UNITED STATES DEPARTMENT OF AGRICULTURE
In cooperation with the
Tennessee Agricultural Experiment Station
DEPARTMENT BULLETIN No. 1354
Washington, D. C. ▼ December, 1925

THE PRODUCTIVENESS OF SUCCESSIVE GENERATIONS OF SELF-FERTILIZED LINES OF CORN AND OF CROSSES BETWEEN THEM [1]

By Frederick D. Richey, *Agronomist in Charge of Corn Investigations,* and L. S. Mayer, *Assistant Agronomist, Office of Cereal Investigations, Bureau of Plant Industry*

CONTENTS

BASIS FOR THE INVESTIGATION

It has long been recognized that too close breeding causes a decreased productiveness in corn and that crossing varieties tends frequently to result in increased vigor and yield. On the basis of this knowledge some of the older methods of corn breeding were planned carefully to avoid possible inbreeding and some to utilize the vigor of first-generation crosses between varieties. The Mendelian interpretation of hybrid vigor, as due to the complementary action of dominant favorable growth factors, gave a plausible explanation of the phenomena of inbreeding and crossbreeding. The general acceptance of this interpretation has caused an extensive revision of corn-breeding methods. It is recognized that maintaining a high degree of hybridity only prevents the expression of unfavorable recessive factors without eliminating them. The newer methods therefore seek to bring these unfavorable factors into expression, where they may be recognized and eliminated. This involves selection within self-fertilized lines as the first step.

A study of the possibility of obtaining larger yields of corn by methods involving selection within self-fertilized lines was begun among the plants of the F_2 generation of the cross Whatley × St.

[1] The breeding plats from which the strains used in these experiments were obtained were conducted by the senior writer in cooperation with Lee Wilson & Co., Armorel, Ark., in 1916, 1917, and 1918 and the Burdette Plantation, Burdette, Ark., in 1919, 1920, and 1921. The senior writer also is responsible for the self and cross pollinations made at the Arlington Experiment Farm in 1921, for the preparation of this seed for planting, and for the general plan of the experiment. The breeding plats in 1922 and subsequent years and the yield experiments in 1922 and 1923 were located at Knoxville, Tenn., in cooperation with the Tennessee Agricultural Experiment Station and under the supervision of the junior writer. The writers wish to express their appreciation of the assistance rendered by S. H. Essary, of the Tennessee Agricultural Experiment Station, during the progress of the experiments at Knoxville.

48045—25†——1

Charles White, designated U. S. Selection No. 201, in 1916. Mass selection was begun at the same time, to provide a standard for measuring progress and in the hope of establishing a variety of economic value for the locality. In selecting within self-fertilized lines, the better plants of a line, the better lines of a strain of related lines, and the better strains of No. 201 were chosen in general. The basis of selection was the production of sound grain per plant, consideration being given also to maturity, general plant proportions, and freedom from extreme abnormalities. Data showing the effects of mass selection through six generations and the productiveness of crosses made following four generations of selection within self-fertilized lines have been published (*6*).[2] The present bulletin, a second progress report, presents the data obtained in 1922 and 1923. These include (1) a comparison of the productiveness of successive generations of self-fertilized lines of corn, (2) a comparison of crosses between these lines, and (3) data on the yields of crosses between lines after six generations of self-fertilization, the yields of analogous crosses following four generations of self-fertilization having been presented previously (*6*).

THE COMPARISON OF SUCCESSIVE GENERATIONS

The number of generations of self-fertilization to practice before comparing crosses between lines of corn has been a subject of discussion among corn breeders. The comparison of the productiveness of successive generations of self-fertilized lines and their crosses was made in the hope that it might give some information on this question.

GROWING SEED FOR COMPARISON

In order to compare the different generations fairly it was necessary to have seed of each that was of the same age and that had been grown under identical conditions. The remnants of the breeding ears had been saved each season. Seed from some of these remnants, together with seed from the 1921 breeding ears, was planted in individual rows at the Arlington Experiment Farm, Rosslyn, Va., in 1921. Some of the plants representing each selected line were self-pollinated, and others were crossed with other selected lines. In making cross-pollinations a mixture of pollen from two to five plants was used to obtain a better representation of the staminate parent.

METHOD OF COMPARISON

The productiveness of the different lines and crosses was compared in cooperation with the Tennessee Agricultural Experiment Station at Knoxville, Tenn., in 1922. The successive generations of one strain were compared in a unit consisting of a number of rows 90 hills long. The individual plats consisted of single rows of 10 hills with 2 plants per hill, making 20 plants per plat, facts permitting. The comparisons of crosses between strains were made in a similar manner. The plan of planting one of these units, that in which the crosses between the 3–1– and 5–1– strains were compared, is shown in Table 1, as an example. The index numbers used to indicate the location of the different crosses in this table correspond to those in column 1 of Table 2.

---

[2] The serial numbers (italic) in parentheses refer to "Literature cited," at the end of this bulletin.

The number of replications ranged from 10 to 20, depending upon the quantity of seed available, the number in each case being given in column 11 of Table 2. Each unit was separated from the adjacent ones by check plats of open-fertilized No. 201, seed for which was obtained from the Burdette Plantation, Burdette, Ark.

TABLE 1.—*Order of planting the crosses between the 3–1– and 5–1– families of No. 201 corn (index Nos. 42–47) and accompanying check rows in field rows Nos. 103 to 115*

[The rows were divided into 9 plats of 10 hills each. The number shown for each plat is the index number of the lot of seed grown in that plat. C indicates a check plat]

Field row	Rows divided into 9 sections of 10 hills each									Field row	Rows divided into 9 sections of 10 hills each								
	1	2	3	4	5	6	7	8	9		1	2	3	4	5	6	7	8	9
No. 103	C	C	C	C	C	C	C	C	C	No. 110	42	45	42	43	46	44	42	44	45
No. 104	42	44	46	42	44	46	42	44	46	No. 111	43	46	43	45	43	45	46	45	46
No. 105	43	45	47	43	45	47	43	45	47	No. 112	44	47	44	42	44	42	44	46	44
No. 106	44	46	42	44	46	42	44	46	42	No. 113	45	44	45	46	45	43	45	43	42
No. 107	45	47	43	45	47	43	45	47	43	No. 114	46	43	46	44	42	46	43	47	43
No. 108	46	42	44	46	42	44	46	42	44	No. 115	C	C	C	C	C	C	C	C	C
No. 109	47	43	45	47	43	45	47	43	45										

Heavy rains shortly after emergence packed the soil and caused severe erosion in places. Storms about tasseling time also damaged the plants. These conditions tended to decrease the stand and to increase the proportion of barren plants. It is believed, however, that the distribution of the replications was such that comparisons among the selfed lines or crosses in any unit are accurate within the limits of their probable errors. On the other hand, close comparisons can not be made safely between the crosses and their parents or between the selfed lines or crosses in different units.

Sample lots of ears, consisting of the total product of one replicate of each line and cross, were saved at harvest, dried, and shelled. The harvest weights were computed to terms of air-dry shelled corn on the basis of these data. The drying and shelling samples for the 3–1– and 5–1– lines and for the cross 3–1– × 5–1– are shown in Plate I.

EXPERIMENTAL DATA

A summary of the experimental data for each selfed line and cross is given in Table 2. Most of the data are self-explanatory. The relations between the lines are shown by the pedigree numbers in the tables. In these, each number separated from the others by a dash (–) represents one generation of selection and self-fertilization. The letter S at the end of a pedigree represents the extra generation of self-fertilization in 1921 in obtaining seed for the comparisons. The average height of plants (column 5) is the arithmetic mean of the estimated heights in the different replications. All other records are based on actual determinations. The data on adjacent check plats in columns 15 and 16 give an idea of the relative productiveness of the different parts of the field. Two rows of nine check plats each were grown between the units of the crosses, and only one row was grown between the units of the self-fertilized lines. Excess checks also were used to fill in when the number of plats needed for any comparison failed to equal the number of plats available in a unit. This accounts for the inequality in the numbers of check plats adjacent to the different units.

TABLE 2.—*Summary of data on height of plants, number of suckers, barren plants, and ears, weight of grain per ear and per plant, and yield of successive generations of self-fertilized lines of corn and of crosses between them*

Index No.	Pedigree No.	Number of seed ears	Total number of plants	Average height of plants	Number per 100 plants			Average weight of shelled grain		Number of replications	Average yield of ears per plat		Equivalent yield of shelled corn per acre[1]	Adjacent check plats[2]	
					Suckers	Barren plants	Ears	Per ear	Per plant		Actual	Corrected stand		No.	Yield per acre
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
				Feet				*Pounds*	*Pounds*		*Pounds*	*Pounds*	*Bushels*		*Bushels*
1	2-2-S	3	271	5.2	0.4	42.4	62.4	0.067	0.042	20	0.8	1.1	5.0±0.10	31	64.0
2	2-2-1-S	4	363	6.0	1.1	13.2	123.7	.166	.205	20	4.4	4.8	24.5± .30		
3	2-2-2-S	5	379	6.1	1.6	10.8	102.9	.188	.194	20	4.8	5.0	23.3± .21		
4	2-2-2-4-S	3	376	5.6	2.4	22.6	90.2	.133	.119	20	2.9	3.1	14.5± .22		
5	2-2-2-2-S	3	297	4.5	1.3	59.6	54.9	.027	.014	20	.4	.5	1.9± .05		
6	2-2-2-2-3-S	3	348	5.4	1.4	39.4	68.4	.096	.066	20	1.6	1.8	7.6± .11		
7	2-2-2-4-4-S	3	388	5.5	1.5	21.9	109.8	.105	.115	20	3.1	3.2	13.9± .22		
8	3-1-S	5	384	6.7	3.4	6.8	109.4	.274	.300	20	6.9	7.1	35.9± .26	28	52.7
9	3-1-1-S	2	356	6.0	1.4	18.8	89.6	.110	.099	20	2.5	2.8	12.1± .19		
10	3-1-1-3-S	2	346	6.0	1.7	12.7	124.6	.140	.174	20	4.0	4.6	21.2± .27		
11	3-1-1-4-S	6	387	6.5	3.4	12.7	102.3	.161	.164	20	4.7	4.8	19.6± .20		
12	3-1-1-3-1-S	2	344	6.4	1.7	9.3	138.1	.162	.224	20	5.1	5.9	27.1± .28		
13	3-1-1-4-3-S	4	351	6.2	1.7	29.1	77.2	.097	.075	20	2.1	2.3	8.7± .14		
14	5-1-S	4	397	6.5	2.8	20.2	79.8	.137	.110	20	3.0	3.0	13.0± .13	30	45.4
15	5-1-2-S	4	392	6.5	1.5	19.6	83.4	.137	.114	20	3.0	3.0	13.8± .17		
16	5-1-2-3-S	4	379	6.3	1.6	17.9	95.0	.085	.081	20	2.3	2.4	9.7± .14		
17	5-1-2-5-S	4	392	6.4	1.8	10.5	102.6	.172	.177	20	4.3	4.3	21.2± .18		
18	5-1-2-3-1-S	4	380	6.5	2.6	27.6	72.6	.069	.050	20	1.5	1.6	6.1± .09		
19	5-1-2-5-2-S	4	393	6.4	2.3	16.5	86.0	.120	.103	20	2.7	2.7	12.3± .12		
20	9-2-S	4	397	6.6	1.5	7.1	140.8	.122	.172	20	4.6	4.6	20.9± .27	28	52.7
21	9-2-1-S	6	413	7.0	3.4	4.6	122.5	.274	.336	20	8.6	8.4	41.1± .32		
22	9-2-2-S	5	388	6.7	1.5	8.5	143.0	.121	.173	20	4.0	4.0	20.2± .28		
23	9-2-2-1-S	4	394	6.7	1.5	10.2	104.1	.200	.208	20	5.2	5.2	25.1± .31		
24	9-2-1-2-S	4	390	7.5	2.3	8.2	126.2	.131	.165	20	5.6	5.6	19.6± .23		
25	9-2-1-2-1-S	6	392	7.0	.5	3.6	121.9	.188	.229	20	6.0	6.1	27.7± .22		
26	9-2-3-2-3-S	3	335	6.8	.9	6.6	112.5	.174	.195	20	4.6	5.5	23.8± .20		

27	12-1-S	4	382	6.0	1.3	14.9	96.6	.131	.127	20	3.2	3.4	15.5± .16		
28	12-1-2-S	6	347	5.5	1.2	12.4	98.3	.075	.074	20	2.4	2.9	9.4± .15		
29	12-1-1-S	3	384	6.5	4.4	11.7	108.1	.210	.227	20	5.5	5.7	27.5± .28		
30	12-1-1-1-S	6	396	6.2	.8	4.6	122.7	.159	.195	20	5.1	5.1	23.5± .26		
31	12-1-1-2-S	2	198	5.9	.5	7.1	105.1	.169	.178	10	4.4	4.5	21.7± .38	34	56.4
32	12-1-2-3-S	5	351	5.5	2.8	12.8	93.2	.103	.096	20	2.5	2.9	12.0± .18		
33	12-1-2-3-2-S	3	364	5.4	.5	17.6	84.3	.106	.090	20	2.1	2.3	11.1± .20		
34	12-1-1-1-2-S	6	396	6.4	1.5	5.1	113.1	.177	.201	20	5.2	5.2	24.0± .23		
35	2-2×7-1	4	390	7.0	1.8	3.9	111.3	.256	.285	20	7.1	7.2	34.3± .31		
36	2-2-1×7-1-1	4	397	7.3	.8	3.5	122.9	.270	.331	20	8.3	8.3	40.0± .50		
37	2-2-2×7-1-1	4	403	7.4	1.5	2.0	118.4	.299	.354	20	8.7	8.6	42.6± .46		
38	2-2-2-4×7-1-1-1	5	405	7.3	2.5	6.4	106.4	.299	.319	20	7.9	7.7	38.0± .50	43	47.1
39	2-2-2-4×7-1-1-2	4	399	7.1	1.3	4.0	109.5	.278	.304	20	7.7	7.8	37.1± .38		
40	2-2-2-4-4×7-1-1-2-3	3	393	7.3	1.0	6.9	117.6	.239	.281	20	6.5	6.6	33.9± .37		
41	2-2-2-4-4×7-1-1-1-3	3	401	7.3	1.0	9.0	97.3	.347	.337	20	8.1	8.1	40.9± .53		
42	3-1×5-1	2	320	7.4	4.1	10.6	98.4	.222	.219	16	5.5	5.4	26.3± .44		
43	3-1-1×5-1-2	2	372	7.6	3.2	3.8	120.4	.300	.361	18	9.5	9.1	43.3± .49		
44	3-1-1-3×5-1-2-5	3	358	7.7	.3	2.0	124.9	.307	.383	18	10.0	10.1	46.9± .64	40	44.0
45	3-1-1-4×5-1-2-3	4	369	7.8	2.7	4.6	109.2	.283	.310	18	8.1	7.9	37.4± .43		
46	3-1-1-3-1×5-1-2-5-2	3	372	7.7	3.0	5.9	114.5	.283	.324	18	9.1	9.0	40.1± .51		
47	3-1-1-4-3×5-1-2-3-1	2	221	7.6	3.6	7.2	100.5	.260	.261	11	7.9	7.8	31.6± .56		
48	9-2×12-1	3	325	7.3	.3	4.6	116.3	.305	.355	16	9.0	8.9	43.3± .46		
49	9-2-1×12-1-2	3	310	7.2	1.0	5.8	107.7	.285	.307	16	7.5	7.7	36.8± .10		
50	9-2-2×12-1-1	3	312	7.3	.6	4.2	126.9	.247	.314	16	7.8	8.0	38.1± .47		
51	9-2-2-1×12-1-1-2	4	316	7.2	.9	13.3	93.0	.257	.239	16	5.9	5.9	28.6± .48	41	47.4
52	9-2-1-2×12-1-2-3	6	318	7.2	.3	5.0	110.7	.327	.362	16	9.7	9.7	43.8± .45		
53	9-2-1-2-1×12-1-2-3-2	5	319	7.2	.6	6.0	106.9	.319	.341	16	9.3	9.3	41.4± .47		
54	9-2-3-2-3×12-1-2-3-2	3	315	6.8	1.6	12.7	90.5	.204	.185	16	4.6	4.6	22.0± .38		
55	12-1×2-2	3	204	6.8	1.5	5.9	100.5	.276	.278	10	7.1	7.0	33.7± .66		
56	12-1-1×2-2-1	1	201	6.9	1.0	3.5	102.5	.282	.289	10	7.4	7.3	34.8± .43		
57	12-1-1×2-2-2	1	198	7.0	2.5	5.6	111.6	.241	.269	10	7.2	7.4	33.1± .41		
58	12-1-1-1×2-2-2-2	1	196	6.8	1.0	2.0	119.4	.261	.312	10	7.3	7.5	37.9± .49		
59	12-1-1-1×2-2-2-4	4	193	7.0	0	7.3	125.4	.238	.299	10	7.3	7.5	36.0± .36	35	46.5
60	12-1-1-2×2-2-2-4	3	198	7.3	3.5	9.1	113.6	.278	.316	10	8.2	8.1	37.5± .53		
61	12-1-2-3-2×2-2-2-2-3	1	195	7.0	1.0	7.7	98.5	.302	.298	10	7.7	7.9	36.2± .82		
62	12-1-2-3-2×2-2-2-4-4	1	199	7.0	.5	5.5	106.5	.304	.324	10	7.7	8.0	40.4± .57		
63	12-1-1-1-2×2-2-2-2-3	5	193	7.1	.5	4.2	108.3	.291	.315	10	8.3	8.5	37.9± .62		
64	12-1-1-1-2×2-2-2-4-4	2	197	7.6	1.0	4.6	139.1	.288	.401	10	9.8	9.9	48.5± .81		

[1] Yield of ear corn per plat, corrected stand basis, multiplied by the percentage of grain multiplied by 1/56 multiplied by 324.
[2] Average yield of the number of check plats stated that were grown adjacent to each unit.

The data on the number of suckers, barren plants, and ears per 100 plants and the weight of shelled grain per ear are of some interest in showing the individuality of the different lines and crosses. The inability to make accurate comparisons between the different groups because of conditions already noted, however, robs these data of much of their value. It seems desirable, therefore, to consider only the yields and those primarily within groups or between comparable averages.

YIELDS OF SELF-FERTILIZED LINES

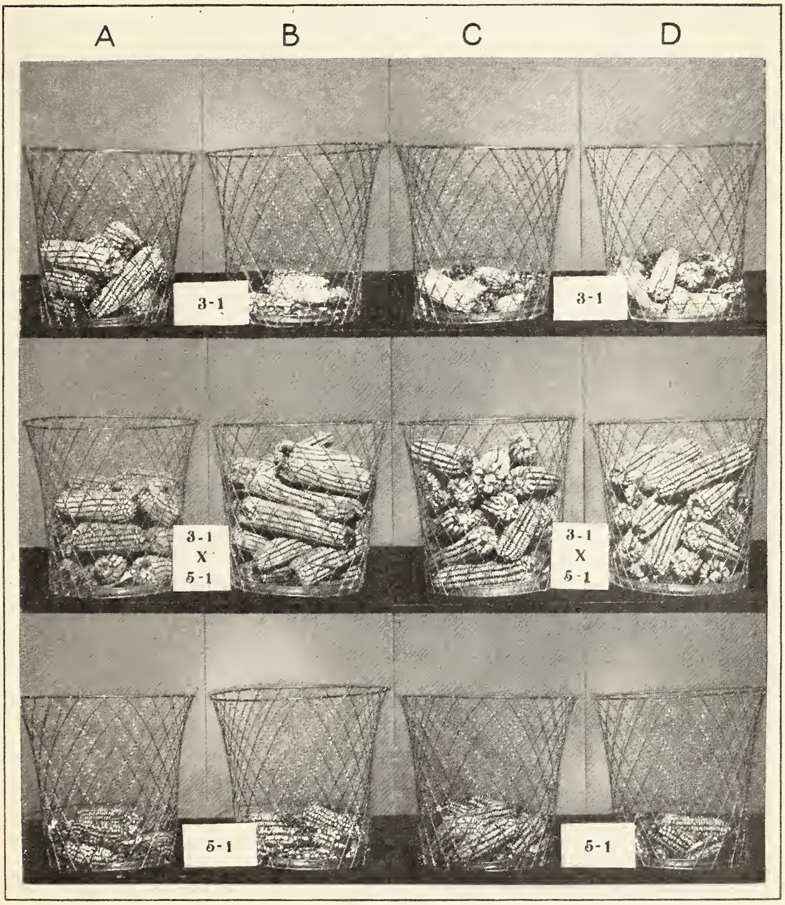
The yields of successive generations of self-fertilized lines are brought together in Table 3 to show the relation between (1) the lines of descent and yield and (2) the average yields in successive generations considered from different points of view. Because of differences in the productiveness of different parts of the field, strain comparisons should be made only when taking into account the yields of the adjacent checks.

TABLE 3.—*Yields of successive generations of self-fertilized lines of corn*

Selfed 3 generations		Selfed 4 generations		Selfed 5 generations		Selfed 6 generations	
Pedigree No.	Yield per acre (bushels)	Pedigree No.	Yield per acre (bushels)	Pedigree No.	Yield per acre (bushels)	Pedigree No.	Yield per acre (bushels)
2-2-S	5.0	2-2-2-S 2-2-1-S	23.3 *24.5	2-2-2-4-S 2-2-2-2-S	14.5 1.9	2-2-2-4-4-S 2-2-2-2-3-S	13.9 7.6
Strain mean	5.0		23.9		8.2		10.8
3-1-S	35.9	3-1-1-S	12.1	3-1-1-3-S 3-1-1-4-S	21.2 19.6	3-1-1-3-1-S 3-1-1-4-3-S	27.1 8.7
Strain mean	35.9		12.1		20.4		17.9
5-1-S	13.0	5-1-2-S	13.8	5-1-2-5-S 5-1-2-3-S	21.2 9.7	5-1-2-5-2-S 5-1-2-3-1-S	12.3 6.1
Strain mean	13.0		13.8		15.5		9.2
9-2-S	20.9	9-2-1-S 9-2-2-S	41.1 *20.2	9-2-1-2-S 9-2-2-1-S	19.6 *25.1	9-2-1-2-1-S 9-2-3-2-3-S	27.7 *23.8
Strain mean	20.9		30.7		22.4		25.8
12-1-S	15.5	12-1-1-S 12-1-2-S	27.5 9.4	12-1-1-1-S 12-1-1-2-S 12-1-2-3-S	23.5 *21.7 12.0	12-1-1-1-2-S 12-1-2-3-2-S	24.0 11.1
Strain mean	15.5		18.5		19.1		17.6
Average A [1]	18.1		19.8		17.1		16.3
Average B [2]	18.1		21.8		16.3		16.6
Average C [3]	17.4		19.2		20.1		19.3
Average D [4]	17.4		14.7		10.8		8.4

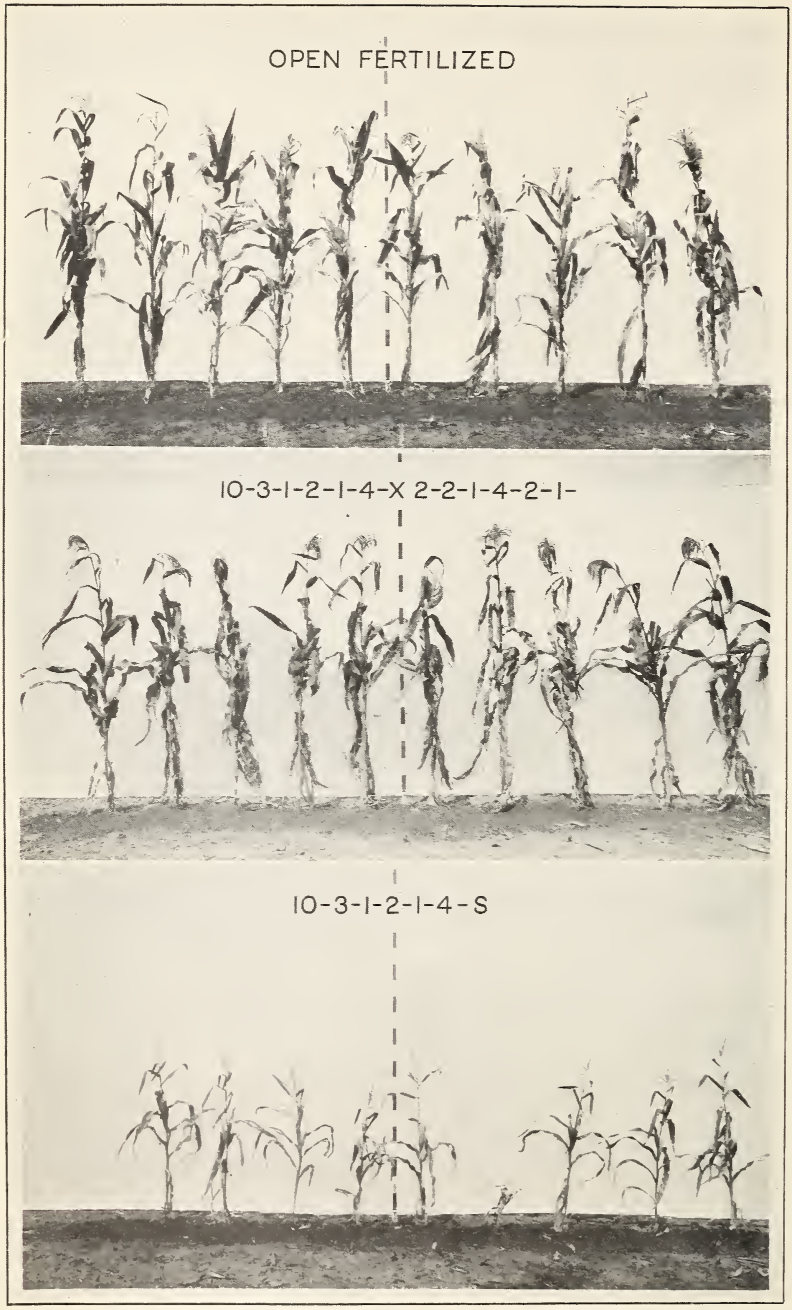
[1] Average of strain means, including all lines.
[2] Average of strain means, excluding lines (marked *) not represented in all generations.
[3] Average yields of the better of each of four pairs of lines in the sixth generation that were represented by comparable pairs in the fifth generation and of their antecedent lines.
[4] Average yields of the poorer of each of four pairs of lines in the sixth generation that were represented by comparable pairs in the fifth generation and of their antecedent lines, comparable to average C.

A general tendency is evident for lines and strains to maintain the same relative positions in the different generations. The outstanding exceptions to this tendency occur in the third and fourth generations,



THE EARS HARVESTED FROM 20 PLANTS OF THE 3–1– STRAIN, OF THE 5–1– STRAIN, AND OF THE CROSS, 3–1– × 5–1–, RESPECTIVELY

The baskets of ears in columns A, B, C, and D were produced from seed that either had been self-fertilized (3–1– and 5–1–) or crossed (3–1– × 5–1–) following two, three, four, and five generations of self-fertilization



REPRESENTATIVE PLANTS OF OPEN-FERTILIZED NO. 201 CORN (CHECK) AND OF THE SELF-FERTILIZED LINE AND CROSS OF THIS VARIETY INDICATED BY THE PEDIGREES owing probably in part to greater variability and in part to the fewer lines in these earlier generations. The 12–1– strain is the only one having parallel lines in three successive generations. The 12–1–1– lines were more productive than those of 12–1–2– in each generation.

Four comparisons between parallel pairs of lines are possible in the fifth and sixth generations, in each of which the more productive line of the pair in the sixth generation also was the more productive in the fifth. The average yields of the more productive and of the less productive lines of these pairs, together with the average yields of their antecedent lines in the third and fourth generations, are shown as averages C and D in Table 3 and are shown graphically in Figure 1. The difference in the fourth generation is due entirely to the effect of the difference between 12–1–1–S and 12–1–2–S, so that little importance attaches to the spread in that generation. For comparison with these data the theoretical curve for decreased yield in six successive generations of inbreeding without selection also is shown in Figure 1. This curve is plotted to decrease from 50 bushels per acre, an approximation of the yield of the open-fertilized noninbred check seed in the present experiment, to 17.4 bushels per acre in the third self-fertilized generation, the average yield of the four selfed lines in that generation. This assumes that the average yield of these four lines in the third generation had not been affected by selection, which may or may not be true, but will serve for purposes of approximation.

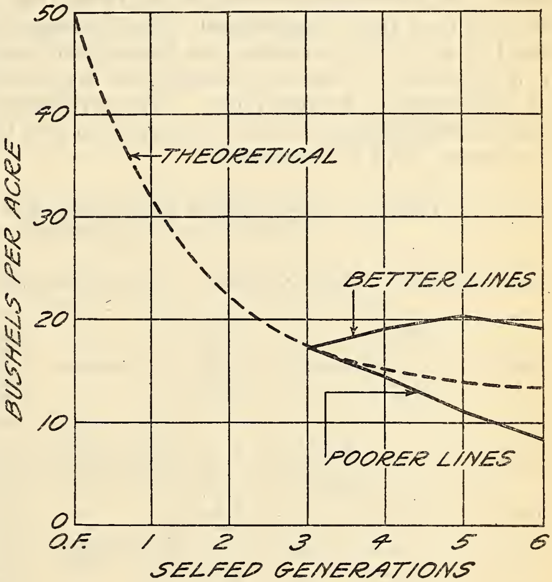


Fig. 1.—Diagram showing the average yields of four better yielding self-fertilized lines of corn (average C of Table 3) and of four poorer yielding lines (average D of Table 3) after three to six generations of self-fertilization and the theoretical decrease in yield in unselected self-fertilized lines of corn

It is evident that two lines have been isolated in each of the four strains after three or four generations of self-fertilization, one of which is more and the other less productive. Moreover, the average of the four less productive lines decreased about 20 per cent between the fifth and sixth generations, whereas that of the four more productive lines remained essentially constant.

The averages of the strain means in the different generations are shown as average A of Table 3. There is a slight, reasonably consistent decrease from the third to the sixth generation. The difference between the yields in these generations is 1.8 bushels per acre. The decrease in the theoretical curve of inbreeding (shown in fig. 1) between the third and sixth generations is from 17.4 to 13.3 bushels, or

4.1 bushels. In so far as the lines compared represent the breeding stocks as a whole, therefore, these averages indicate that selection has been effective in maintaining productiveness somewhat above what would be expected under self-fertilization without selection.

Average B of Table 3 differs from average A in that only those lines represented directly in all generations are included. In some ways this would seem the fairer method of comparison, but the small numbers available may make the general average the more reliable approximation. In any event the difference is unimportant.

YIELDS OF CROSSES BETWEEN LINES

The yields of the crosses between lines after successive generations of self-fertilization are brought together in Table 4. The evidence here is not so clear as to individuality as it is for the behavior of the self-fertilized lines themselves. The averages shown as A and B are based upon all the crosses in a generation and upon those crosses in each generation that are represented by analogous crosses in all of the generations, respectively. No particular advantage is evident from inbreeding more than three generations before crossing in so far as average yield is concerned.

TABLE 4.—*Yields of crosses between lines of corn that had been self-fertilized for different numbers of generations*

Selfed 2 generations		Selfed 3 generations		Selfed 4 generations		Selfed 5 generations	
Pedigree No.	Yield per acre (bushels)	Pedigree No.	Yield per acre (bushels)	Pedigree No.	Yield per acre (bushels)	Pedigree No.	Yield per acre (bushels)
2-2×7-1	34.3	2-2-2×7-1-1	42.6	2-2-2-4×7-1-1-1	38.0	2-2-2-4-4×7-1-1-1-3	40.9
		2-2-1×7-1-1	*40.0	2-2-2-4×7-1-1-2	37.1	2-2-2-4-4×7-1-1-2-3	33.9
Mean	34.3		41.3		37.6		37.4
3-1×5-1	26.3	3-1-1×5-1-2	43.3	3-1-1-3×5-1-2-5	46.9	3-1-1-3-1×5-1-2-5-2	40.1
				3-1-1-4×5-1-2-3	37.4	3-1-1-4-3×5-1-2-3-1	31.6
Mean	26.3		43.3		42.2		35.9
9-2×12-1	43.3	9-2-1×12-1-2	36.8	9-2-1-2×12-1-2-3	43.8	9-2-1-2-1×12-1-2-3-2	41.4
		9-2-2×12-1-1	*38.1	9-2-2-1×12-1-1-2	*28.6	9-2-3-2-3×12-1-2-3-2	*22.0
Mean	43.3		37.5		36.2		31.7
12-1×2-2	33.7	12-1-1×2-2-2	33.1	12-1-1-1×2-2-2-4	36.0	12-1-1-1-2×2-2-2-4-4	48.5
		12-1-1×2-2-1	*34.8	12-1-1-1×2-2-2-2	37.9	12-1-1-1-2×2-2-2-2-3	37.9
				12-1-1-2×2-2-2-4	*37.5	12-1-2-3-2×2-2-2-4-4	*40.4
						12-1-2-3-2×2-2-2-2-3	*36.2
Mean	33.7		34.0		37.1		40.8
Average A[1]	34.4		39.0		38.3		36.5
Average B[2]	34.4		39.0		40.2		39.5
Average C[3]	31.4		39.7		40.3		43.2
Average D[4]	31.4		39.7		37.5		34.5

[1]Average of means, including all crosses.
[2]Average of means, excluding crosses (marked *) not represented by analogous crosses in all generations.
[3]Average yileds of the better of each of 3 pairs of crosses made following 5 generations of self-fertilization that were represented by analogous crosses made after 4 generations of self-fertilization and of the corresponding antecedent crosses.
[4]Average yields of the poorer of each of 3 pairs of crosses made following 5 generations of self-fertilization that were represented by analogous crosses made after 4 generations of self-fertilization and of the corresponding antecedent crosses, comparable to average C.

The average yields of the better of each of three pairs of crosses made following five generations of self-fertilization represented by analogous crosses made following four generations of self-fertilization are shown as average C. The corresponding averages for the poorer crosses of the pairs are shown as average D. The difference following four generations of self-fertilization is small. This difference also is even less significant than its size might indicate, as it results chiefly from one large difference. It is evident that four generations of inbreeding were not enough to establish uniformity of behavior in combination sufficient to permit picking the better lines for crossing in this particular material. Whether this lack of individuality of the lines in crosses is an accident due to the choice of the lines for the experiment is not known. None of these crosses were particularly productive, and certainly there is more individuality shown in the behavior of other crosses, to be considered later.

TABLE 5.—*Yield of self-fertilized lines of corn and of crosses between them* [1]

Pistillate parent		Cross	Staminate parent	
Pedigree No.	Yield per acre (bushels)	Yield per acre (bushels)	Yield per acre (bushels)	Pedigree No.
12-1-1-1-2-S	24.0	48.5	13.9	2-2-2-4-4-S.
3-1-1-3-S	21.2	46.9	21.2	5-1-2-5-S.
9-2-1-2-S	19.6	43.8	12.0	12-1-2-3-S.
3-1-1-S	12.1	43.3	13.8	5-1-2-S.
2-2-2-S	23.3	42.6		7-1-1-S.
9-2-1-2-1-S	27.7	41.4	11.1	12-1-2-3-2-S.
2-2-2-4-4-S	13.9	40.9		7-1-1-1-3-S.
12-1-2-3-2-S	11.1	40.4	13.9	2-2-2-4-4-S.
3-1-1-3-1-S	27.1	40.1	12.3	5-1-2-5-2-S.
2-2-1-S	24.5	40.0		7-1-1-S.
9-2-2-S	20.2	38.1	27.5	12-1-1-S.
2-2-2-4-S	14.5	38.0		7-1-1-1-S.
12-1-1-1-S	23.5	37.9	1.9	2-2-2-2-S.
12-1-1-1-2-S	24.0	37.9	7.6	2-2-2-2-3-S.
12-1-1-2-S	21.7	37.5	14.5	2-2-2-4-S.
3-1-1-4-S	19.6	37.4	9.7	5-1-2-3-S.
2-2-2-4-S	14.5	37.1		7-1-1-2-S.
9-2-1-S	41.1	36.8	9.4	12-1-2-S.
12-1-2-3-2-S	11.1	36.2	7.6	2-2-2-2-3-S.
12-1-1-1-S	23.5	36.0	14.5	2-2-2-4-S.
12-1-1-S	27.5	34.8	24.5	2-2-1-S.
2-2-2-4-4-S	13.9	33.9		7-1-1-2-3-S.
12-1-1-S	27.5	33.1	23.3	2-2-2-S.
3-1-1-4-3-S	8.7	31.6	6.1	5-1-2-3-1-S.
9-2-2-1-S	25.1	28.6	21.7	12-1-1-2-S.
9-2-3-2-3-S	23.8	22.0	11.1	12-1-2-3-2-S.

[1] The coefficient of correlation between the yield of a cross and that of its pistillate parentis -0.07 ± 0.12.

RELATION BETWEEN PRODUCTIVENESS OF PARENT LINES AND CROSSES

There is no outstanding difference between the average yields of the crosses made after three, four, and five generations of self-fertilization. Neither is there any pronounced difference between the average yields of the self-fertilized lines in the fourth, fifth, and sixth generations. The relation of the productiveness of the crosses to that of the parent lines in these three generations may therefore be considered as a unit. The yields of the crosses are shown in Table 5, arranged in the order of their productiveness. The yields of the parent lines also are shown, in so far as they are available. No particular relation is evident between the yields of the crosses and that of their parents; in fact, the coefficient of correlation between the yields of the crosses and those of the pistillate parent lines is -0.07 ± 0.12.

DETERMINING THE VALUE OF INDIVIDUAL LINES FOR CROSSING

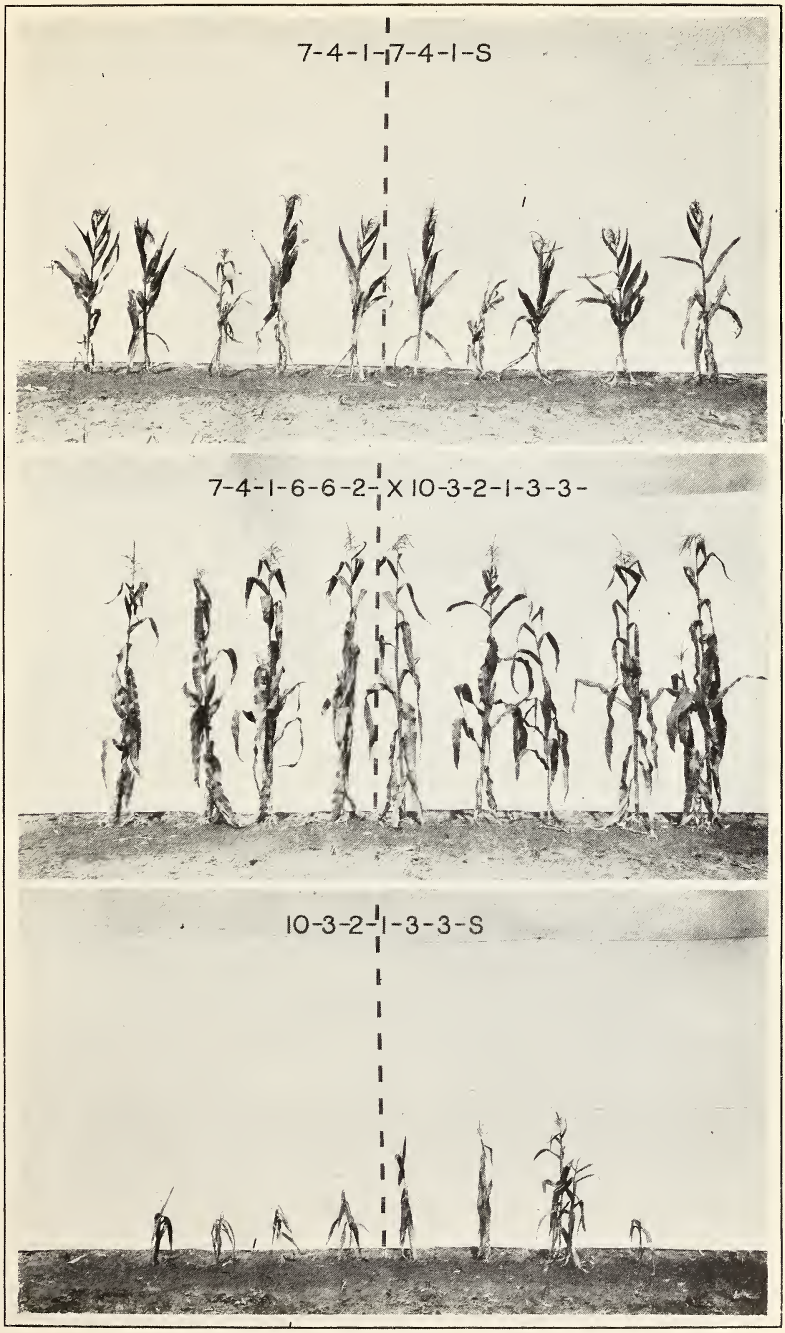
The primary object of the breeding experiments with No. 201 was to determine whether larger yields of corn could be obtained by the methods used. In a previous publication (*6*) it was stated that "the method of crossing [varieties] followed by mass selection has established a variety of economic value for the locality." That this variety continues to be of economic importance is shown by the fact that No. 201 has been accepted for certification under the name Delta Prolific by the Arkansas Seed Growers' Association, four growers offering a total of 950 bushels of certified seed of this variety for planting in 1925 (*1*). The data presented here show comparisons between the productiveness of check plants grown from open-fertilized seed of No. 201 (Delta Prolific) obtained from the Burdette Plantation and crosses between individual lines of this variety that had been self-fertilized for six generations. Any significant increases over the yield of the check, therefore, must be considered as evidence that the productiveness of a commercially profitable variety can be increased by the methods used. Whether such increases are worth while practically will depend upon a number of factors that are discussed in connection with the data.

OBTAINING THE CROSSED SEED

In the experiments reported previously (*6*) comparisons were made between strain crosses. Each of the parent strains was represented by a composite of a number of lines, some of which were very diverse in character. Strains Nos. 2–2–, 5–1–, 7–4–, and 10–3– had the highest average value as parents and gave the best average results when crossed among themselves. The present experiments were planned to measure the value for crossing of the individual lines in these strains.

The selection of the individual lines for crossing was made among the rows of the breeding plat at Knoxville, Tenn., in 1922. An effort was made to include as much diversity as possible, considering both the pedigree records and the appearance of the plants. Thus, two lines of a strain that showed striking differences in plant characteristics might be included without regard to when they had segregated for these differences. Similarly, different lines of a strain might be included because they had become separated after only two generations of inbreeding, whether they looked alike or not. Representative plants of a number of these inbred lines are shown in Plates II to VI. Representative plants of crosses between the lines and of open-fertilized noninbred No. 201 also are shown for comparison. All of the plants illustrated were grown at the Arlington Experiment Farm and were unselected, not more than 10 plants of any line or cross having been available.

In all, 18 lines in the four strains were selected, and as many crosses between the individual lines of the different strains were made as conditions permitted. One additional line, 10–3–1–2–1–5, was used to supplement the sib line, 10–3–1–2–1–4. Besides this, tassels from



REPRESENTATIVE PLANTS OF THE SELF-FERTILIZED LINES OF NO. 201 CORN AND THE CROSS INDICATED BY THE PEDIGREES—A

REPRESENTATIVE PLANTS OF THE SELF-FERTILIZED LINES OF NO. 201 CORN AND THE CROSS INDICATED BY THE PEDIGREES—B

REPRESENTATIVE PLANTS OF THE SELF-FERTILIZED LINES OF No. 201 CORN AND THE CROSS INDICATED BY THE PEDIGREES—C

REPRESENTATIVE PLANTS OF THE SELF-FERTILIZED LINES OF NO. 201 CORN AND THE CROSS INDICATED BY THE PEDIGREES—D plants of a 7–4–1– line were mailed to Knoxville from Washington, D. C., and one additional cross with 10–3– was obtained in this way. Failure of lines to blossom at the same time and damage by storm, insects, and diseases prevented obtaining as many crosses as desired. Enough combinations were obtained, however, to determine the relative value of the different lines in so far as major differences are concerned.

METHOD OF COMPARISON

The crosses were grown at Knoxville in 1923. One crossed ear represented each combination between individual lines, and the productiveness of this cross was compared directly with that of the variety by the hill-checking method (*5*). One seed of the cross and two seeds of the check were planted in each hill, the two kinds being about 6 to 8 inches apart and the check seed always being toward the southeast end of the row. A row was 120 hills long, and as many hills in the row were planted in the way described as there were seeds on the crossed ear, the rest of the row being planted with check seed. The plat was thinned to a stand of one crossed plant and one check plant in each hill, facts permitting, when the plants were 8 to 10 inches high. The rows were gone over just before harvest, and all hills not containing one crossed plant and one check plant were eliminated. The remaining perfect hills then were harvested in 10-hill sections, the product of the plants from crossed seed and check seed in each section being harvested and weighed separately. The relative productiveness of the different crosses is compared through average superiority or inferiority to the check.

The ears from the last 18 to 20 plants of the cross in each row were stored until dry. They were then reweighed and shelled, and the percentages of air-dry shelled grain were determined. The shrinkage and shelling percentages of the check were determined from six similar samples. The field weights were computed to terms of air-dry shelled grain on the basis of these data. The drying and shelling samples of some of the crosses, together with the product of a corresponding number of check plants, are shown in Plates VII and VIII. These illustrate the excellent quality of the ears produced by some of the crosses.

EXPERIMENTAL DATA

A summary of the data is given in Table 6, the crosses being arranged in the descending order of their relative productiveness. Column 1 shows the field-row number and is of interest in indicating any possible effect that location in the plat may have had on relative productiveness. There is some tendency for data from rows that occurred near each other in the field to occur near each other in the table, but examination of the pedigrees in column 2 shows that this probably is due largely to similar combinations having been grouped in the field to some extent.

The total number of perfect hills given in column 3 indicates also the number of replications used in determining the probable errors. The yield of any one to four plants beyond the last multiple of 10 was added to the yield of the last 10-plant replicate and the sum divided by the number of plants involved and multiplied by 10 to bring the yield to a 10-plant basis. If there were five or more such odd plants their yield was divided by the number, and the quotient, multiplied by 10, was treated as another replicate.

TABLE 6.—*Relative productiveness of crosses between self-fertilized lines of corn as differences in yield per 10 plants over or under the yield of the corresponding check plants in the number of perfect hills stated*

Field row	Pedigree No.	Number of perfect hills	Yield (pounds) Check	Yield (pounds) Difference between check and cross [1]
1	2	3	4	5
No. 64d	10-3-1-1-2-2 × 2-2-2-4-4-1	6	3.79	[2] 2.40±
No. 52	10-3-1-2-2-3 × 7-4-2-1-1-2	71	4.25	2.31±0.24
No. 39	10-3-1-2-1-5 × 7-4-1-6-6-2	67	4.78	1.77± .24
No. 16	2-2-2-4-2-1 × 10-3-1-1-2-2	50	5.77	1.65± .30
No. 12	10-3-1-1-2-2 × 5-1-2-2-1-3	90	6.34	1.26± .21
No. 60	10-3-1-1-1-4 × 7-4-1-6-6-2	85	3.57	1.23± .21
No. 21	7-4-1-6-6-2 × 10-3-1-1-2-2	60	5.78	1.20± .27
No. 40	10-3-1-2-2-3 × 2-2-1-3-2-1	62	4.54	.94± .27
No. 23	10-3-1-1-2-2 × 5-1-2-3-2-2	87	5.18	.88± .21
No. 46	7-4-1-6-6-2 × 2-2-2-4-4-1	75	5.04	.86± .23
No. 14	10-3-1-2-2-3 × 2-2-2-4-4-1	93	6.08	.83± .21
No. 36	5-1-2-2-1-3 × 2-2-2-4-2-1	93	5.86	.72± .21
No. 11	10-3-1-1-1-4 × 5-1-3-3-1-2	89	5.66	.55± .21
No. 63	10-3-1-2-1-5 × 5-1-3-1-1-2	76	4.46	.54± .23
No. 33	10-3-1-1-1-4 × 5-1-3-1-1-2	90	5.36	.51± .21
No. 13	10-3-1-2-1-4 × 2-2-2-4-2-1	86	6.20	.51± .21
No. 32	7-4-1-6-6-2 × 10-3-2-1-3-3	84	5.84	.44± .23
No. 25	10-3-1-2-2-3 × 5-1-2-2-1-3	83	5.14	.43± .23
No. 59	10-3-2-1-3-3 × 7-4-1-Arlington [3]	37	4.53	.37± .35
No. 29	5-1-2-3-2-2 × 2-2-2-4-6-2	91	5.31	.32± .21
No. 65	10-3-1-2-1-5 × 5-1-3-3-1-2	70	4.24	.31± .24
No. 6	5-1-2-3-2-2 × 2-2-2-4-2-1	98	5.98	.27± .20
No. 73	7-4-1-6-6-2 × 5-1-2-2-1-3	35	6.71	.21± .35
No. 24	10-3-1-2-1-4 × 7-4-2-6-2-2	93	5.32	.20± .21
No. 9	7-4-1-6-6-2 × 2-2-1-3-2-1	80	5.90	.17± .23
No. 67	2-2-2-4-6-2 × 10-3-1-1-2-2	44	4.40	.17± .35
No. 1	2-2-1-3-2-1 × 5-1-2-2-1-3	78	6.66	.10± .23
No. 2	2-2-2-4-2-1 × 5-1-3-1-1-2	70	5.68	.03± .24
No. 53	10-3-2-1-2-1 × 2-2-2-4-6-2	75	3.71	.01± .23
No. 44	5-1-2-3-2-2 × 7-4-2-1-1-2	76	4.56	− .08± .23
No. 43	2-2-2-4-4-1 × 10-3-1-1-1-4	50	4.82	− .12± .30
No. 50	10-3-1-1-1-4 × 2-2-2-4-6-2	78	4.12	− .12± .23
No. 22	7-4-2-6-2-2 × 5-1-2-2-1-3	88	5.51	− .14± .21
No. 64a	2-2-2-4-4-1 × 10-3-2-1-2-1	4	4.17	− .17±
No. 68	5-1-2-2-1-3 × 10-3-1-1-1-4	47	4.91	− .32± .30
No. 26	2-2-1-3-2-1 × 7-4-2-1-1-2	60	5.36	− .35± .27
No. 61	10-3-2-1-3-3 × 5-1-2-3-2-2	59	3.98	− .44± .27
No. 27	2-2-2-4-4-1 × 7-4-2-1-1-2	84	5.41	− .45± .23
No. 20	5-1-3-3-1-2 × 7-4-1-6-6-2	82	6.72	− .49± .23
No. 51	10-3-1-1-2-2 × 2-2-1-3-2-1	27	4.17	− .49± .42
No. 49	7-4-2-6-2-2 × 10-3-1-1-2-2	50	4.37	− .51± .30
No. 47	7-4-1-7-4-1 × 5-1-3-3-1-2	77	5.18	− .53± .23
No. 37	5-1-3-1-1-2 × 10-3-1-2-2-3	81	5.68	− .54± .23
No. 55	7-4-1-6-6-2 × 10-3-1-2-2-3	49	4.88	− .54± .30
No. 42	2-2-1-3-2-1 × 7-4-1-7-4-1	35	6.29	− .55± .35
No. 30	5-1-3-1-1-2 × 10-3-2-1-3-3	93	5.74	− .63± .21
No. 41	10-3-2-1-2-1 × 5-1-3-3-1-2	45	5.49	− .64± .30
No. 10	7-4-2-6-2-2 × 2-2-2-4-4-1	86	5.81	− .66± .21
No. 45	5-1-3-3-1-2 × 10-3-1-1-2-2	70	4.87	− .66± .24
No. 74	10-3-1-2-1-4 × 2-2-2-4-6-3	50	6.12	− .69± .30
No. 57	10-3-1-1-1-4 × 7-4-2-6-2-2	90	4.93	− .83± .21
No. 62	7-4-1-7-4-1 × 5-1-3-1-1-2	70	4.75	− .90± .24
No. 31	5-1-3-3-1-2 × 7-4-2-6-2-2	82	5.31	−1.02± .23
No. 56	7-4-1-7-4-1 × 2-2-2-4-6-2	92	4.81	−1.05± .21
No. 19	5-1-3-1-1-2 × 2-2-2-4-4-1	84	5.45	−1.09± .23
No. 72	5-1-3-3-1-2 × 10-3-1-2-2-3	14	4.98	−1.13± .60
No. 69	10-3-2-1-2-1 × 5-1-3-1-1-2	55	4.98	−1.17± .27
No. 48	7-4-2-1-1-2 × 5-1-3-1-1-2	25	5.60	[2] −1.18±
No. 64b	5-1-3-1-1-2 × 7-4-1-6-6-2	16	4.93	−1.21± .60
No 5	5-1-2-2-1-3 × 7-4-1-7-4-1	105	6.19	−1.30± .19
No. 34	5-1-2-3-2-2 × 7-4-1-7-4-1	92	5.54	−1.36± .21
No. 38	5-1-3-3-1-2 × 10-3-2-1-3-3	43	5.81	−1.38± .35
No. 70	2-2-1-3-2-1 × 10-3-1-1-1-4	15	5.76	−1.45± .60
No. 7	5-1-3-1-1-2 × 2-2-1-3-2-1	89	5.86	−1.49± .21
No. 28	2-2-2-4-6-2 × 10-3-2-1-3-3	81	5.87	−1.50± .23
No. 18	2-2-2-4-6-2 × 5-1-3-3-1-2	79	5.79	−1.63± .23

[1] Positive values are excess yields of the cross over the check; negative values are excess yields of the check over the cross.
[2] The drying samples for these crosses were lost. The differences between the harvest weights, multiplied by 0.8, are shown for approximation.
[3] Pollen from plants of 7-4-1-? grown at Arlington Experiment Farm.

TABLE 6.—*Relative productiveness of crosses between self-fertilized lines of corn as differences in yield per 10 plants over or under the yield of the corresponding check plants in the number of perfect hills stated*—Continued

Field row	Pedigree No.	Number of perfect hills	Yield (pounds)	
			Check	Difference between check and cross
1	2	3	4	5
No. 71	2-2-2-4-6-2 × 7-4-2-6-2-2	48	6.06	−1.63±0.30
No. 35	2-2-1-3-2-1 × 5-1-2-3-2-2	81	6.08	−1.64± .23
No. 66	2-2-2-4-2-1 × 7-4-2-6-2-2	9	4.21	−1.66±....
No. 4	2-2-2-4-6-2 × 5-1-3-1-1-2	103	5.97	−1.67± .20
No. 17	2-2-2-4-4-1 × 5-1-2-3-2-2	44	5.91	−1.75± .35
No. 3	2-2-2-4-4-1 × 5-1-2-2-1-3	19	6.94	−2.38± .60
No. 64c	7-4-1-7-4-1 × 10-3-2-1-2-1	20	6.67	−2.38± .60
No. 8	5-1-3-3-1-2 × 2-2-1-3-2-1	54	6.76	−2.95± .30
No. 54	10-3-2-1-3-3 × 5-1-2-2-1-3	18	5.99	−5.52± .60
No. 15	10-3-2-1-3-3 × 2-2-2-4-4-1	70	7.23	−5.67± .24
No. 58	10-3-2-1-2-1 × 2-2-2-4-2-1	30	6.82	−6.46± .42

The average yields of the checks are shown in column 4. The average difference between the yield of each cross and its corresponding check, together with the probable error of the difference, is shown in column 5. Yields of crosses lower than the check are indicated by a minus sign (−). The data are in pounds of air-dry shelled corn per 10 plants. A perfect stand would have been about 7,000 plants per acre. The values shown multiplied by 12.5 give an approximate acre difference in bushels with the same plant yields under perfect stand conditions.

The data on the crosses grown in field rows Nos. 15, 54, and 58 are included only for completeness. Their behavior was so much like that of the self-fertilized lines of their pistillate parents that experimental error is suggested as a possible explanation. In any event the behavior of these crosses clearly is outside the range of normal behavior of the crosses as a whole. Except as shown in Tables 6 and 7, therefore, these crosses will not be considered as having been in the experiment.

The probable errors shown for the mean of n comparisons were obtained by dividing the generalized probable error of ±0.60 pound for a difference in any single comparison in the experiment by $\sqrt{n-1}$. The generalized probable error was determined from the data on the 62 crosses for which there were four or more replications. The difference between the yield of a cross and its check in each replication and the mean of these differences were determined. The deviations of the differences in the individual replicates from their respective means then were obtained. The 470 deviations so obtained were used to compute the probable error of any single difference. This is similar to the method described by Hayes (*2*), differing chiefly in that the actual deviations were used rather than the percentage deviations.[3]

[3] The distribution of the 470 deviations within classes limited by multiples of the probable error, together with the expected theoretical distribution, is—

Number of deviations	Multiples of probable error				
	±E	±2E	±3E	±4E	±5E
Observed	236.0	383.0	449.0	465.0	470.0
Expected	235.0	386.7	449.8	466.7	469.7

That competition may have an important effect in comparisons under the hill-checking method has been shown (*4*). This effect unquestionably is a disturbing factor in experiments in which an attempt is being made to establish absolute differences in productiveness. In experiments like the present, however, competition may be helpful in accentuating small differences. It was partly with this in mind that the hill-checking method was used. Under the conditions of the experiment there was little apparent effect except toward the lower limits of productiveness of the crosses. Omitting the data on the four comparisons for which no probable errors are shown and the three in which the yields of the crosses were so low as to be clearly beyond the normal range of the crosses as a whole, 70 comparisons remain. The average yield of the checks in these comparisons is 5.39 pounds, and the correlation between the yield of a check and the excess yield of a cross is -0.34 ± 0.07. If the 14 comparisons in which the crosses yielded from 1.30 to 2.95 pounds less than the checks also are omitted, the correlation between the yield of a check and the excess yield of a cross disappears, being only 0.001 ± 0.09.

The chief interest of this study lies in the value of the individual lines and strains for making productive combinations. This is shown more clearly in Table 7, in which the yields of the crosses above or below the checks are arranged to show the strain tendencies. The individuality of certain lines in combination is very evident. Thus, crosses of three of the lines of 5–1– with 2–2–2–4–2–1 are slightly superior to the check, whereas the same lines crossed with 2–2–2–4–4–1 give decidedly inferior yields. Similarly, 7 of the 10 crosses involving 7–4–1–6–6–2 yielded more than the check, whereas all of the 7 crosses involving 7–4–1–7–4–1 yielded less than the check. The lines of the 10–3–1– strain are the outstanding ones of the experiment. The crosses involving these lines have a higher mode and higher mean productiveness than any other group. The 10–3–1– lines also have a wider range of compatibility, producing one or more high-yielding crosses when combined with each line of the other strains.

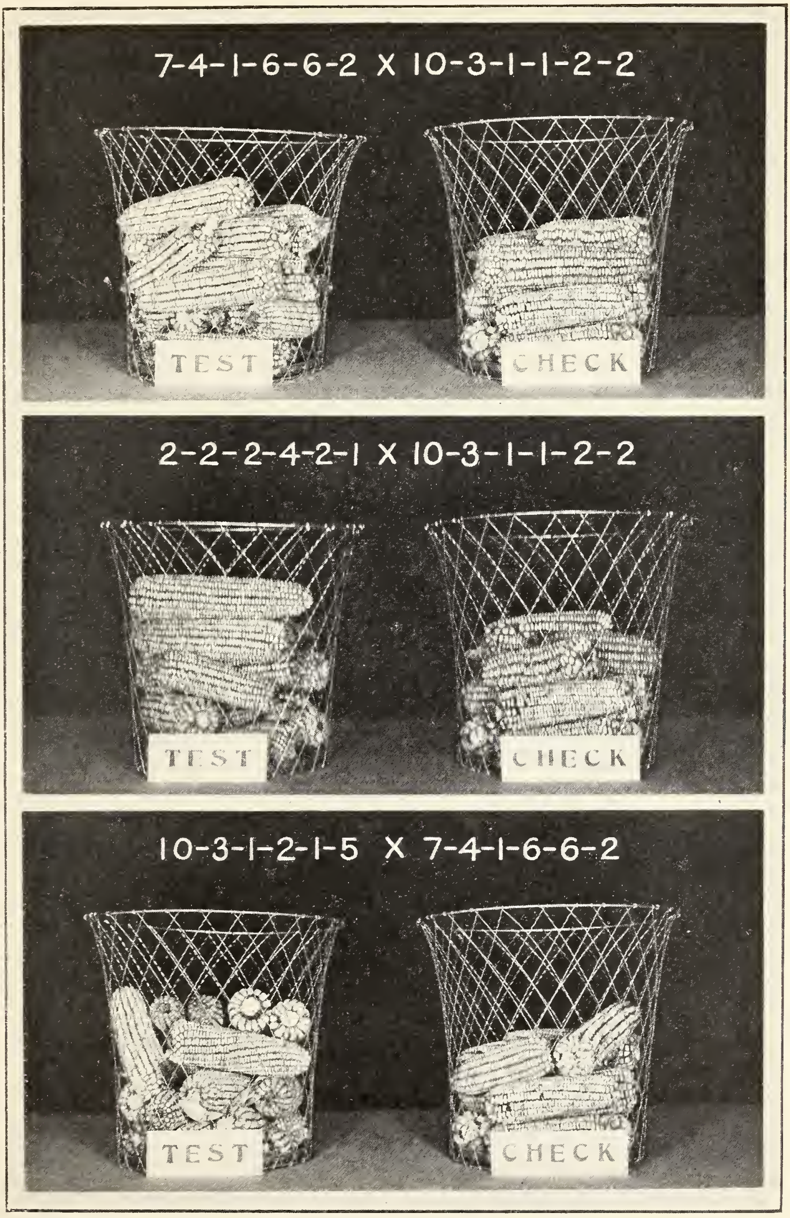
TABLE 7.—*Average yield of crosses between self-fertilized lines of corn above or below the yield of the corresponding check, arranged to show the tendencies within lines and strains*

[Data in pounds, showing the difference in yields from 10 hills]

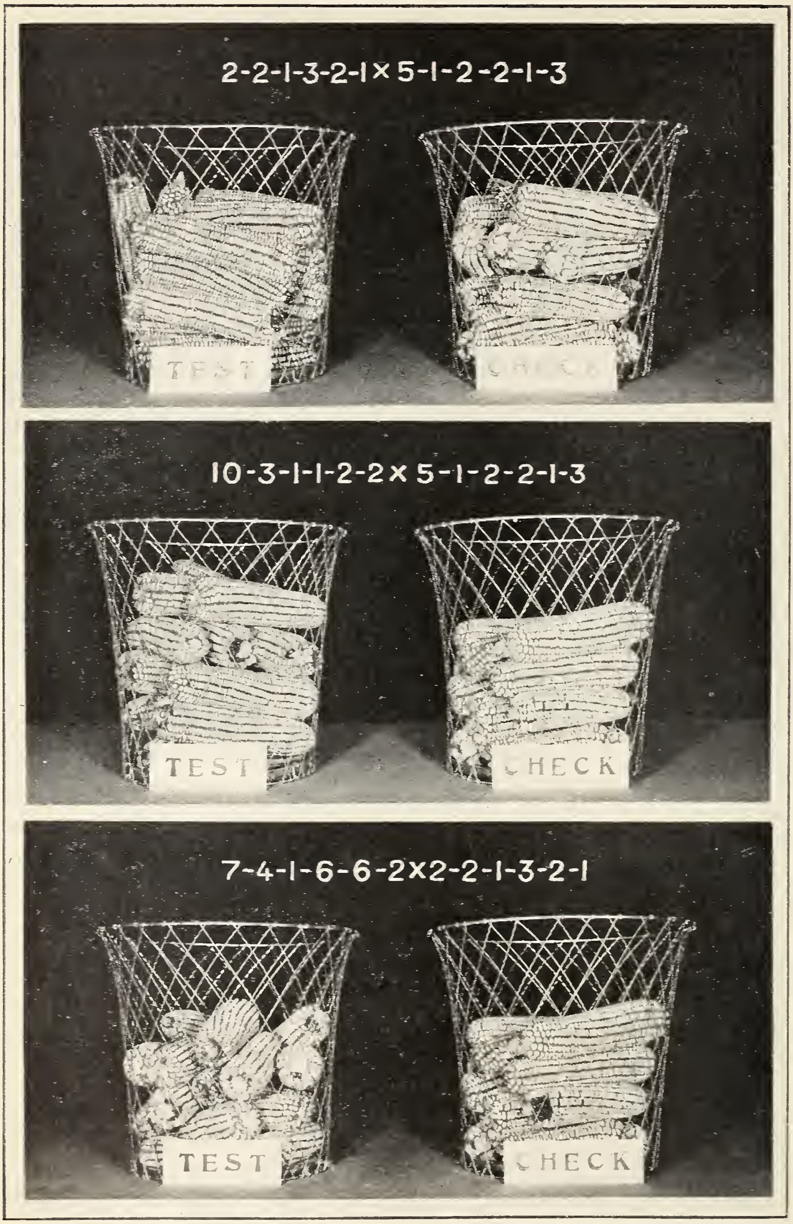
Parent lines	2–2–1–3–2–1	2–2–2–4–2–1	2–2–2–4–4–1	2–2–2–4–6–2, or –3	5–1–2–2–1–3	5–1–2–3–2–2	5–1–3–1–1–2	5–1–3–3–1–2	7–4–1–6–6–2	7–4–1–7–4–1	7–4–2–1–1–2	7–4–2–6–2–2
5–1–2–2–1–3	+0.10	+0.72	−2.38									
5–1–2–3–2–2	−1.64	+.27	−1.75	+0.32								
5–1–3–1–1–2	−1.49	+.03	−1.09	−1.67								
5–1–3–3–1–2	−2.95			−1.63								
7–4–1–6–6–2	+.17		+.86		+0.21		−1.21	−0.49				
7–4–1–7–4–1	−.55			−1.05	−1.30	−1.36	−.90	−.53				
7–4–2–1–1–2	−.35		−.45			−.08	[1] −1.18					
7–4–2–6–2–2		−1.66	−.66	−1.63	−.14			−1.02				
10–3–1–1–1–4	−1.45		−.12	−.12	−.32		+.51	+.55	+1.23			−0.83
10–3–1–1–2–2	−.49	+1.65	[1] +2.40	+.17	+1.26	+.88		−.66	+1.20			−.51
10–3–1–2–1–4, or 5		+.51		−.69			+.54	+.31	+1.77			+.20
10–3–1–2–2–3	+.94		+.83		+.43		−.54	−1.13	−.54		+2.31	
10–3–2–1–2–1		−6.46	−.17	+.01			−1.17	−.64		−2.38		
10–3–2–1–3–3			−5.67	−1.50	−5.52	−.44	−.63	−1.38	+.44	[2] +.37		

[1] Estimated dry weight.

[2] 10–3–2–1–3–3×7–4–1–Arlington.



THE EARS PRODUCED BY 20 PLANTS FROM EACH OF THE CROSSES BETWEEN SELF-FERTILIZED LINES INDICATED BY THE PEDIGREES AND FROM THE CORRESPONDING 20 CHECK PLANTS OF OPEN-FERTILIZED NO. 201 CORN—A



THE EARS PRODUCED BY 20 PLANTS FROM EACH OF THE CROSSES BETWEEN SELF-FERTILIZED LINES INDICATED BY THE PEDIGREES AND FROM THE CORRESPONDING 20 CHECK PLANTS OF OPEN-FERTILIZED No. 201 CORN—B

It should be possible to eliminate from further experiments many of the lines used, thus reducing the number of crosses to be compared in determining the most productive single and double crosses. It should also be possible to select certain lines for crossing with a reasonable assurance that the combinations will be materially more productive than the open-fertilized variety. Thus, 2–2–1–3–2–1, 2–2–2–4–6–2, both of the 5–1–3– lines, 7–4–1–7–4–1, 7–4–2–6–2–2, and both of the 10–3–2– lines may be eliminated without any apparent danger of serious loss. The 36 crosses necessary to obtain all desired combinations between the remaining 10 lines then can be compared with greater accuracy. At the same time combinations between crosses may be obtained to determine the better double crosses.

DISCUSSION

Omitting from consideration the cross grown in field row 64d because of the few plants, the average yield of the first six crosses listed in Table 6 exceeded that of their checks by 1.57 pounds, or 30 per cent. That all of these crosses involved a line of the 10–3–1– strain and that three of them were between 7–4–1–6–6–2 and a 10–3–1– line is excellent evidence that the superior productiveness of these particular crosses was not due to chance. There can be no question, then, that significantly larger yields have been obtained by the methods followed. Whether larger yields can be obtained practically remains to be proved by further experiments, although indirect evidence indicates that they can.

The strain cross 10–3–×7–4– yielded about 6 per cent more than No. 201, F_6, in the 1921 experiments (*6*). The F_1 of the varietal cross, Whatley×St. Charles White, yielded about 9 per cent more than No. 201, F_6, or about 3 per cent more than 10–3–×7–4– in the same experiments. Other strain crosses yielded slightly more than 10–3–×7–4–, but none were significantly more productive than Whatley×St. Charles White, from which No. 201 originated. On the basis of these results it was concluded that "So far there has been no advantage in yield from the laborious methods of hand-pollinating over what could have been obtained by growing the F_1 varietal cross each year" (*6*, p. 19).

The average yield of the 11 crosses between lines of the 7–4– and 10–3– strains again was about 6 per cent more than No. 201 in the 1923 experiments. This average superiority, however, was composed of individual yields, some superior by much more than 6 per cent, together with others that were inferior to the variety. The average yield of the three better crosses between 7–4–1–6–6–2 and lines of 10–3–1– was 1.40 pounds, or 30 per cent, more than the yield of No. 201 in the corresponding checks. On the basis of the 9 per cent superiority of the Whatley×St. Charles, F_1, over the Delta Prolific, as previously reported (*6*), this is an indicated superiority of 21 per cent for these three crosses over the F_1 varietal cross. It is recognized clearly that such a detailed conclusion is unwarranted on the basis of data from two experiments differing in time, space, and method. The results of the experiments in 1921 and 1923 are consistent, however, and the indicated difference is large. The more general conclusion that some of the crosses produced significantly larger yields in 1923 than could have been obtained from the F_1

varietal cross, Whatley×St. Charles White, therefore seems entirely justified.

Whether particular crosses can be relied upon to give larger yields year after year remains to be determined. The higher yields of crosses involving 10–3– in 1921 and 1923, the consistency with which crosses involving 7–4–1–6–6–2 were superior, and all of the other evidences of individuality among the self-fertilized lines and of crosses between them indicate that the large yields of certain crosses were not due to chance. The lines had been self-fertilized six generations and were reasonably uniform when the crosses compared in 1923 were made. The experiments of Jones (*3*) suggest that these lines will remain fairly constant from now on, except as germinal changes of one kind or another may occur. Even such changes should interfere little with maintaining the lines sufficiently constant for practical purposes.

The data presented offer a number of points of interest besides the question of the possibility of obtaining larger yields from crosses between self-fertilized lines. The erratic yields of the lines in the comparison of successive generations give an excellent idea of what to expect during the earlier generations of self-fertilization in such an experiment. Lines are isolated occasionally that apparently breed true almost from the beginning. The 12–1–1– and 12–2–2– lines afford a good example of this condition. Segregating following the second selfed generation, these lines have remained consistently different through what is now the eighth generation of self-fertilization. Other lines become constant more slowly, offering greater opportunity for selection.

There is abundant evidence in the data of Table 3 that selection can be effective in obtaining lines more productive than the average of the generation; in fact, when the small number of lines involved in these experiments is considered, there seems to be every reason to expect that self-fertilized lines can be obtained that will be productive enough to obviate the need for utilizing double crosses for commercial planting. An even better example of the effects of selection is afforded by the 10–3– strain. Little difference was apparent between the rows grown from 10–3–1–1–, from 10–3–1–2–, and from 10–3–2–1– in the breeding plat in 1921. Selection since then has resulted in isolating reasonably fair lines of 10–3–1–2–, one of which is shown in Plate IV. Lines of the 10–3–1–1– strain have been obtained that are uniformly as good as the best plants shown in this illustration. The 10–3–2– lines, on the other hand, became steadily poorer until they can be propagated now only with great difficulty (Pl. V).

The data from the comparison of crosses made following different numbers of generations of self-fertilization indicate no general advantage for crosses made following five generations over analogous crosses made after three generations of self-fertilization. This suggests that there is little inherent relation between the yield of a cross and the number of generations that its parent lines had been self-fertilized before crossing. In other words, self-fertilization appears to be a means of obtaining definite entities from which specific high-yielding combinations can be selected rather than a direct cause of these high yields.

The lack of any definite correlation between the yields of the parent lines and their crosses indicates that selection for crossing must be based finally on the performance of the lines in combination rather than in the self-fertilized condition. Obviously, however, it is necessary for practical reasons to have lines that are productive in themselves. There is nothing in these experiments to indicate that just as high-yielding crosses can not be obtained from lines which are themselves productive as can be had from self-fertilized lines that are low yielding and undesirable.

Considering the investigation as a whole, the data indicate that significantly larger yields of corn can be obtained from F_1 crosses between self-fertilized lines. Much attention heretofore has been focused upon what might be expected when corn was self-fertilized continuously with a minimum of selection. This was natural and desirable. The newer systems of corn breeding are distinguished chiefly in the utilization of inbreeding, which was carefully avoided in the older systems. The attention that has been devoted to the expectations under self-fertilization without selection seems to have been unfortunate also in some respects. It has tended to emphasize the importance of self-fertilization to such an extent as to minimize the importance of selection. The present data suggest that the increased yields of the crosses are due to selection rather than self-fertilization, the function of the latter being principally to obtain definite entities from among which to select. Finally, although it is desirable for practical reasons to have self-fertilized lines which are as productive as may be, the present investigation indicates that the final selection of lines for use in crosses must be based upon their performance in crosses.

SUMMARY

The yield of 70 F_1 crosses between lines of corn self-fertilized for six generations before crossing ranged from considerably less to considerably more than the yield of the parent variety.

The average yield of three of these crosses was 30 per cent more than that of the parent variety, and the consistency of the data showed clearly that this superiority was not due to chance.

This 30 per cent increased yield indicates that these crosses are significantly more productive than the F_1 varietal cross Whatley × St. Charles White, which has been outstanding in a number of varietal comparisons in northeastern Arkansas.

Comparisons between successive generations of self-fertilized lines and between crosses following self-fertilization for different numbers of generations show the importance of selection in obtaining larger yields by the methods followed and indicate that the principal rôle of self-fertilization is to isolate definite lines differing from each other among which selection may be practiced.

It is necessary for practical reasons to have inbred lines that are productive in themselves. The data indicate, however, that there is little or no relation between the productiveness of the self-fertilized lines and that of their crosses and that the final value of the lines for crossing must be determined by comparisons of the productiveness of their crosses.

LITERATURE CITED

(1) ANONYMOUS.
1924. Growers of Arkansas pure bred farm seeds inspected and certified [by] Arkansas Seed Growers' Association cooperating with Arkansas College of Agriculture. 6 pp. Fayetteville, Ark.

(2) HAYES, H. K.
1923. Controlling experimental error in nursery trials. *In* Jour. Amer. Soc. Agron., vol. 15, pp. 177–192.

(3) JONES, D. F.
1924. The attainment of homozygosity in inbred strains of maize. *In* Genetics, vol. 9, pp. 405–418, illus.

(4) KIESSELBACH, T. A.
1918. Studies concerning the elimination of experimental error in comparative crop tests. Nebr. Agr. Exp. Sta. Research Bul. 13, 95 pp., illus.

(5) KYLE, C. H.
1910. Directions to cooperative corn breeders. U. S. Dept. Agr., Bur. Plant Indus. [Doc.] 564, 10 pp., illus.

(6) RICHEY, F. D.
1924. Effects of selection on the yield of a cross between varieties of corn. U. S. Dept. Agr. Bul. 1209, 20 pp., illus.

ORGANIZATION OF THE UNITED STATES DEPARTMENT OF AGRICULTURE

October 19, 1925

Secretary of Agriculture	W. M. Jardine.
Assistant Secretary	R. W. Dunlap.
Director of Scientific Work	———
Director of Regulatory Work	Walter G. Campbell.
Director of Extension Work	C. W. Warburton.
Director of Information	Nelson Antrim Crawford.
Director of Personnel and Business Administration	W. W. Stockberger.
Solicitor	R. W. Williams.
Weather Bureau	Charles F. Marvin, *Chief.*
Bureau of Agricultural Economics	Thomas P. Cooper, *Chief.*
Bureau of Animal Industry	John R. Mohler, *Chief.*
Bureau of Plant Industry	William A. Taylor, *Chief.*
Forest Service	W. B. Greeley, *Chief.*
Bureau of Chemistry	C. A. Browne, *Chief.*
Bureau of Soils	Milton Whitney, *Chief.*
Bureau of Entomology	L. O. Howard, *Chief.*
Bureau of Biological Survey	E. W. Nelson, *Chief.*
Bureau of Public Roads	Thomas H. MacDonald, *Chief.*
Bureau of Home Economics	Louise Stanley, *Chief.*
Bureau of Dairying	C. W. Larson, *Chief.*
Fixed Nitrogen Research Laboratory	F. G. Cottrell, *Director.*
Office of Experiment Stations	E. W. Allen, *Chief.*
Office of Cooperative Extension Work	C. B. Smith, *Chief.*
Library	Claribel R. Barnett, *Librarian.*
Federal Horticultural Board	C. L. Marlatt, *Chairman.*
Insecticide and Fungicide Board	J. K. Haywood, *Chairman.*
Packers and Stockyards Administration	John T. Caine, *In Charge.*
Grain Futures Administration	J. W. T. Duvel, *In Charge.*

This bulletin is a contribution from

Bureau of Plant Industry	William A. Taylor, *Chief.*
Office of Cereal Investigations	Carleton R. Ball, *Senior Agronomist in Charge.*

ADDITIONAL COPIES
OF THIS PUBLICATION MAY BE PROCURED FROM
THE SUPERINTENDENT OF DOCUMENTS
GOVERNMENT PRINTING OFFICE
WASHINGTON, D. C.
AT
10 CENTS PER COPY
▽