its pedigree is S-37-388 × Sunrise. The male parent originated from an inbred line and is quite uniform; Advance could thus be termed a single cross. The seed for planting is produced by natural crossing in fields composed of two rows of S-37-388 alternating with two rows of Sunrise, commonly termed 2 × 2 crossing blocks, and because the percentage of natural crossing is greater on S-37-388 than on Sunrise it is used as the female parent. Even so, a low proportion of cross-pollination occurs to result in few actual hybrids in the "hybrid" seed. A shortage of hybrids is also a serious fault of the hybrid Advent, which is a rust-resistant counterpart of Advance, and with the hybrid Admiral. This paper reports the effect of different methods of seed production on the percentage of hybrids in the seed for planting and the effect of per cent hybrids on the yield of the succeeding crop. Secondly, the results of a study of synthetics and double crosses as alternate methods of using inbred lines of sunflowers are given.

MATERIALS AND METHODS

The pedigrees of the three hybrids used for the study of methods of seed production are as follows:

Advance — S-37-388 × Sunrise
Advent — S-37-388RR × Sunrise
Admiral — S-37-388RR (CM5 × CM27).

Seed of Advance and Advent was produced by commercial growers in 2 × 2 crossing blocks and at the Experimental Farm, Morden, in small natural

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crossing plots or by hand-pollination. In the small natural crossing plots, single rows of the female parent of the two hybrids were planted in a 1 × 2 arrangement with the male parent. In the hand-pollination, liberal amounts of pollen were applied every second day during flowering. The female parent was not emasculated. Additional lots of seed were obtained by planting a 50-50 mixture of the two parents of Advance and harvesting them together. Some samples from the two parents in the mixture also were harvested separately. Samples of Admiral were produced by hand-pollination and in 2 × 4 crossing blocks of experimental and commercial size.

The percentage of hybrids in Advance and Advent was determined in the field by vigor and by size and shape of the seed, or in the greenhouse by the method described by Stefansson (9) using seedling markers. The determinations in Admiral were made in the field.

The second study reported here was with four groups of inbred lines, consisting of four unrelated or distantly related lines in each group. The lines were similar in flowering data within the groups and had good combining ability with either the male or female parent of Advance.

The four groups of inbred lines were used to prepare Synthetics 10 to 13 inclusive. One hundred viable seeds of each line within the groups were mixed, planted in isolation and allowed to interpollinate freely. During successive seasons, second and third generations were produced in small isolated plots containing 100 to 200 plants.

The lines of each group also were crossed in all combinations by hand and without emasculation. In making these crosses, lines known to cross well under natural pollination were used as the female parent whenever possible. The following season the three possible double crosses within each group were made by hand and by natural crossing in isolation. The isolated plots for the natural crossing were of four rows 20 feet long with the two single crosses placed in an *x y x y* arrangement. Seed from one of the inner rows was used in the subsequent yield trials. In most instances the coincidence of flowering was good. Where differences occurred, 5 to 10 plants judged to have the best opportunity for cross-pollination were marked when in bloom and their seed used for the yield tests.

In 1957, the first and second generation of each synthetic, the single and double crosses of their component lines, a sample of Advance produced by natural crossing and a second generation sample of Advance were tested for yield. Advance produced by hand-pollination was included in some tests. The following season the third generation of each synthetic was added to the tests and the double crosses were deleted.

The designs of the yield tests varied with the number of entries. Six replicates were used except for one test in which there were eight. The plots were one row 20 feet long and were spaced 3 feet apart. Sixty to seventy seeds per plot were planted and the stand thinned at random after emergence to 6 to 8 inches between plants. One rod was harvested for yield estimates.

RESULTS

Methods of Producing Hybrid Seed

Most lots of seed from the commercial 2 × 2 crossing blocks contained less than 50 per cent hybrids. Thus 52 samples of Advance ranged from 16 to 54, with a mean of 39 per cent; 19 samples of Advent had a range of 36 to 54, with a mean of 45 per cent; and 19 samples of Admiral showed a range of 32 to 50 and a mean of 39 per cent.

TABLE 1.—PER CENT HYBRIDS AND YIELD PER ACRE IN POUNDS OF ADVANCE AND ADVENT SUNFLOWERS GROWN FROM SEED PRODUCED BY HAND-CROSSING AND BY NATURAL CROSSING IN 1 × 2 PLOTS AND IN 2 × 2 COMMERCIAL CROSSING BLOCKS

Year of test	Variety	Hand cross		1 × 2 natural cross		2 × 2 natural cross	
		% hybrids	Yield	% hybrids	Yield	% hybrids	Yield
1953	Advance[1]	92	1800	80	—	54	1225
1954	Advance[1]	91	2274	77	1965	—	—
1955	Advance	89	—	84	—	—	—
1956	Advance	96	—	87	—	—	—
1959	Advance[2]	93	2167	92	1975	—	—
1959	Advance[1]	93	2046	92	—	56	1372
1959	Advent[1]	79	2205	77	2164	—	—
1960	Advance[1]	79	1299	76	1423	51	1125
1960	Advent[1]	84	2178	73	1869	47	1531

[1]Mean of two yield tests
[2]Mean of three yield tests

TABLE 2.—PER CENT OF HYBRIDS AND YIELDS OBTAINED FROM SEED OF THE FEMALE PARENT (S–37–388) AND MALE PARENT (SUNRISE) OF ADVANCE PRODUCED IN 2 × 2 CROSSING BLOCKS AND IN FIELDS OF 50–50 MIXTURE

Seed	Source[1]	No. of samples	% hybrids		Yield per acre (pounds)	
			Mean	Range	Mean	Range
			1953			
S-37-388	CB	3	59	54–64	1110	1052–1173
Sunrise	CB	3	36	31–40	917	875– 996
S-37-388	50-50	5	67	62–72	1099	958–1201
Sunrise	50-50	5	44	38–49	1026	976–1150
Mixture	50-50	5	54	47–58	1008	958–1059
			1954			
S-37-388	CB	7	44	40–51	1877	1759–1975
Mixture	50-50	7	30	24–38	1698	1463–1872

[1]CB = 2 × 2 crossing block, 50–50 = mixture

The percentage of hybrids in Advance and Advent produced by hand-pollination and by natural crossing in 1 × 2 plots was much greater (Table 1). There was a highly significant correlation of +.716 between yield and percentage of hybrids for the 16 paired values in Table 1. Weighted averages show that the yields from the 1 × 2 natural cross and the 2 × 2 commercial natural cross were 94 and 72 per cent, respectively, of the hand-crossed seed. In 1960, commercial samples, containing 47 and 51 per cent hybrids, yielded only 78 per cent of the seed from 1 × 2 natural cross. Hand-crossed seed of Admiral, not reported in Table 1, and of its rust-susceptible counterpart, has shown 88 per cent hybrids or more.

Two experimental three-way crosses were produced in a 2 × 4 arrangement, using two different inbred lines as the females and Advance as the male. Both these inbreds had given 82 per cent hybrids in 1 × 2 crossing plots with Sunrise. In the 2 × 4 crossing blocks one produced 81 per cent hybrids and the other 74 per cent.

In 1953, seed from five fields planted to a 50-50 mixture of the two parents of Advance and from three 2 × 2 crossing blocks was tested (Table 2). The mean percentage of hybrids in the two parents harvested separately from the fields of the mixture was higher than in the corresponding parents from the crossing blocks. However, the mean percentage of hybrids in the five samples of the mixture of the two parents was lower than in the S-37-388 or female parent from the crossing blocks (i.e., Advance). Likewise, average yields, as well as maximum and minimum yields, were lower from the mixture than from S-37-388 or Advance out of the crossing blocks.

The tests in 1954 (Table 2) show that seven samples of the mixture gave a mean yield of 1698 pounds per acre compared with 1877 for seven samples of S-37-388 or Advance from the crossing blocks. The mean percentage of hybrids was 44 in the S-37-388 from the crossing blocks and only 30 in the seed from the mixture. The mean differences in yield and in percentage of hybrids were highly significant. Co-variance analysis also showed a highly significant correlation of +.703 between yield and percentage of hybrids. In the two seasons a total of 10 entries of S-37-388 from the crossing blocks gave a mean yield of 1647 pounds per acre and had 49 per cent hybrids while 12 entries of the 50-50 mixture gave 1411 pounds per acre and had 40 per cent hybrids.

Synthetics

The results of the tests of Synthetics 10 to 13 and the single and double crosses of their component lines are shown in Tables 3 to 6 inclusive. In these tables any two means followed by the same letter were not significantly different, on the basis of the Duncan multiple range test.

In every test the highest yield was obtained from a single cross. Except for the cross CM21 × CM31 (Table 5), and some crosses of the lines in Synthetic 13 (Table 6), notably CM35 and CM79 in which cross-compatibility was indicated by only 4 and 6 per cent hybrids in the two seasons, most of the single crosses had a high percentage of hybrids.

TABLE 3. — PERFORMANCE OF SYNTHETIC 10 SUNFLOWER AND OF SINGLE AND DOUBLE CROSSES MADE FROM ITS COMPONENT LINES

Pedigree	1957			1958		
	Per cent hybrids	Yield per acre (lb.)	Duncan multiple range test (P = .05)	Per cent hybrids	Yield per acre (lb.)	Duncan multiple range test (P = .05)
Advance HC[1]	—	—		98	2756	a
Advance NC	74	1561	a b	72	2071	d e
Advance 2nd gen.	—	979	f g	—	1621	g h
Synthetic 10 1st gen.	—	1020	e f g	—	1888	e f g
Synthetic 10 2nd gen.	—	1317	b c d	—	1966	e f
Synthetic 10 3rd gen.	—	—		—	1941	e f
CM1 × CM28	72	944	g	57	1729	f g h
CM1 × CM2	77	980	f g	70	1633	g h
CM1 × CM27	91	1291	b c d e	62	1541	h
CM2 × CM27	92	1533	a b c	85	2597[2]	a b
CM28 × CM2	86	1750	a	84	2319	c d
CM28 × CM27	76	1381	b c d	81	2372	b c
(CM2 × CM27) (CM1 × CM28) HC	—	1400	b c d	—	—	
(CM28 × CM2) (CM1 × CM27) HC	—	1371	b c d	—	—	
(CM1 × CM2) (CM28 × CM27) HC	—	1262	c d e f	—	—	
(CM2 × CM27) (CM1 × CM28) NC	—	1254	c d e f	—	—	
(CM1 × CM27) (CM28 × CM2) NC	—	1197	d e f g	—	—	
(CM1 × CM2) (CM28 × CM27) NC	—	1106	d e f g	—	—	

[1]HC = Cross made by hand-pollination; NC = Cross made by natural pollination
[2]Pedigree = S-37-388 × CM27 in 1958

TABLE 4. — PERFORMANCE OF SYNTHETIC 11 SUNFLOWER AND OF SINGLE AND DOUBLE CROSSES MADE FROM ITS COMPONENT LINES

Pedigree	1957			1958		
	Per cent hybrids	Yield per acre (lb.)	Duncan multiple range test (P = .05)	Per cent hybrids	Yield per acre (lb.)	Duncan multiple range test (P = .05)
Advance HC[1]	92	1700	b c	100	2557	a
Advance NC	69	1437	d e f g h	67	1883	b c
Advance 2nd gen.	—	844	j	—	1385	d
Synthetic 11 1st gen.	—	1397	e f g h	—	1982	b c
Synthetic 11 2nd gen.	—	1318	g h	—	1844	b c
Synthetic 11 3rd gen.	—	—		—	1616	c d
CM3 × CM15	89	1373	f g h	95	2099	b
S-37-388 × CM3	84	1070	i	89	1450	d
CM30 × CM3	81	1576	b c d e f	95	2456	a
S-37-388 × CM15	96	1987	a	100	2610	a
CM30 × CM15	100	1652	b c d	98	2503	a
CM30 × S-37-388	90	1795	a b	92	1968	b c
(CM30 × S-37) (CM3 × CM15) HC	—	1619	b c d e	—	—	
(CM30 × CM3) (S-37 × CM15) HC	—	1513	c d e f g	—	—	
(S-37 × CM3) (CM30 × CM15) HC	—	1496	c d e f g	—	—	
(S-37 × CM3) (CM30 × CM15) NC	—	1332	g h	—	—	
(CM30 × S-37) (CM3 × CM15) NC	—	1241	h i	—	—	

[1]HC = Cross made by hand-pollination; NC = Cross made by natural pollination

Though the synthetics usually were lower-yielding than Advance produced by natural crossing, in most tests the differences were not significant. The two most prominent exceptions were the second generation of Synthetic 12 and of Synthetic 13 in 1957 (Tables 5 and 6). No reason was apparent for the poor performance of Synthetic 12 in this season. Two of the lines in Synthetic 13 are susceptible to aster yellows while the Advance hybrid is resistant. This disease was severe in 1957. In the following year, when aster yellows was not serious, the third generation of this synthetic was higher-yielding than the sample of Advance produced by natural crossing, even falling into the same group of means as the hand-crossed sample of Advance which had 91 per cent hybrids. In 1959, its fourth generation, and the third generation, were tested against hand-crossed Advance and did not differ significantly from the latter in yield. Note that in each test reported in Tables 3 to 6 the second generation of Advance was substantially lower-yielding than the first generation, the difference being significant in six of the eight tests. In contrast, the advancing generations of the synthetics either showed an increase in yield, or at least no significant decrease.

When the mean yields of the three single crosses involving each line are calculated they reveal marked differences in the combining ability of the lines within the synthetics. As examples, in 1957, in Synthetic 10, CM1 had a mean yield of 1072 pounds per acre compared with 1402 for CM27; in Synthetic 12, CM13 had a mean of 1351 against 2227 for CM32 and in Synthetic 13 the mean for CM35 was 904 versus 1844 for CM33. In the latter instance, the poor performance of CM35 may be caused by incompatibility shown in the cross CM35 × CM79.

The yields of the double crosses produced by hand were higher than those from natural crossing, with the exception of the (CM13 × CM21) (CM32 × CM31) cross (Table 6) which performed poorly in the hand-cross. Aside from this one exception the double crosses produced by hand did not differ significantly in yield, indicating that these tests did not disclose differences in performance of the double crosses due to arrangement of lines within them. The double crosses produced by natural pollination, again with the exception noted, did not differ significantly from either one or both generations of the respective synthetic. For Synthetic 10 the three double crosses produced by natural pollination were all lower-yielding than the second generation of the synthetic.

DISCUSSION

The performance of the single crosses reported here shows that high yields can be obtained from many of them if the seed contains a high percentage of hybrids. Thus single crosses in which a high percentage of hybrids can be obtained under natural pollination may be the ultimate in the utilization of heterosis in sunflowers. However, the percentage of hybrids in the seed of Advance and Advent, when produced commercially in 2 × 2, or Admiral in 2 × 4 crossing blocks is much too low for their full value to be realized.

TABLE 5. — PERFORMANCE OF SYNTHETIC 12 SUNFLOWER AND OF SINGLE AND DOUBLE CROSSES MADE FROM ITS COMPONENT LINES

Pedigree	1957			1958		
	Per cent hybrids	Yield per acre (lb.)	Duncan multiple range test (P = .05)	Per cent hybrids	Yield per acre (lb.)	Duncan multiple range test (P = .05)
Advance HC[1]	—	—		97	2863	a
Advance NC	61	1522	d e f	69	1876	c d
Advance 2nd gen.	—	1179	g h	—	1433	d
Synthetic 12 1st gen.	—	1110	g h	—	1846	c d
Synthetic 12 2nd gen.	—	1133	g h	—	1795	c d
Synthetic 12 3rd gen.	—	—		—	1773	c d
CM13 × CM21	75	1297	f g	79	1805	c d
CM30[2] × CM13	97	2018	b c	99	2217	b c
CM13 × CM31	74	739	i	70	1863	c d
CM32 × CM21	99	2473	a	100	2634	a b
CM21 × CM31	58	1318	f g	74	2045	c
CM32 × CM31	96	2192	a b	100	2871	a
(CM32 × CM21) (CM13 × CM31) HC	—	1921	b c	—	—	
(CM32 × CM13) (CM21 × CM31) HC	—	1789	c d	—	—	
(CM13 × CM21) (CM32 × CM31) HC	—	906	h i	—	—	
(CM32 × CM21) (CM13 × CM31) NC	—	1205	f g h	—	—	
(CM32 × CM13) (CM21 × CM31) NC	—	1407	e f g	—	—	
(CM13 × CM21) (CM32 × CM31) NC	—	1683	c d e	—	—	

[1]HC = Cross made by hand-pollination; NC = Cross made by natural pollination

[2]CM30 is a sib line of CM32 and performs similarly.

TABLE 6. — PERFORMANCE OF SYNTHETIC 13 SUNFLOWER AND OF SINGLE AND DOUBLE CROSSES MADE FROM ITS COMPONENT LINES

Pedigree	1957			1958		
	Per cent hybrids	Yield per acre (lb.)	Duncan multiple range test (P = .05)	Per cent hybrids	Yield per acre (lb.)	Duncan multiple range test (P = .05)
Advance HC[1]	93	1812	a b	91	2554	c
Advance NC	64	1733	a b	69	2044	e
Advance 2nd gen.	—	1010	f g	—	1689	e
Synthetic 13 1st gen.	—	963	f g	—	1891	e
Synthetic 13 2nd gen.	—	1007	f g	—	2042	e
Synthetic 13 3rd gen.	—	—		—	2457	c d
CM33 × CM34	87	1769	a b	89	2655	b c
CM33 × CM35	79	1808	a b	84	3286	a
CM33 × CM79	58	1956	a	90	3027	a b
CM35 × CM34	61	700	g	56	2076	d e
CM35 × CM79	4	203	h	6	1173	f
CM79 × CM34	66	1653	b c	70	2080	d e
(CM33 × CM34) (CM35 × CM79) HC	—	1359	d e	—	—	
(CM33 × CM35) (CM79 × CM34) HC	—	1451	c d	—	—	
(CM33 × CM79) (CM35 × CM34) HC	—	1584	b c d	—	—	
(CM33 × CM79) (CM35 × CM34) NC	—	1195	e f	—	—	
(CM35 × CM79) (CM33 × CM34) NC	—	961	f g	—	—	

[1]HC = Cross made by hand-pollination; NC = Cross made by natural pollination

From the data in Table 1 it is evident that quantity of male pollen has an important bearing on the percentage of hybrids in Advance and Advent. Thus, when liberal quantities of pollen were provided by hand, the percentage of hybrids was always high, ranging from 79 to 96. These values also indicate that cross-incompatibility is not a factor in these crosses. When the pollen was transferred by insects, presumably in lesser quantities, in 1 × 2 natural crossing plots, the percentage of hybrids was lower. It was much lower in seed produced commercially in 2 × 2 crossing blocks, a fact which may be attributed to the lower ratio of male parent in these fields. The same positive effect of quantity of male pollen is seen in the high percentages of hybrids obtained when Admiral was produced by hand-pollination and when the two experimental three-way crosses were produced in the 2 × 4 crossing blocks using Advance as a male parent. However, when Admiral was produced in 2 × 4 crossing blocks the percentage of hybrids was similar to Advent and Advance from 2 × 2 crossing blocks. Obolensky (7) has noted differences in the amount of pollen produced by inbred lines. Perhaps the male parent of Admiral does not produce pollen as profusely as the male parent of the other two named hybrids or as Advance did in the two experimental three-way crosses.

The percentage of hybrids in the seed of each of the parents of Advance was higher when they were grown in the 50-50 mixture than when they were grown in 2 × 2 crossing blocks. Thus, by bringing the parents into closer proximity in the mixture, a condition which would facilitate transfer of pollen, the percentage of cross-fertilization was increased. However, even though an increase occurred, the percentage of hybrids in the mixture was inferior to the percentage in seed of S-37-388 from the 2 × 2 crossing blocks or Advance produced by the common means. This inferiority was expressed in lower yields of the mixture and shows that this method is not satisfactory for producing hybrid seed of Advance. The same may be expected for Advent.

The superior yield of the double crosses, made by hand, compared with the same crosses made by natural pollination, indicates that a greater amount of crossing occurred with hand-pollination wherein greater amounts of pollen would have been transferred to the female parent than in natural crossing plots.

Furgala (1) reported a higher percentage of hybrids in seed from crossing blocks populated with honeybees than in seed from crossing blocks without honeybees. His result is in agreement with those given here in that greater amounts of pollen would have been transferred in the populated fields. Obolensky (7), on the other hand, obtained results differing from those in the present study. He found that variation of the proportion of female (S-37-388) to male (Sunrise) parents between 1:1 and 3:1 in crossing plots had no effect on the percentage of hybrids obtained from seed of the female. Also, seed from the parents grown in mixtures containing 10 to 50 per cent male showed little difference in percentage of hybrids between the two parents or between them and the female from the crossing plots. His data were, however, gathered from a very limited study in one season.

While the percentage of hybrids occurring in the mixture of the Advance parents reported here and the resulting yields were inferior to those of seed from the crossing blocks, this may be a situation specific to the two parents under study. Obolensky (7) found no significant correlation between self-compatibility and amount of pollen produced, and Russell (8) reported a significant negative correlation between self-compatibility and the amount of crossing under open pollination. Thus it may be possible to select lines that are relatively self-incompatible and are good pollen producers and to obtain a high percentage of hybrids by planting them in mixtures. An inference that this is possible is seen in the results of Kugler *et al.* (5). Two hybrids, produced by hand-pollination, gave yields of 135 and 189 per cent of the Klein check variety. The same hybrids, produced by mixing the parents, both gave yields of 182 per cent of Klein. While no data on percentage of hybrids are given, the yields of the mixtures indicate that they contained as many hybrid plants as the seed from pollination by hand. Therefore, the ultimate of a single cross in which a high percentage of hybrids can be obtained under natural pollination may be attainable.

Until this ultimate is achieved, the performance of the synthetics reported here shows that they have prospect of being a better means of using inbred lines than hybrids, such as Advance, produced by natural pollination. While, in general, they did not outyield samples of Advance containing 61 to 100 per cent hybrids, they likely would have yielded much better than most commercial samples of Advance, because the latter had an average of only 39 per cent hybrids in 52 lots examined. Also, their performance in relation to the double crosses produced by natural pollination shows that heterosis can be exploited as effectively with synthetics made of four lines as with double crosses made from the same lines.

Besides promising better yield than the present hybrids that are produced by natural pollination, seed of synthetics would cost less. Because of the special care required in planting and harvesting crossing-blocks and the low yield of the inbred parents the cost of hybrid seed has ranged from 25 to 40 cents per pound. Seed of synthetics might be produced for 10 cents per pound or less.

One practical disadvantage of the synthetics would be less uniformity than in a single-cross hybrid. Also, the lines entering a synthetic all should carry resistance to the prevalent diseases. Otherwise situations will occur such as the poor performance of Synthetic 13 in the aster yellows epidemic of 1957. This requirement is more difficult to fulfil than for a single-cross hybrid, composed of just two lines. Also, only one line of the single cross, preferably the female, need carry resistance if the character is dominant.

Tysdal *et al.* (10) have presented theoretical values showing that yields of synthetics can approach F_1 hybrids, particularly if the amount of sibbing in the component lines is low. They also showed that the yields of synthetics increase as the number of lines in them increases from two to eight. A slight further increase is possible with 16 lines. Kinman and Sprague (4) in a study of ten inbred lines of corn in their 45 possible single crosses, predicted that the best synthetic could be composed of the five or six lines

of best combining ability. Furthermore, synthetics in corn have shown good performance in field tests. Hayes *et al.* (2) reported on one composed of the eight best combining lines out of a group of twenty. Its yield was similar to a recommended hybrid for the area. Lonnquist and McGill (6) used S_1 lines from a second cycle of recurrent selection to form four synthetics which averaged 96 per cent of the yield of the hybrid U.S. 13. Kiesselbach (3) found that the yield of double crosses in F_2, or in other words synthetics composed of four lines, was 85 per cent of the F_1. If comparable performance can be obtained from synthetics in sunflowers they will be valuable in sunflower production. Even the best samples of commercially produced Advance and Advent, containing 47 to 56 per cent hybrids, only yielded 72 per cent of the samples from hand-pollination as was shown by the data of Table 1. Commercial lots in general, which frequently have less than 40 per cent hybrids, would be even poorer.

Improved synthetics should be attainable in sunflowers. Those reported here contained four lines instead of the larger numbers which appear more desirable on the basis of theoretical considerations. Several of the lines used in the present synthetics are known to be relatively self-fertile. Choice of lines with lower self-fertility or less prone to sibbing should give further improvement. The selection of groups of lines known to combine well with each other in all combinations would be equally or more important. This condition did not exist in the groups of lines used in these synthetics. When these studies were commenced the choice of unrelated lines of similar flowering date was limited. Since then several promising new inbred lines have been developed. The objective now is to identify a group of lines that are cross-compatible and have superior combining quality with each other. Such a group should form a high-yielding synthetic.

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