ASSOCIATIONS BETWEEN NUMBER OF KERNEL ROWS, PRODUCTIVENESS, AND DELETERIOUS CHARACTERS IN CORN[1]

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INTRODUCTION

Two different methods of selecting seed corn have been used for many years in the southern part of the United States. Under one of them, seed has been selected from plants bearing two or more ears; under the other, seed has been selected on the basis of the size of the ear. As a result, two classes of varieties, prolific and nonprolific, are now in common use. In general, the prolific varieties bear more than one ear on a plant, whereas the nonprolific varieties bear only one. The ears in the prolific varieties are smaller, and it would seem that the yields of the two might be equal, the differences in size and in number of ears offsetting each other. Experiments with comparable varieties have shown otherwise. Studies of the ears in prolific and nonprolific varieties showed that there were characteristic differences between them in the number of rows of kernels on the ear and in the size and angularity of the kernels.

The effect of differences in these characters upon yield has been investigated, using groups of ears within both prolific and nonprolific varieties and within a number of F_1 varietal crosses. The relation of the number of rows of kernels to smut resistance, to freedom from abnormalities, and to general vigor and productiveness also has been studied in self-fertilized lines. It is the object of this paper to present the data from these experiments and to discuss their application to corn improvement.

EXPERIMENTAL METHODS

The soil and climatic conditions where the experiments were made usually gave yields of 30 to 50 bushels of corn per acre with a good local variety. The different varieties or selections compared required practically the same time to mature, which was well within the seasonal limits.

From 20 to 50 ears were used to represent each variety or selection. Seed ears were selected in the studies on number of rows, etc., that differed in the character being studied but that were as nearly alike in other respects as the material permitted. All of the seed used was examined closely, and defective or irregular kernels were eliminated before planting.

Specially constructed hand planters were used with which an exact number of kernels could be planted at a given place and covered uniformly. The hills were spaced 3 feet apart in the row, center to center, by means of a metal spacing cable. The number of plants per acre was adjusted in accordance with soil productiveness by regulating the space between the rows.

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The hill-checking method was used in all comparisons—that is, one test plant and one check plant were grown in each hill. These two plants were 8 to 10 inches apart in the rows, and always in the same order so that they could be identified. The seed for the test plants in any one row was of one of the varieties or selections being compared. The seed for the check plants was composited by taking a definite number of kernels from a definite number of ears and was the same for all of the rows in the experiment.

In general, two kernels were planted where one plant was desired, the extra seedlings being removed when they were from 4 to 8 inches high. This partly eliminated irregularity in stand. The effect of the remaining irregularity in stand, as well as the effect of soil variation, was avoided by harvesting only perfect hills. A perfect hill was defined as one containing a check plant and a test plant that could be identified definitely and that apparently had had equal growing conditions.

Each variety or selection in an experiment was grown in single rows replicated in different parts of the plat. The perfect hills in these rows were harvested, and the production of the test plants and of the check plants was determined for each row. The weight of ears from the test plants in all rows of one variety or strain in the experiment, divided by the weight of ears from the corresponding check plants, expressed as a percentage, constitutes a relative yield as here used. It is believed that the reliability of results obtained by the hill-checking method is proportional in general to the total number of perfect hills grown. Accordingly, the number of perfect hills on which the relative yields are based is given in the data.

In the varietal experiment in 1912 moisture determinations were made on the shelled grain, and these are given in the data, but no corrections were made in the yields. In most of the experiments the ears were uniformly dry at harvest, or, if not, corrections were made on the basis of data from drying samples.

VARIETAL EXPERIMENTS

EXPERIMENTS IN SOUTH CAROLINA IN 1912

The varietal experiments in South Carolina in 1912 were conducted on 10 farms in different parts of the State. Ten varieties, each of which had been grown previously on one of these farms for three or four years, were used throughout the experiments. One hill-checked row of each of the 10 varieties constituted a section which was replicated 10 times, each of the varieties being used as the check in one section.

The total yield of all the plants of a variety in the experiment was divided by the total yield of all the plants grown in the same perfect hills with it to obtain its relative yield. Computed in this way, the relative yields are percentages of the average yield of all the varieties in the experiment.

The experiment was destroyed by storm and flood on one farm. Two varieties were found to be somewhat earlier than the others, and their yields are not presented. This leaves the yields obtained on 9 farms from 8 varieties, 4 prolific and 4 nonprolific, as a basis for comparison. It was evident that these widely distributed farms represented different growing conditions, so that the combined data from them may be looked upon as representing the average reaction of these varieties to nine different cropping seasons.

A summary of the data from these experiments is shown in Table I, those from the prolific and nonprolific varieties being grouped separately. The prolific varieties averaged more than one ear per plant, and the nonprolific averaged less than one ear. It is evident from the data that the nonprolific varieties must have had a considerable proportion of barren plants. The average relative yield of the prolific varieties was 9 per cent greater than that of the nonprolific, notwithstanding the fact that the ears contained less moisture [2] at the time the weights were taken. The most prolific variety in the experiment also was the most productive, and all of the prolific varieties were more productive than any one of the nonprolific except variety No. 5.

TABLE I.—*Relative percentage yields of prolific and nonprolific varieties on nine farms in different parts of South Carolina in 1912*

Prolific varieties					Nonprolific varieties				
Variety No.	Perfect hills	Relative yield	Moisture	Ears per plant	Variety No.	Perfect hills	Relative yield	Moisture	Ears per plant
		Per cent	*Per cent*				*Per cent*	*Per cent*	
7	5,933	119	16.20	1.45	5	5,963	115	17.65	0.95
4	5,714	113	16.29	1.29	2	5,528	100	17.97	.92
3	5,938	109	16.04	1.12	1	5,818	93	17.03	.97
8	5,941	106	15.81	1.28	10	6,052	88	17.70	.85
Total	23,526	[a]112	----------	[a]1.28	-----	23,361	[a]103	----------	[a].92

[a] Computed directly from the basic data.

EXPERIMENTS IN GEORGIA IN 1915

Varietal experiments were conducted on each of four farms near Thomasville, Ga., in 1915. The growing conditions on each farm were different, and the results may be considered as the average reaction from four cropping seasons.

In planning these experiments it was the intention to include all of the varieties with outstanding characteristics that are commonly grown under climatic conditions similar to those under which the experiments were conducted. Twelve of the thirteen varieties included were studied carefully on the farms from which they were obtained in the fall of 1914, and the seed ears for planting were characteristic of the varieties. A summary of the data from these experiments is shown in Table II, the prolific and nonprolific varieties being grouped separately.

As a class, the prolific varieties had larger yields, more ears per plant, smaller percentages of barren plants, smaller ears per productive plant, and fewer rows of kernels per ear, than did the nonprolific varieties.

[2] The moisture determinations were made from samples of shelled grain taken from each plat. They do not take into consideration the moisture in the cobs. As the yields are based on the weight of ear corn, no attempt was made to correct for differences in moisture.

TABLE II.—*Relative percentage yields of prolific and nonprolific varieties on four farms near Thomasville, Ga., in 1915*

Variety	Perfect hills	Relative yield	Ears per plant	Length of total ears per bearing plant (A)	Average diameter of ears (B)	Yield index (A×B²)	Barren plants	Kernel rows per ear
		Per cent		*Inches*	*Inches*		*Per cent*	
Prolific varieties:								
Garrick	495	146	1.32	7.9	1.9	28.5	4.8	11.61
Wannamaker	476	142	1.20	7.9	1.9	28.5	5.5	12.41
Weekley	482	130	1.25	7.2	1.8	23.3	6.2	12.84
Whaley	408	126	1.29	7.4	1.8	24.0	6.1	12.64
Whatley	467	124	1.59	6.3	1.8	20.4	5.1	13.38
Round	472	103	1.34	7.3	1.6	18.7	8.9	11.44
Littlecob	308	86	1.29	7.8	1.5	17.6	7.1	10.18
Total or average	3,108	[a] 124	1.33	7.4	1.8	23.0	[a] 6.2	12.07
Nonprolific varieties:								
Loveless	462	110	.86	8.4	1.9	30.3	9.7	13.62
Watson	448	107	.98	7.8	1.9	28.2	14.1	13.60
Stone	327	98	.88	8.0	1.9	28.9	14.7	13.96
Cochran	464	87	.91	7.5	1.8	24.3	16.8	13.68
Gwaltney	395	87	.90	7.2	2.0	28.8	14.7	12.64
Laguna	390	69	.91	7.3	2.1	32.2	15.5	14.69
Total or average	2,486	[a] 93	.91	7.7	1.9	28.8	[a] 14.1	13.70

[a] Computed directly from basic data.

The data in column 7 of Table II were obtained by multiplying the average length of total ears per bearing plant by the square of the average diameter of the ears. This gives an index of the volume of ear produced per bearing plant and consequently an index to the yield of the bearing plants. On the basis of the yield index the prolific varieties made their higher yield with a production per bearing plant that actually was less than that of the nonprolific varieties.

Assuming that selection aims to produce the largest individual plant yields, the breeders of the nonprolific varieties had evidently done more effective work than the breeders of the prolific varieties, if only the bearing plants are considered. For some reason, however, the returns were smaller. This was due to the fact that the nonprolific varieties had a disproportionate number of plants without grain. Each of the nonprolific varieties had a larger percentage of barren plants than any one of the prolific varieties, the average percentage of barren plants being 14.1 per cent for the nonprolific group and 6.2 per cent for the prolific group.

COMPARISONS WITHIN VARIETIES

In general, the ears in the nonprolific varieties in the preceding experiments had more kernel rows and more angular, tighter-fitting kernels than the ears in the prolific varieties. In order to study the relation of such differences to yield, a series of experiments was begun in 1914. In all of these experiments, groups of ears were selected that differed in one or more characters of the ears or kernels. The relative productiveness of these groups was then determined.

Many experiments have been conducted on the relation between yield and the different characters of seed ears. The results of these were summarized by Richey[3] in 1922 as follows:

[3] RICHEY, F. D. THE EXPERIMENTAL BASIS FOR THE PRESENT STATUS OF CORN BREEDING. Jour. Amer. Soc. Agron. 14:4. 1922.

Inasmuch as these data are based on comparisons between ears all of which were suitable for seed, the preponderance of evidence in certain cases seems convincing in spite of the fact that the determining differences in yield are small. There is every indication that selection on the basis of production (weight of ear in this case) is of value. Likewise it is indicated that it is preferable to obtain production by adding to the length rather than to the circumference of the ears, and that smoother, fewer-rowed ears with a lower shelling percentage than the standard show type are inclined to be the better yielders.

Kiesselbach [4] stated in substance that in a six-year comparison the long, slender, smooth ears surpassed all other kinds, including the long, large, rough ears; the short, large, rough ears; the short, slender, smooth ears; and unclassified seed of Nebraska White Prize, the variety from which the selections were made. He does not state but shows in an illustration that the most productive type had markedly fewer rows than the ordinary Nebraska White Prize. He also shows in the same bulletin that hybrids producing smooth, few-rowed ears yielded more than hybrids producing ears with a larger number of rows and rougher kernels.

Several experiments were conducted at different points in South Carolina and Florida. The performances of groups of ears differing in the number of rows of kernels were compared at Lykesland, S. C., in 1914, 1916, and 1917; at Brooksville, Fla., in 1917; and at Darlington, S. C., in 1915 and 1916. In the experiments at Lykesland the ears with different numbers of rows were classified further on the basis of angularity of kernel in 1914 and on the basis of kernel size in 1916. Additional studies of the relation of angularity of kernel to yield were made within a variety at Lykesland in 1914 and 1915, and at Darlington in 1915, and within two series of varietal crosses at Darlington in 1914. Summaries of the data from these experiments are given in Tables III, IV, V, VI, and VII.

NUMBER OF KERNEL ROWS AND YIELD

Data on the relation of number of kernel rows to yield in the Roger and Williamson varieties are shown in Table III. These are typical nonprolific varieties, the ears being rough, with comparatively many kernel rows and tightly spaced angular kernels. Three groups of ears in each variety were compared in 1915, and six groups in the Roger variety were compared in 1916.

TABLE III.—*Data on the relation of the number of kernel rows to yield in the Roger and Williamson varieties at Darlington, S. C., in 1915 and 1916*

Points considered	1915						1916					
	Williamson			Roger			Roger					
Number of rows on seed ears	12 and 14	16 and 18	20	12	14 and 16	18	10	12	14	16	18	20
Number of perfect hills grown	602	506	530	462	414	453	730	751	763	778	727	700
Relative yields	108	107	97	106	94	88	98	100	105	96	94	95

The yields were inversely proportional to the number of kernel rows in both varieties in 1915. The highest yield in 1916 was from

[4] KIESSELBACH, T. A. CORN INVESTIGATIONS Nebr. Agr. Exp. Sta. Research Bul. 20, 151 p. 1922.

the ears with 14 rows, the modal number in the Roger variety. Each of the three few-rowed groups (10, 12, and 14 rows), however, yielded more than any one of the three many-rowed groups.

The data show a consistent relation between the number of rows on the seed ears and the yield produced from them, the ears with the lower number of rows yielding more as a class than those with the higher number of rows.

The Garrick variety was included in both the South Carolina and Georgia varietal experiments and was highest yielding in each. From the standpoint of selection, this variety is the most perfect product of the prolific ideal that was studied. It was learned by interview that Mr. Garrick had grown this corn at Weston, S. C., for about 30 years. His ideal had been the production of two or more ears per plant, and he had given no special attention to the character of the ears and kernels. Several thousand ears of this variety were studied on the home farm. The ears were large for the prolific class of corn, the kernels were intermediate between angular and rounded, and the characteristic numbers of rows of kernels on an ear were 10 and 12. The indentation was distinct and smooth to slightly rough.

Data on the relation of number of rows of kernels to yield in the Garrick variety are shown in Table IV. As different lots of ears were used in each experiment, eight distinct comparisons are shown. Ears with the fewest rows of kernels gave the highest yields in six comparisons, and ears with the most rows gave the lowest yields in seven comparisons. Ears with 12 rows of kernels yielded more than those with more than 12 rows, in all of the eight comparisons.

TABLE IV.—*Data on the relation of number of kernel rows, angularity of kernels, and weight of kernels in the parent ears to yield in the Garrick variety grown at different places and in different seasons*

Place and date of experiment, and character of kernel classes compared in 1914 and 1916	Relative yields from ears with stated number of kernel rows (per cent)						Perfect hills grown from ears with stated number of kernel rows						Weight of kernels (grams) per 1,000 from ears with the stated number of kernel rows			
	8	10	12	14	16	Average [a]	8	10	12	14	16	Total	10	12	14	Av.
Lykesland, S. C., 1914:																
Kernels angular	----	91	84	83	---	87	-----	317	291	295	----	903	----	----	----	----
Kernels intermediate	----	99	101	96	---	99	-----	319	295	292	----	906	----	----	----	----
Kernels rounded	----	89	93	84	---	88	-----	264	300	315	----	879	----	----	----	----
Total or average [a]	----	94	93	87	---	-----	-----	900	886	902	----	------	----	----	----	----
Lykesland, S. C., 1916:																
Kernels large	----	119	100	89	---	102	-----	606	619	657	----	1,882	466	418	374	419
Kernels midsized	----	101	92	86	---	93	-----	644	685	595	----	1,924	387	378	346	370
Kernels small	----	94	93	86	---	91	-----	715	602	671	----	1,988	355	334	324	338
Total or average [a]	----	104	95	87	---	----	-----	1,965	1,906	1,923	---	------	403	377	348	----
Lykesland, S. C., 1917	112	----	109	---	100	-----	1,085	-----	579	-----	572	------	----	----	----	----
Brooksville, Fla., 1917	104	101	100	94	95	-----	650	630	1,220	1,144	599	------	----	----	----	----

[a] Computed directly from the basic data.

Both in the prolific and the nonprolific varieties that were studied there was a strong general tendency for the ears with fewer rows of kernels to yield more than those with larger numbers of rows.

ANGULARITY OF KERNEL AND YIELD

One characteristic difference between the prolific and nonprolific varieties was in the shape of the kernels. The nonprolific varieties tended to have more angular kernels that are crowded more closely on the ear. This angularity probably is due, in part at least, to the greater lateral pressure during their development.

Data on the relation of angularity of kernel to yield in one experiment with the Garrick variety, in which the ears with rounded kernels yielded 9 per cent more than those with angular kernels, are shown in Table V.

TABLE V.—*Data on the relation of angularity of kernels on the seed ears to the number of kernel rows and to yield in the Garrick variety at Lykesland, S. C., in 1914*

Angularity of kernels on seed ears	Kernel rows on seed ears (average)	Perfect hills	Relative yields
			Per cent
Angular	13.2	1,542	93
Rounded [a]	10.8	1,735	102

[a] This class included kernels of both the intermediate and rounded classes of other experiments.

In 1913, one row of plants of each of 15 varieties was grown in a field of the Roger variety and detasseled before pollen was shed. A similar series was grown in a field of Garrick. The ears of the resulting crosses were grouped on the basis of angularity of kernel and these groups were compared, with the results shown in Table VI.

TABLE VI.—*Data on the relation of angularity of the kernels on the parent ears to yield in two series of varietal crosses at Darlington, S. C., in 1914*

Shape of kernels	15 varieties crossed by Roger			15 varieties crossed by Garrick		
	Rows on parent ears (average)	Perfect hills	Relative yields	Rows on parent ears (average)	Perfect hills	Relative yields
			Per cent			*Per cent*
Angular	16.1	1,882	105	14.8	1,919	119
Intermediate	12.9	1,848	110	12.9	1,934	123
Rounded	13.7	1,885	108	13.7	1,898	125

The number of plants of each female parent variety was so limited that the rounded-kernel class was poorly represented in some crosses.

The ears with angular kernels produced the lowest yields in both series of crosses. The ears with kernels of intermediate angularity produced the highest yields in the Roger crosses, whereas the ears with kernels of intermediate angularity produced more than the ears with angular and less than those with rounded kernels in the Garrick crosses.

In the preceding experiments the ears with angular kernels had more rows of kernels than those with rounded kernels. To avoid any possible effect of the number of kernel rows on yield, the classification for angularity also was made within groups of ears of the Garrick variety having the same number of rows of kernels. Data from these experiments are given in Tables IV and VII.

As the data in Table IV are for different lots of ears and those in Table VII are for the same lots of ears grown in different places, four distinct comparisons are provided in the two tables. The ears with kernels of intermediate angularity produced more than either of the extreme classes in all four comparisons. In two of the comparisons the ears with rounded kernels produced significantly more than those with angular kernels and in the other two comparisons the differences were negligible.

SIZE OF KERNEL AND YIELD

In connection with the experiments at Lykesland in 1916, the ears which had been classified for number of rows of kernels were grouped further into those with large, midsized, and small kernels. The data from this experiment are shown in Table IV.

TABLE VII.—*Data on the relation of weight and angularity of kernels on the parent ears to the yield of 12-rowed ears of the Garrick variety grown at Darlington and Lykesland, S. C., in 1915*

Shape of kernels	Weight per 1,000 kernels	Grown at Darlington, S. C.		Grown at Lykesland, S. C.	
		Perfect hills	Relative yields	Perfect hills	Relative yields
	Gm.		*Per cent*		*Per cent*
Angular	382	958	88	765	88
Midangular	399	905	99	798	102
Midrounded	397	3,852	102	3,330	102
Rounded	379	3,778	96	3,332	97

The yields tended to be directly proportional to the size of the kernels, and the yield of the ears having both the fewest rows and the largest kernels was very distinctly the highest. It will be noted in Table VII that the ears with midangular and midrounded kernels had heavier kernels than those of the extreme classes. The larger yields of these intermediate groups, therefore, may have been a result of their having heavier kernels, although this is not certain.

INTERRELATION OF NUMBER OF KERNEL ROWS, ANGULARITY OF KERNEL, AND SIZE OF KERNEL

It has been shown in connection with some of the preceding experiments that angularity of kernel is related to weight of kernel and that both of these characteristics are related to the number of rows of kernels on an ear. These interrelations probably are universal within a variety, and it is not possible to separate the effect of each individual factor in these experiments. Fortunately, however, this is not necessary from the present point of view, as it is necessary to know only that ears chosen within a variety to represent similar combinations of these characters react in a similar manner. Both in the varietal experiments and in the comparisons within varieties, the groups of ears with fewer rows of kernels and with less angular kernels have produced higher yields than those with more rows and more angular kernels

EXPERIMENTS WITH SELF-FERTILIZED LINES

Systematic selection within self-fertilized lines in several varieties has given comparatively quick results in the isolation of strains with distinct characteristics. In addition, it has afforded a view of some indirect effects of selection that could not be seen in the studies with open-fertilized material. Some of the results are given in the following pages.

EFFECT OF SELECTION UPON THE NUMBER OF ROWS OF KERNELS

Many plants of the Garrick variety were selfed in 1916 and good seed ears were selected from these to represent six classes with different numbers of kernel rows on an ear. These ranged from 8 to 18 rows, inclusive. These classes were maintained in the succeeding years by continuous selection. The effect of the selection during the first five years upon the percentage of progeny ears having the same number of kernel rows as the parent ear is shown in Table VIII.

TABLE VIII.—*Data on the effect of selecting continuously within selfed lines for different numbers of kernel rows, upon the percentages of the progeny conforming to the parental number of kernel rows*

Kind of data	Kernel rows on parent ears	Years in which the progeny were grown				
		1917	1918	1919	1920	1921
Number of parent ears	8	18	8	15	52	49
	10	24	8	19	64	69
	12	24	5	11	53	76
	14	21	4	10	52	76
	16	18	4	8	37	40
	18	3	4	2	15	16
Number of progeny ears classified	8	3,265	1,076	2,653	2,563	2,499
	10	4,790	1,050	3,486	3,513	4,642
	12	4,903	597	1,750	2,352	3,804
	14	3,095	498	1,198	2,147	3,432
	16	3,410	441	835	1,332	1,516
	18	572	477	197	530	612
		Per cent	*Per cent*	*Per cent*	*Per cent*	*Per cent*
Percentages of progeny ears having the same number of kernel rows as the parent ear.	8	21.2	25.4	47.7	68.6	85.6
	10	45.9	44.2	55.9	63.1	66.5
	12	38.7	38.6	44.9	46.8	52.9
	14	19.1	30.6	33.6	36.3	50.3
	16	11.8	13.0	26.1	32.9	43.9
	18	8.6	4.2	19.7	22.5	43.8
Highest percentage of progeny ears in an individual ear row having the same number of kernel rows as the parent ear.	8	35.9	32.3	86.6	100.0	100.0
	10	66.2	56.8	75.7	93.3	95.0
	12	51.0	49.0	66.9	81.3	77.0
	14	46.2	35.0	45.8	64.3	88.0
	16	26.3	20.6	33.9	59.3	63.0
	18	25.8	11.3	30.9	46.2	60.0

With the exception of the 10, 12, and 18 rowed classes in 1918, there was an annual increase throughout the five years in the degree to which the progeny ears in each class conformed to the parental character. The rate of increase, however, was not the same for each class. In the parent variety the mode for number of kernel rows was 12. During the first three selfed generations the 10-rowed class led in percentage of conformity to the parental number and the 8-rowed group took and maintained the lead after that. In the data for 1920 and 1921 the percentage of conformity to the parental number tended to be inversely proportional to the number of rows on the ears.

INDIRECT EFFECT OF SELECTION ON INDENTATION AND ANGULARITY OF KERNELS

After the Garrick lines had been selfed and selected for different numbers of kernel rows for five years they were examined to determine whether there had been any indirect effect upon the indentation and shape of the kernels. The results of this examination are shown in Table IX, the classifications for indentation and angularity being based upon the characteristic tendency of the ears in the individual ear rows. These studies were made at the Arlington Experiment Farm, Rosslyn, Va., and in cooperation with the Pee Dee Substation of the South Carolina Agricultural Experiment Station, Florence, S. C.

TABLE IX.—*Data on the effect of selecting for different numbers of kernel rows upon the indentation and angularity of kernels of self-fertilized lines of Garrick grown at Florence, S. C.,[a] and Rosslyn, Va., in 1921*

Kernel rows on parent ears	Ear rows grown	Percentages of ear rows producing ears with mode for kernel indentation stated					Percentages of ear rows producing ears with mode for angularity of kernels stated		
		None	Trace on only a few kernels	Shallow and smooth	Mid-depth and wrinkled	Deep and rough	Rounded	Intermediate	Angular
		Per cent	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*
8	46	26.1	6.5	45.7	19.6	2.2	69.6	28.3	2.1
10	59	16.9	6.8	52.5	13.6	10.2	59.3	32.2	8.5
12	59	18.6	8.5	42.4	16.9	13.6	55.9	33.9	10.2
14	65	7.7	1.5	50.8	20.0	20.0	46.2	40.0	13.8
16	52	5.8	3.8	38.5	26.9	25.0	42.3	28.8	28.8
18	34	8.8	0.0	35.3	20.6	35.3	44.1	20.6	35.3

[a] The data at Florence, S. C., were obtained in cooperation with the Pee Dee Substation of the South Carolina Agricultural Experiment Station.

The classification for indentation was more or less difficult, but it is believed that it was fairly accurate in the extreme classes. The largest percentages of ear rows with no indentation were from the parents with 8, 10, and 12 kernel rows, and the largest percentages in the class with deep and rough indentation were from parents with 14, 16, and 18 kernel rows. It is evident from this that selection for low numbers of rows on the ears tended to result in a different indentation from that obtained by selecting for higher numbers of kernel rows. Similarly, rounded kernels naturally followed selection for low numbers of kernel rows, and angular kernels followed selection for higher numbers of rows.

RELATION OF SIZE OF EARS TO NUMBER OF ROWS OF KERNELS

All of the ears produced in the Garrick selfed lines in 1921 were measured as to length and diameter. The total length of all the ears from each ear row was divided by the number of bearing plants in that row to obtain the total length of ear per plant. A yield index then was computed by multiplying this value by the square of the average diameter of the ears in the row. These data, and the average number of ears per plant produced by parent ears with different numbers of kernel rows, are shown in Table X.

TABLE X.—*Effect of selecting for numbers of rows of kernels upon number of ears per bearing plant, and length and diameter of ears, in selfed lines of Garrick grown at Florence, S. C.,*[a] *and Rosslyn, Va., in 1921*

Kernel rows on parent ears	Total progeny studied		Ears per plant	Average length of total ears per bearing plant (*A*)	Average diameter of ears (*B*)	Yield index ($A \times B^2$)
	Number of plants	Number of ears				
				Inches	*Inches*	*Inches*
8	1,091	2,366	2.17	13.21	1.48	28.94
10	1,742	3,493	2.01	12.86	1.58	32.10
12	1,587	2,944	1.86	12.67	1.68	35.76
14	1,757	3.209	1.83	12.13	1.75	37.15
16	1,348	2,091	1.55	9.92	1.81	32.50
18	867	1,335	1.54	9.76	1.85	33.40

[a] The data at Florence, S. C., were obtained in cooperation with the Pee Dee Substation of the South Carolina Agricultural Experiment Station.

The number of ears per plant tended to be inversely proportional to the number of rows on the parent ear and directly proportional to the length of ear per plant. The length of total ears per bearing plant tended to be inversely proportional, and the average diameter of ear tended to be directly proportional to the number of rows on the parent ears. The yield indexes were largest in the two middle classes for number of rows of kernels. The classes with 16 and 18 rows have larger yield indexes than the classes with only 8 or 10 rows. The yield indexes are based only on bearing plants and the differences are small. Inasmuch as the percentage of barren plants (Table XI) was materially larger in the classes with more kernel rows, the acre yield of the fewer-rowed ears evidently was larger. This agrees, in general, with the data previously presented from open-fertilized corn.

RELATION OF DELETERIOUS CHARACTERS TO NUMBER OF ROWS OF KERNELS

Many abnormalities occur among corn plants in lines that have been self-fertilized in successive generations. Some of these are eliminated by selection and others become more or less fixed and characteristic of individual hereditary lines. All of these abnormal characters have a more or less deleterious effect upon yield.

After five generations of selfing and selection for different numbers of kernel rows, data were obtained on the proportion of plants in the different Garrick lines having certain deleterious characters. The characters considered were: Plaited and erect leaves, entangled leaves, chlorophyl blotch, dead blotch, red and yellow flame, and barrenness. The dead blotch and the red and yellow flame characters both result in the premature death of the plants having them.

The data were obtained on a total of 4,013 plants in 158 ear rows grown in cooperation with the Pee Dee Substation of the South Carolina Agricultural Experiment Station, at Florence, S. C., and on 3,167 plants in 105 ear rows grown at the Arlington Experiment Farm, Rosslyn, Va. Notes were taken on all of the deleterious characters in the experiment in South Carolina, but in the experiment in Virginia barrenness and red and yellow flame were the only ones noted. A summary of the data from these experiments, in so far as they relate to the present problem, is shown in Table XI, the data being grouped according to the number of rows on the parent ears.

In both experiments the lines from parent ears with 8, 10, and 12 rows had smaller percentages of plants affected than the lines from parent ears with 16, 18, and 20 rows. This was true for each of the deleterious characters considered, although the differences in plants affected with dead blotch and chlorophyl blotch were small.

TABLE XI.—*Data on the relation of number of kernel rows on parent ears to percentages of plants having deleterious characters in selfed lines of Garrick grown at Rosslyn, Va., and Florence, S. C.,*[a] *in 1921*

Deleterious characters	Percentage of plants affected[b]	
	Parent ears having 8, 10, and 12 rows	Parent ears having 16, 18, and 20 rows
	Per cent	*Per cent*
Florence, S. C.:		
Plaited and erect leaves	39.99	54.46
Entangled leaves	8.03	15.68
Chlorophyl blotch	13.17	13.37
Dead blotch	29.45	32.34
Red and yellow flame	.96	16.66
Florence, S. C.—Continued.		
Barrenness	1.61	6.77
Rosslyn, Va.:		
Red and yellow flame	1.89	7.40
Barrenness	1.94	8.70

[a] The data at Florence, S. C., were obtained in cooperation with the Pee Dee Substation of the South Carolina Agricultural Experiment Station.
[b] The total numbers of plants studied were 4,013 in South Carolina and 3,167 in Virginia.

RELATION OF SMUT RESISTANCE TO NUMBER OF ROWS OF KERNELS

The selfed lines in the Garrick variety were studied in 1922[5] to learn whether there was any evidence of resistance to smut. The studies were made at the Arlington Experiment Farm, Rosslyn, Va., on reclaimed land along the Potomac River where smut infection normally is high. The 138 ear rows that were studied represented 13 of the original selfed lines started in 1917 which had survived six generations of selfing and selection. Some of the ear rows in 5 of the 13 original lines or families were entirely free from smut. Three of these five families had been selected during the first five generations of selfing for 12 or less rows on the ear. The percentages of ear rows free from smut in these families were 33.3, 36.4, and 37.5. Two of the five families had been selected for 14 or more rows during the same period. The percentages of ear rows free from smut in these families were 5 and 25. The average percentage of smut-free ear rows in all of the lines from few-rowed parent ears was 12.2, and in all of the lines from many-rowed parent ears was 4.7.

Studies of smut resistance were continued with the Garrick lines in 1923 and additional investigations were begun with Cuban Yellow, a flint variety from southern Florida, and with Boone County White. Inbred lines of Cuban Yellow that had been selfed for four generations and lines of Boone County White that had been selfed three generations were used. In the selection of the lines in these varieties no attention had been given to the number of kernel rows on the ear. The experiments were conducted at the Arlington Experiment Farm, Rosslyn, Va.

[5] Notes on infection by smut and the artificial inoculations (referred to later) were made by W. H. Tisdale, Pathologist in Charge of Smut Investigations, Office of Cereal Investigations, Bureau of Plant Industry, United States Department of Agriculture, and his associates

In order to provide more opportunity for infection, stable manure with which large quantities of smut spores had been mixed was spread on the experimental plat in the spring. Later, a water suspension of conidia of the smut fungus from pure culture was applied to the growing points of the plants after they had been wounded with a sharp wire.

A summary of the data on freedom from smut in the Garrick lines in 1923 is given in Table XII, classified according to the number of kernel rows on the parent ears. Data on freedom from smut in the parent ear rows in 1922 also are given. All of the few-rowed parent ears used in this experiment were from ear rows that were entirely free from smut in 1922, as was one of the many-rowed parent ears. The other seven parent ears of the many-rowed class were from the most nearly smut-free ear rows of this class from which selfed ears were obtained in 1922. Inasmuch as approximately equal numbers of hand pollinations were attempted in the rows of both classes in 1922, this failure to obtain selfed ears from the many-rowed class furnishes an interesting side light on the greater vigor of the plants from the few-rowed parent ears.

TABLE XII.—*Data on the relation of number of kernel rows on the parent ears to freedom from smut in selfed lines of Garrick grown at Arlington Experiment Farm, Rosslyn, Va., in 1922 and 1923*

Family No.	Parent ears with 8 to 12 kernel rows						Family No.	Parent ears with 14 to 20 kernel rows					
	Parent rows, 1922			Progeny rows, 1923				Parent rows, 1922			Progeny rows, 1923		
	Ear row No.	Total plants	Smut-free plants	Ear row No.	Total plants	Smut-free plants		Ear row No.	Total plants	Smut-free plants	Ear row No.	Total plants	Smut-free plants
			P. ct.			*P. ct.*				*P. ct.*			*P. ct.*
49	76	20	100.0	2	89	49.4	86	45	20	95.0	20	117	29.9
				4	85	51.8		49	22	100.0	22	77	64.9
				5	103	79.6		69	26	88.5	23	84	31.0
	78	19	100.0	7	101	75.2							
				8	102	80.4							
54	26	17	100.0	10	107	77.6	99	51	18	94.5	25	132	62.1
				11	114	84.2					26	113	61.9
				13	97	93.8					29	108	61.1
	30	20	100.0	14	98	81.6		256	38	60.5	30	108	29.6
				16	113	85.0					31	115	17.4
				17	123	90.2							
Total ear rows		76	100.0	-------	1,132	[a] 78.2	Total ear rows		124	[a] 83.9	-------	854	[a] 44.6

[a] Computed directly from the basic data

Only 2 of the 11 rows from ears with from 8 to 12 rows of kernels had lower percentages of smut-free plants than the most nearly smut-free rows from ears with 14 to 20 rows of kernels in 1923, and the rows from ears with fewer kernel rows averaged 33.6 per cent more smut-free plants than the rows from ears with more kernel rows.

The percentages of smut-free plants were lower in 1923 than in the parent-ear rows in 1922. This may have been due to a difference in the seasons, to the artificial inoculation of soil and plants in 1923, or to the fact that the data for 1922 are based only on ear rows as selected having the fewest smutted plants. In any event, the difference in freedom from smut in the parent-ear rows of the two classes in 1922 was only 16.1 per cent, whereas the difference in 1923 was 33.6 per cent.

The data on freedom from smut in the experiment with the selfed lines of Cuban Yellow and Boone County White varieties are given in Table XIII, arranged according to the number of rows of kernels on the parent ears.

TABLE XIII.—*Percentages of smut-free plants in selfed lines of Cuban Yellow and Boone County White from parent ears with different numbers of rows of kernels, at Arlington Experiment Farm, Rosslyn, Va., 1923*

Variety	Rows from parent ears											
	12-kernel rows		14-kernel rows		16-kernel rows		18-kernel rows		20-kernel rows		22-kernel rows	
	Total plants	Smut-free plants	Total plants	Smut-free plants	Total plants	Smut-free plants	Total plants	Smut-free plants	Total plants	Smut-free plants	Total plants	Smut-free plants
		P. ct.		*P. ct.*		*P. ct.*		*P. ct.*		*P. ct.*		*P. ct.*
Cuban Yellow	97	73.2	88	51.1	110	31.8	119	47.9				
	106	78.3	100	65.0	106	67.0						
	108	60.2	107	58.9								
	92	78.3	112	58.9								
	110	63.6	87	71.3								
	111	59.5	109	55.0								
	118	81.4	108	69.4								
	111	40.5	114	52.6								
	106	50.0										
	106	54.7										
	109	77.1										
Total or average	1,174	[a]65.0	825	[a]60.1	216	[a]49.1	119	[a]47.9				
Boone County White.	105	37.1	103	90.3	104	31.7	100	38.0	72	72.2	100	54.0
			99	47.5	106	83.0	86	69.8	97	78.4		
			111	91.9	89	47.2	82	72.0				
			95	48.4	91	84.6						
			69	73.9	98	69.4						
			97	83.5	94	51.1						
			105	73.3	99	86.9						
			59	44.1	93	46.2						
			83	67.5	107	89.7						
			65	49.2	112	43.8						
Total or average	105	[a]37.1	886	[a]69.0	993	[a]63.4	268	[a]58.6	169	[a]75.7	100	[a]54.0

[a] Computed directly from basic data.

In the Cuban Yellow variety, the ear rows having the largest percentages of smut-free plants were from ears with 12 rows of kernels, and the average percentage of smut-free plants decreased as the number of kernel rows increased.

In Boone County White, the ear rows with the largest percentages of smut-free plants were from ears with 14 rows of kernels. The one ear with 12 rows of kernels produced plants of which only 37.1 per cent was free from smut, and the two ears with 20 rows produced plants of which 75.7 per cent was free from smut. Omitting these classes, there was a consistent negative relation between the percentages of plants free from smut and the number of rows of kernels on the parent ears.

There were but few parent ears with numbers of rows other than those in the two principal classes in the lines of the Cuban Yellow and the Boone County White varieties. Moreover, these lines had been selfed only for four and three generations, respectively. When the data are considered as a whole, however, they are in agreement with those obtained with the Garrick variety in indicating that lines characterized by relatively low numbers of rows on the ears are more resistant to smut than those characterized by larger numbers of kernel rows.

RELATION OF VIGOR TO NUMBER OF ROWS OF KERNELS

Reference already has been made to the selection of selfed lines of Cuban Yellow and Boone County White and to the fact that no attention was paid to the number of rows of kernels on the seed ears. These lines were selected on the basis of their general vigor, freedom from abnormality, and productiveness.

Most of the ears of the Cuban Yellow had 14 or 16 rows of kernels when selfing was begun. After four generations of selection for vigor, without reference to the number of rows of kernels, nearly all of the breeding ears had 12 or 14 kernel rows, the 12-rowed class being the largest (Table XIII). Most of the ears in the Boone County White variety had 16 or 18 rows of kernels when selfing was begun. After three generations of selection for vigor, without reference to the number of rows of kernels, 20 of the 27 breeding ears had 14 or 16 rows. Thus, selection for vigor and productiveness in the selfed lines of both of these varieties has decreased the characteristic number of rows of kernels on the ear.

The seventh selfed generation of the Garrick lines was grown at Baton Rouge, La., in 1923, in cooperation with the Louisiana Agricultural Experiment Station. Thirteen of the 108 original selfed lines of 1917 were represented in this planting and each of these lines or families was represented by from 3 to 13 ear rows.

The seed ears representing a family in 1923 varied somewhat in regard to the number of rows of kernels in 11 of the 13 families. The ear rows of each of these 11 families were classified into desirable and undesirable rows according as the plants in them approached the normal stability and vigor of open-fertilized corn. This classification was based upon a consideration of the culms, roots, leaves, chlorophyl, ears, and manner and time of dying.

Data on the relation of the number of kernel rows on the parent ears to the desirability or undesirability of the ear rows grown from them are shown by families in Table XIV. The last column in this table shows the differences between the average number of kernel rows on the parent ears producing desirable and undesirable ear rows in each of the 11 families. The parent ears producing desirable ear rows had fewer kernel rows than those producing undesirable ones in 9 of the 11 families, and averaged 1.52 of a row less in all of the rows.

If the future breeding stocks are selected on the basis of the most vigorous and productive ear rows, it is evident that the tendency will be to reduce the number of kernel rows on the ears in the families with higher numbers until the numbers in all families are about the same level. This is in agreement with the change in the number of rows in the Cuban Yellow and Boone County White varieties which showed the effects of this tendency during four years and three years of selection, respectively.

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TABLE XIV.—*Data on the relation of number of rows of kernels on the parent ear to desirability or undesirability of plants in the ear rows from them in 11 selfs fertilized families of Garrick at Baton Rouge, La., in 1923* [a]

Family No.	Kernel rows on the 1917 selfed seed ears	Classification of the 1923 ear rows	Parent ears with the number of kernel rows stated producing ear rows classed as desirable and undesirable							Total ear rows	Kernel rows on parent ears (average)	Difference between average number of kernel rows on parent ears of desirable and undesirable ear rows
			8	10	12	14	16	18	20			
32	10	Desirable	1	1	----	----	----	----	----	2	9.00	−0.14
		Undesirable	4	3	----	----	----	----	----	7	8.86	
57	10	Desirable	6	1	1	----	----	----	----	8	8.75	3.65
		Undesirable	----	----	4	1	----	----	----	5	12.40	
38	10	Desirable	----	2	----	----	----	----	----	2	10.00	1.33
		Undesirable	----	2	----	1	----	----	----	3	11.33	
49	12	Desirable	----	1	1	----	----	----	----	2	11.00	1.67
		Undesirable	----	----	2	1	----	----	----	3	12.67	
54	12	Desirable	----	1	4	----	1	----	----	6	12.33	.07
		Undesirable	----	1	2	2	----	----	----	5	12.40	
79	14	Desirable	----	1	----	2	3	----	----	6	14.33	−1.33
		Undesirable	----	----	1	1	----	----	----	2	13.00	
86	14	Desirable	----	----	1	5	----	1	----	7	14.29	.04
		Undesirable	----	----	3	1	1	----	1	6	14.33	
90	16	Desirable	----	----	----	2	----	----	----	2	14.00	2.00
		Undesirable	----	----	----	1	1	1	----	3	16.00	
93	16	Desirable	----	----	----	1	----	----	1	2	17.00	3.00
		Undesirable	----	----	----	----	----	----	1	1	20.00	
99	16	Desirable	----	----	----	2	----	----	----	2	14.00	2.40
		Undesirable	----	----	1	----	1	3	----	5	16.40	
107	18	Desirable	----	----	1	----	1	----	----	2	14.00	4.00
		Undesirable	----	----	----	----	1	1	1	3	18.00	
All families		Desirable	----	----	----	----	----	----	----	41	12.61	1.52
		Undesirable	----	----	----	----	----	----	----	43	14.13	

[a] The data were obtained in cooperation with the Louisiana Agricultural Experiment Station.

DISCUSSION

Corn breeding probably has received more attention in this country than any other problem of crop improvement. If it were dependent only upon the selection of strains with constructive characters, such as size of ear, it would hardly be a serious problem. Yet this vast experience has created among the thoughtful only uncertainty and caution in making general recommendations. The possibilities of selection within self-fertilized lines as a means of corn improvement are being investigated extensively. The problem is not an easy one, however, and it is impossible to predict what the future may bring in the way of a practical application of this principle. In any event, the bulk of the seed corn planted in the United States will be obtained by mass selection for some time to come, and it therefore is important to know what characters, if any, can be used safely as a guide in such selection.

The experiments with open-fertilized seed reported give further evidence that seed ears with larger numbers of kernel rows and smaller and more angular kernels tend to produce lower yields. This was true in some of the experiments in spite of a higher yield per bearing plant because the seed from the many-rowed ears produced more barren plants. The data from the experiments with self-fertilized lines indicate that the larger proportion of weak and barren plants in strains with many-rowed ears was due to a tendency for such strains to have more deleterious characters.

Selection for large ears frequently has resulted in ears with larger numbers of kernel rows, and it seems probable that the benefits accruing from increased size of ear may have been nullified for the reasons already noted. The diameter of ear and the number of rows of kernels are correlated, though how much of this relation is unavoidable is unknown. Size of ear is dependent upon length as well as diameter, however, and the number of kernel rows need not be increased in obtaining longer ears. It therefore seems that selection on the basis of total length of ear (or ears) per plant, together with as much diameter as may be had without too many rows of kernels, may be recommended as satisfying the size requirements without increasing the ill effects that apparently are associated with a larger number of kernel rows. It is probable that the maximum length of total ear per plant can be obtained by having more than one ear on a plant. Whether this is necessary to obtain the maximum yield, however, or whether plants bearing one long ear may be equally productive under some conditions, remains to be determined.

SUMMARY

Experiments are reported in which prolific varieties were more productive as a class than comparable nonprolific varieties. The ears in the prolific varieties had fewer rows of kernels and smaller diameters and the kernels were less angular than in the nonprolific varieties.

In comparisons between groups of ears, both within prolific and nonprolific varieties, and within several F_1 crosses, those with fewer kernel rows, larger kernels, or less angular kernels were more productive. In the comparisons, both between and within varieties, the lots with fewer kernel rows produced fewer barren plants and, in some cases, made the larger total yield in spite of a smaller yield per bearing plant as measured by the yield index.

Selection for different numbers of kernel rows in selfed lines resulted in an essentially steady increase during five generations in the degree of conformity to the parental number. The rate of this increase was greatest in the lines with the fewest rows and decreased as the number of rows increased. Selection also resulted incidentally in other differences. Thus, the lines having smaller numbers of kernel rows had a greater length of ear per plant, ears with a smaller diameter, and kernels more rounded and with less indentation than the lines having larger numbers of kernel rows. Finally, the fewer-rowed lines were more resistant to corn smut, had fewer plants with heritable deleterious characters, and were more vigorous and productive in general.