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A STATISTICAL STUDY OF THE RELATION BETWEEN SEED-EAR CHARACTERS AND PRODUCTIVENESS IN CORN

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PREVIOUS INVESTIGATIONS

The question of a possible relation between the physical characters of seed ears and productiveness is an important one in corn breeding and has been given much attention. Earlier investigations have been reviewed in detail (*7*)[1] and need be considered but briefly. The conclusion reached by investigators using data from ear-row plats has been practically unanimous that slight differences in the physical characters of good ears were of no value in determining their productiveness. This conclusion unquestionably was warranted on the basis of the individual studies. Nevertheless, when the data are considered as a whole certain trends are apparent. Thus, most of the comparisons were in favor of the heavier, longer, fewer rowed ears and those with a lower shelling percentage or smoother indentation. It should be noted that many of the differences are not statistically significant and that all are negligible practically. The real evidence consists in the preponderance of small differences in productiveness among ears that already were above the average of their respective varieties, at least in weight, length, and circum-

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

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ference. The evidence from ear-to-row studies is supported further by data from direct comparisons between selected lots of ears differing in various characters and from comparisons among unselected ears (*7*). In these comparisons too, however, the differences in general were small.

Since the above experiments were reviewed the data from the Nebraska and the New York (Cornell University) Agricultural Experiment Stations have been brought together (*3*, *6*), and Wallace (*9*) has reported a brief statistical study based on data from the Iowa Agricultural Experiment Station. Etheridge (*1*) has reported new data from the Missouri Agricultural Experiment Station in which no significant relation was found between ear characters and yield. Hayes and Alexander (*2*) have reported data from the Minnesota Agricultural Experiment Station, on the basis of which "the chances are 37 to 1 that selection for the score-card type of ear has led to a slight reduction in yield even though the plants were first selected on a yield basis from perfect-stand hills" (*2*, p. 17). Finally Kyle and Stoneberg (*4*) have reported that fewer rowed ears tended to be more productive than ears with larger numbers of kernel rows, both within and between varieties. This was true in some cases in spite of the fact that the yield per bearing plant was more for the ears with larger numbers of kernel rows. Kyle and Stoneberg also showed that selection within selfed lines tended to reduce the number of kernel rows and that self-fertilized strains with fewer kernel rows tended to be more desirable from the standpoint of general vigor, to be more resistant to corn smut, and to have smaller percentages of plants with heritable deleterious characters than comparable strains with more kernel rows.

Soil heterogeneity, irregularities in stand, insect damage, and all of the other conditions that continually interfere with successful field experimentation are related in no way to seed value. Nevertheless, they determine a large part of the total variation in yield from row to row of an ear-row plat and largely obscure the relations between yield and factors that are related to seed value. Even small correlations may be important under such conditions if they are significant statistically. In general, however, the number of records has not been large enough to establish the statistical significance of small correlations. Finally, the complex interrelations among the ear characters tend to obscure the meaning of the coefficients of total correlation that are obtained. Thus, there are very obvious physical relations between weight of ear and length or circumference of ear, factorial relations between shelling percentage and the weight of ear or cob, and presumably there are relations, such as that between length and circumference of ears, resulting from the inherent vigor of the parent plants and the environment in which each grew. These factors must be considered together if the whole relation between yield and ear characters is to be analyzed.

In view of these facts further study of the relation of the characters of seed ears to productiveness seems warranted. The problem is attacked here through partial and multiple correlation studies on data from ear-row plats.

MATERIAL AND METHODS

A project for the production of improved varieties of corn for the different geographic sections of the United States was carried by the Bureau of Plant Industry of the United States Department of Agriculture for many years. Ear-row selection was conducted in a number of localities in connection with this project, and records of the individual productiveness of several thousand ears of corn were obtained. As measurements of the seed ears were recorded, the accumulated data are well suited to a statistical study of the relation between seed-ear characters and productiveness.

EAR-ROW PLATS

The same general plan was followed in all of the plats, though the details differed. Each ear was used to plant an individual row. The tassels were pulled from the plants at one end of each row before pollen was shed, the detasseled halves being at the opposite ends of adjacent rows. At harvest time each row was husked, and the weight of ears was recorded, with such other data as seemed desirable. Seed ears were selected from the detasseled plants of the higher yielding rows for the next year's planting, additional ears being selected from the general field in some seasons to avoid too close breeding. The plats were grown under conditions that were reasonably uniform. The rows were the same length for any one season and variety. More seeds were planted than the number of plants desired, and the plats were thinned later to the final stands.

VARIETIES

Data were used from experiments covering from 9 to 14 years with each of four varieties, comprising 3,265 ears in all.[2] They were chosen because they represented more or less distinct types grown in different environments and were more continuous over a longer period than for the other varieties. Brief notes on each variety follow.

Cereal Investigations (C. I.) No. 77 originated in 1880 as a cross and has been kept pure since that time. It is a white dent variety with white cobs. The plants are 9 to 10 feet high and require 120 days to mature. The ear-row plats were on productive bottom lands of the Scioto River near Piketon, Ohio, from 1907 to 1920, inclusive. The size of the plats differed from year to year, the extremes being 30 rows in 1911 and 199 rows in 1920. Data on 1,230 ear rows were used. The ear rows were not planted in duplicate.

Cereal Investigations No. 119 is a selection from Boone County White. It is a large-eared white dent corn with white cobs. It has been kept pure since 1880. The plants are 8 to 10 feet high and require at least 120 days to mature. The ear-row plats have been located at various places near Washington, D. C., from 1907 to 1918. The number of ear rows ranged from 26 in 1909 to 73 in 1914, the total for the period being 621 rows. The ear rows usually were planted in duplicate.

Cereal Investigations No. 120 originated as the cross Hickory King × C. I. No. 119, made at Arlington, Va., in 1902. Since that time it has been kept pure. The kernels are broad, white, and rather flinty. The plants are about 7 feet high and require about 120 days to mature. The plats were located near Round Hill, Va., from 1907 to 1918. The plantings were all made in duplicate. The

[2] The records on which these studies are based were made by H. H. Biggar, E. B. Brown, G. J. Burt, H. S. Garrison, J. M. Hammerly, C. P. Hartley, C. H. Kyle, F. D. Richey, H. M. Steece, C. E. Trout, and J. G. Willier.

size of the plats varied from 48 to 100 ear rows, the total for the period being 795 rows.

Cereal Investigations No. 133 is a selection from Minnesota No. 13. It is an early yellow dent with rather short kernels. The plants are about 7 feet high and require about 90 days to mature. The plats were located near Oconomowoc, Wis., from 1908 to 1917. No data are available for 1915, when the crop did not mature. The plats varied in size from 46 to 90 ear rows, the total for the period being 619 rows. No duplicate plantings were made.

VARIABLES

The variables considered are shown in Table 1. The letters under "Symbol" are used throughout to indicate the respective variables in connection with the symbols for the different constants. The units and limits of measurement and the class intervals also are given in Table 1. Most of these are self-explanatory.

The basic yield records comprised the total ears husked from the respective rows as weighed at harvest time or the mean of two rows when the planting was duplicated. It was necessary to avoid the influence of the wide variation in yield from year to year due to soil and climate. The mean yield of all rows of a variety in a season therefore was computed, and the yields of the individual rows were expressed as percentages of the mean for that season. These percentages were used in computing the correlations and are designated as variable *A* in Table 1. This gives the same weight to a deviation of 5 bushels in a season in which the average yield was 50 bushels as to a deviation of 8 bushels in an 80-bushel year.

TABLE 1.—*Yield and physical characters of seed ears that are treated as variables in this bulletin, together with the units and limits of measurement and the class intervals used in determining the different constants*

Symbol	Variable	Units and limits of measurement	Class intervals
A	Yield	1 per cent	5 per cent.
B	Weight	1 gram	15 grams.
C	Length	¼ inch	¼ inch.
D	Butt circumference [1]	do	Do.
E	Tip circumference [2]	do	Do.
F	Cob weight	1 gram	4 grams.
G	Percentage of grain	1 per cent	1 per cent.
H	Rows of kernels	Actual number	2 rows.
I	Kernels per row	do	2 kernels.

[1] Measured about one-third of the distance from the butt.
[2] Measured about one-third of the distance from the tip.

Records of the moisture content and shelling percentage of the harvested ears were not available. However, the varieties were well adapted to the respective environments in which they were grown, unduly late rows producing excessively sappy ears were not selected for propagating further, regardless of their yield, and selection for any specific type of ear was not continuous. Consequently it seems safe to assume that the effect of differences in moisture and shelling percentage was very slight, if not entirely negligible.

The means, maxima, minima, standard deviations, and coefficients of variation are shown in Table 2 and ratios between the means of some of the characters in Table 3. These show the diversity in character and variability in the varieties.

TABLE 2.—*The mean and extreme values for yield and for eight characters of seed ears and their coefficients of dispersion*

Variable and unit of measurement	C. I. No.	Mean	Maximum	Minimum	Standard deviation	Coefficient of variation
Yield ... per cent	77	100 ±0.225	130	50	11.7 ±0.159	...
	119	100 ± .382	145	60	14.1 ± .269	...
	120	100 ± .225	140	50	9.4 ± .159	...
	133	100 ± .371	145	20	13.7 ± .263	...
Weight of ear ... grams	77	347 ± .955	520	220	42.2 ± .574	12.2 ±0.171
	119	363 ±1.512	535	220	43.8 ± .836	12.0 ± .235
	120	345 ± .935	490	205	35.3 ± .597	10.2 ± .177
	133	226 ± .788	310	145	29.1 ± .558	12.9 ± .251
Length of ear ... inches	77	8.85± .015	11.25	7.00	.629± .009	7.11± .097
	119	8.84± .023	11.25	6.25	.699± .013	7.91± .152
	120	8.60± .016	11.50	7.00	.623± .011	7.24± .123
	133	7.33± .014	9.00	5.50	.531± .010	7.24± .140
Butt circumference ... do	77	6.81± .008	8.25	5.50	.353± .005	5.19± .071
	119	7.08± .011	8.25	6.00	.374± .007	5.28± .101
	120	6.97± .008	8.25	5.75	.334± .006	4.79± .081
	133	6.24± .008	7.25	5.00	.313± .006	5.02± .097
Tip circumference ... do	77	6.19± .008	7.50	4.50	.337± .005	5.44± .074
	119	6.44± .012	7.50	5.25	.364± .007	5.65± .108
	120	6.32± .008	7.50	5.25	.313± .005	4.96± .084
	133	5.56± .008	6.50	4.50	.298± .006	5.36± .013
Weight of cob ... grams	77	49.4 ± .210	99	23	9.86 ± .134	20.0 ± .282
	119	58.8 ± .339	99	27	11.60 ± .222	19.7 ± .405
	120	48.7 ± .233	91	27	9.30 ± .157	19.1 ± .345
	133	39.1 ± .202	71	19	7.45 ± .143	19.1 ± .379
Percentage of grain	77	85.7 ± .045	92	76	2.20 ± .030	2.56± .035
	119	83.8 ± .071	90	75	2.36 ± .045	2.82± .054
	120	85.8 ± .054	92	78	2.09 ± .035	2.44± .041
	133	82.6 ± .069	90	72	2.54 ± .049	3.07± .059
Number of rows of kernels	77	14.7 ± .033	20	10	1.61 ± .022	10.9 ± .151
	119	16.6 ± .054	24	12	1.90 ± .036	11.4 ± .224
	120	13.0 ± .034	18	10	1.36 ± .023	10.5 ± .181
	133	15.8 ± .045	22	10	1.67 ± .032	10.6 ± .205
Number of kernels per row	77	46.5 ± .094	62	32	4.10 ± .056	8.80± .121
	119	47.7 ± .146	64	34	4.34 ± .083	9.09± .176
	120	47.7 ± .117	62	32	4.06 ± .069	8.51± .146
	133	38.3 ± .092	52	28	3.40 ± .065	8.86± .171

METHODS OF COMPUTATION

The standard deviations and coefficients of total correlation were computed from correlation tables with class intervals as shown in Table 1. The records for each variety for the entire period were treated as a unit, and corrections then were made to offset the fluctuation in the means from season to season. It does not seem necessary to publish the 144 tables that were used. One is given for illustration as Table 4, but it should be kept in mind that the distributions shown were influenced by the fluctuation from year to year as well as by the variation within the seasons.

TABLE 3.—*Ratios between some of the ear characters*

Ratio	C. I. No. 77	C. I. No. 119	C. I. No. 120	C. I. No. 133
Weight of ear to volume [1]	10.62	10.29	10.37	9.95
Weight of cob to volume [1]	1.51	1.67	1.46	1.72
Butt circumference to length of ear	.769	.801	.810	.851
Number of kernels per row to length of ear	5.25	5.40	5.55	5.23
Number of rows to butt circumference	2.16	2.34	1.87	2.53
Tip circumference to butt circumference	.909	.910	.907	.891

[1] The value used to represent volume was obtained by dividing the squared butt circumference by 4π and multiplying by the length. This assumes the ears to be equally cylindrical but should be sufficiently accurate for the present purpose.

TABLE 4.—*Correlation between weight of ear and length of ear in C. I. No. 77, showing methods of computation*

Class centers	Weight of ear in grams (B): 220	235	250	265	280	295	310	325	340	355	370	385	400	415	430	445	460	475	490	505	520	f	d_C	fd_C	fd_C^2	Σd_B	(Σd_B) (d_C)
Length of ear in inches (C):																											
7.00	1		3	4	6	1	2	1		1												19	0	0	0	75	0
7.25		2	3		3		3	1														12	1	12	12	45	45
7.50				8	4	10	10	1	4	2	1											40	2	80	160	217	434
7.75		1	3	5	5	2	5	5	3	2												31	3	93	279	159	477
8.00		3	5	7	16	22	18	26	16	16	12	3	1	3								148	4	592	2, 368	974	3, 896
8.25		1		10	9	15	12	13	12	5	3	3	1					1				85	5	425	2, 125	538	2, 690
8.50			3	8	4	18	30	30	22	21	22	13	5	6	2	1						185	6	1, 110	6, 660	1, 435	8, 610
8.75				1	5	9	12	11	13	7	5	5	1						1			70	7	490	3, 430	519	3, 633
9.00				2	1	19	22	36	29	39	36	23	13	16	2	5	3					246	8	1, 968	15, 744	2, 200	17, 600
9.25						5	9	10	10	10	7	8	4	2	4			1				70	9	630	5, 670	624	5, 616
9.50						5	9	8	11	26	19	19	8	15	6	6	3	2	1			138	10	1, 380	13, 800	1, 421	14, 210
9.75				1	1	1	2	4	4	1	5	3	11	5	3	1						42	11	462	5, 082	430	4, 730
10.00					1	1	1	4	5	12	6	12	9	15	7	6	3	3	1	1		87	12	1, 044	12, 528	1, 010	12, 120
10.25							1	3		1	1	3	2	2	3		3	2	1	1		23	13	299	3, 887	290	3, 770
10.50						1				3	1	4	6	3	3	2		2				25	14	350	4, 900	303	4, 242
10.75												1										1	15	15	225	11	165
11.00												1	1			2	1		1		1	7	16	112	1, 792	107	1, 712
11.25																1						1	17	17	289	15	255
f	1	7	17	46	55	109	136	153	129	146	118	98	62	67	30	24	13	11	5	2	1	1, 230		9, 079	78, 951	10, 373	84, 205
d_B	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20						
fd_B	0	7	34	138	220	545	816	1, 071	1, 032	1, 314	1, 180	1, 078	744	871	420	360	208	187	90	38	20	10, 373					
fd_B^2	0	7	68	414	880	2, 725	4, 896	7, 497	8, 256	11, 826	11, 800	11, 858	8, 928	11, 323	5, 880	5, 400	3, 328	3, 179	1, 620	722	400	101, 007					

$\Sigma fd_B^2/N$ = 82. 1195

$(\Sigma fd_B/N)^2$ = 71. 1211

$\sigma^2_{B(t)}$ = 10. 9984

$\left\{\frac{N_1 B_1^2 + N_2 B_2^2 + \cdots + N_n B_n^2}{N} - B^2\right\}$ = 3. 0736

σ^2_B = 7. 9248

σ_B = 2. 8151

$\Sigma fd_C^2/N$ = 64. 1878

$(\Sigma fd_C/N)^2$ = 54. 4836

$\sigma^2_{C(t)}$ = 9. 7042

$\left\{\frac{N_1 C_1^2 + N_2 C_2^2 + \cdots + N_n C_n^2}{N} - C^2\right\}$ = 3. 3684

σ^2_C = 6. 3358

σ_C = 2. 5171

$\Sigma d_B d_C/N$ = 68. 4593

$(\Sigma fd_B/N)$ $(\Sigma fd_C/N)$ = 62. 2489

$p_{BC(t)}$ = 6. 2104

$\left\{\frac{N_1 B_1 C_1 + N_2 B_2 C_2 + \cdots N_n B_n C_n}{N} - BC\right\}$ = 1. 9192

p_{BC} = 4. 2912

$r_{BC} = \frac{p_{BC}}{\sigma_B \sigma_C} = \frac{4.2912}{7.0859} = 0.6056$

The coefficients of partial correlation of the first order were computed according to the well-known formula—

$$r_{AB\cdot C}=\frac{r_{AB}-r_{AC}r_{BC}}{\sqrt{1-r_{AC}^2}\sqrt{1-r_{BC}^2}}.$$

The values of $\sqrt{1-r^2}$ were taken from the tables prepared by Miner (*5*).

The partial coefficients of higher orders and the coefficients of multiple correlation were computed by the methods described by Tolley and Ezekiel (*8*).

CORRECTION FOR HETEROGENEITY OF DATA

Let X be the mean of a variable for a series of years in which X_1, X_2, ... X_n are the annual means. Similarly, let $\sigma_{X(t)}$ be the "total" standard deviation, as determined from the mingled records of all seasons, and σ_X be the square root of the weighted mean of the squared annual standard deviations. Then,

$$\sigma^2_{X(t)}-\left\{\frac{N_1X_1^2+N_2X_2^2+...+N_nX_n^2}{N}-X^2\right\}=\sigma^2_X \quad (1)$$

in which N_1, N_2, ... N_n are the numbers of records in the individual seasons and N is the total population. The quantity within the brackets will be 0 only when X_1, X_2, ... X_n are identical, in which case $\sigma^2_{X(t)}=\sigma^2_X$. If the annual means are not identical the quantity within the brackets will be positive, and $\sigma^2_{X(t)}$ will be larger than σ^2_X by this amount.

Using a similar notation, let $p_{xy(t)}$ be the mean product moment of the deviations of X with those of an associated variable, Y, as determined from the mingled records for all seasons, and let p_{xy} be the weighted mean of the annual mean product moments. Then,

$$p_{xy\,(t)}-\left\{\frac{N_1X_1Y_1+N_2X_2Y_2+...\,N_nX_nY_n}{N}-XY\right\}=p_{xy} \quad (2)$$

The quantity within the brackets will be 0 if either X_1, X_2, ... X_n or Y_1, Y_2, ... Y_n are identical, or both, or if the fluctuations of the annual means are such as to bring about equality accidentally. In the absence of these conditions the quantity within the brackets will have either a positive or negative value, and $p_{xy\,(t)}$ will differ from p_{xy} in this amount.

The coefficient of correlation between two variables as computed from the mingled records for a series of years is affected by one or both of the above propositions, depending upon whether the means of one or both variables remain constant. In the correlations between yield and the different ear characters the mean annual yield remained constant at 100 per cent, whereas the means of the ear characters changed from season to season. Consequently, the standard deviation of yield and the product moments for yield with the ear characters were correct as determined from the mingled records, but the standard deviations of the ear characters were unduly large and the coefficients of correlation correspondingly too small.

In the correlations between the different ear characters the product moments and the standard deviations of both variables were affected by the fluctuation from season to season.

The following corrections were applied to eliminate these effects of heterogeneity:

The standard deviations of the ear characters as determined from the mingled records were adjusted according to equation 1 to obtain the weighted means of the squared annual standard deviations. The square roots of these values were considered to be the true average standard deviations for the period with the effect of the fluctuation in the seasonal means eliminated. They are the only standard deviations reported for the ear characters and were used in computing all of the reported coefficients of variation and correlation. The standard deviations as obtained directly from the correlation tables were used in computing the probable errors of the means, however, as in this connection variation from season to season must be considered.

The product moments for yield with the other variables were not affected by heterogeneity and were used as determined from the tables. The product moments for the pairs of associated ear characters were adjusted according to equation 2 to obtain the weighted means of the annual product moments, and these were used in computing all coefficients of correlation between ear characters. This method of correcting for heterogeneity is illustrated in connection with Table 4.

The coefficients of correlation reported here express, then, the ratio of the average of the annual product moments of the deviations of two associated variables over a series of years to the product of their average standard deviations for the same period, both averages being properly weighted. Such a coefficient measures the true average correlation of the variables under all of the varying conditions that obtained during the different seasons. It is purely a function of the variation of the two variables within the different seasons and is unaffected in any way by the fluctuation of the annual means. The regression equations based upon these average correlations give the best measure for the deviations of one variable in terms of the deviations of the other if written in terms of deviation. They may be converted to absolute values, however, only by using the individual annual means in the conversion, giving rise to a different regression equation in absolute values for each season.

In discussing this method, Dr. Sewall Wright kindly called the writers' attention to his paper (*10*), in which the same coefficient was derived from a somewhat different point of view. In Doctor Wright's proof the average of the individual coefficients was treated as the correct measure of correlation, and the coefficient as used here was shown to approximate that average when variation in the individual coefficients was no greater than may be expected in random sampling. Here the coefficients reported are considered as the correct measure of correlation, which the average of the annual coefficients will approximate when they fluctuate no more than may be expected in random sampling.

BASIS OF INTERPRETATION

Before discussing the coefficients of correlation, it is desirable to consider briefly the basis on which they will be interpreted. The odds are about 45 to 1 that correlation exists between two variables for which the determined coefficient of correlation is three or more times its probable error. This limit has been taken as the criterion of statistical significance, and no individual coefficient less than three times its probable error is considered significant.

TABLE 5.—*Coefficients of variation for yield for 1,300 check rows that were grown in various seasons under conditions similar to those of the ear rows dealt with*

Variety and season	Number of rows	Coefficient of variation	Variety and season	Number of rows	Coefficient of variation
C. I. No. 77:			C. I. No. 120:		
1911 [1]	74	10.0	1917	60	5.9
1912 [1]	162	21.4	1918	47	18.5
1915 [1]	64	10.0	1919	64	5.5
1915	19	5.8	1920	53	11.3
1916	13	4.5			
1917	13	9.4	Total or mean	224	[2] 10.9
1918	17	6.6			
1919	21	7.2	C. I. No. 133:		
			1911 [1]	84	12.4
Total or mean	383	[2] 15.5	1912 [1]	72	7.8
			1913 [1]	70	7.7
C. I. No. 119:			1914 [1]	90	8.4
1917	62	14.0	1916	19	5.9
1918	47	13.0	1917	21	16.6
1919	142	9.6	1918	15	8.2
1920	53	2.8	1919	18	12.3
Total or mean	304	[2] 10.6	Total or mean	389	[2] 9.9
			Total or mean for all varieties	1,300	[3] 11.91

[1] Hill-checked rows.
[2] Weighted according to the number of rows.
[3] Unweighted average of the four varietal coefficients.

The true meaning of a coefficient of correlation depends on far more than its statistical significance, however, and arbitrary limits can not be set within which it is or is not important for all cases. Thus, a coefficient of less than ± 0.3 between two ear characters would be relatively unimportant. A similar coefficient between one of the characters of the seed ears and yield, however, would indicate a rather important relation. This is evident from a consideration of the following facts:

Check rows were grown in a number of the ear-row plats from which the data used were obtained. The check rows were planted with uniform seed in any given plat and were distributed at regular intervals across the field. Their yields should afford a measure of the variation due to causes other than seed value. The coefficients of variation of 1,300 check rows are shown in Table 5. The mean coefficient of variation for the 1,300 rows, computed as indicated in the table, is 11.91. The unweighted mean of the standard deviations on a percentage basis of the individual ear rows of the same four varieties is 12.25. Based on the squares of these values, the variation among the check rows was 94.5 per cent as large as that among the individual ear rows. It is not possible to say that 94.5 per cent is a statistically accurate measure of the variation in the individual ear rows due to conditions not related to differences in the seed value of the individual ears planted in them. It seems entirely conservative, however, to estimate that 90 per cent of the variation in the yield of the ear rows was due to causes affecting the yields of the check rows also and in no way related to the object of the present study.

If ${}_X\sigma_A$ is the standard deviation of A for constant X, its value is given by the formula ${}_X\sigma_A^2 = \sigma_A^2(1 - r_{AX}^2)$. Then, $100 \times r_{AX}^2$, gives the percentage of the squared standard deviation of A that disappears when X is made constant or that is a function of the variability of X. The value of $(1 - r_{AX}^2)$ gives the maximum limit for the squared correlation between A and any other variable, such as B, that is independent of X. Finally, the ratio $r_{AB}^2 \div (1 - r_{AX}^2)$ measures the portion of all the variability in A not a function of X that is a function of B. If we let X represent variability in experimental conditions in no way related to variation in the factors being studied, it is evident that a relatively low value for r_{AB}, nevertheless, may indicate an important relation between A and B if the value of r_{AX}^2 be large.

On the assumption that 90 per cent of the variation was due to variability in the experimental conditions, $r_{AX}^2 = 0.90$ and $(1 - r_{AX}^2) = 0.10$. The latter, therefore, is the maximum limit for the squared correlation between yield and any ear character. The coefficients of correlation between yield and the ear characters have the same significance under these conditions as coefficients 3.16 times as large would have in data in which the yields had not been influenced by variation in experimental conditions. It should be kept in mind, however, that this interpretation applies only to the 10 per cent of the variation remaining after eliminating the effect of accidental variation. This remaining variation is so small that the coefficients must be interpreted as indicating very slight but very definite tendencies.

CORRELATIONS AMONG THE EAR CHARACTERS

The coefficients of total correlation among the eight ear characters are shown in Table 6, and the coefficients of partial correlation between some of the characters are shown in Table 7. The corresponding coefficients are much alike for the four varieties, the differences being about what would be expected from a knowledge of the varietal characteristics. It should be borne in mind that these ears constituted a carefully selected population. The seed ears in any season were from a comparatively few rows which had been selected because they produced the largest yields in the previous year. A lack of environmental influence is indicated by the small correlations between such characters as length and circumference of ear.

TABLE 6.—*The coefficients of correlation among eight characters of seed ears*

Symbol	Variable	C. I. No.	*B* Weight of ear	*C* Length of ear	*D* Butt circumference	*E* Tip circumference	*F* Weight of cob	*G* Percentage of grain	*H* Number of rows	*I* Number of kernels per row
			Coefficients of correlation between the variables designated in the column headings below and the variables in column 2							
1	2	3	4	5	6	7	8	9	10	11
B	Weight of ear	77	----------	0.6056±0.0122	0.6363±0.0114	0.5586±0.0132	0.6376±0.0114	−0.0502±0.0192	0.3549±0.0168	0.3788±0.0164
		119	----------	.6031± .0172	.5777± .0181	.4889± .0206	.5727± .0182	.0533± .0270	.3232± .0243	.4169± .0224
		120	----------	.6047± .0152	.4751± .0185	.4703± .0186	.6207± .0147	− .1061± .0236	.2383± .0225	.3329± .0213
		133	----------	.6142± .0169	.5918± .0176	.5605± .0186	.6344± .0162	.0193± .0271	.2358± .0256	.3813± .0232
C	Length of ear	77	0.6056±0.0122	----------	.0410± .0192	− .0199± .0192	.3861± .0163	− .0285± .0192	− .0205± .0192	.5527± .0134
		119	.6031± .0172	----------	− .0213± .0271	− .0948± .0269	.3958± .0229	− .0253± .0271	− .0630± .0270	.5795± .0180
		120	.6047± .0152	----------	− .1140± .0236	− .1422± .0234	.4336± .0194	− .1493± .0234	− .1414± .0234	.5445± .0168
		133	.6142± .0169	----------	.1057± .0268	.0833± .0269	.3983± .0228	.0191± .0271	− .0388± .0271	.5552± .0187
D	Butt circumference	77	.6363± .0114	.0410± .0192	----------	.7461± .0085	.4377± .0155	− .0664± .0191	.5164± .0141	− .0022± .0192
		119	.5777± .0181	− .0213± .0271	----------	.7605± .0114	.3284± .0242	.0259± .0271	.4814± .0208	− .0273± .0271
		120	.4751± .0185	− .1140± .0236	----------	.7533± .0103	.3171± .0215	− .0636± .0238	.5043± .0178	− .1982± .0230
		133	.5918± .0176	.1057± .0268	----------	.7361± .0124	.4576± .0214	− .0892± .0269	.4294± .0221	.0005± .0271
E	Tip circumference	77	.5586± .0312	− .0199± .0192	.7461± .0085	----------	.3911± .0163	− .0838± .0191	.4769± .0148	− .0749± .0191
		119	.4889± .0206	− .0948± .0269	.7605± .0114	----------	.2878± .0249	.0140± .0271	.4465± .0217	− .0545± .0270
		120	.4703± .0186	− .1422± .0234	.7533± .0103	----------	.2821± .0220	− .0309± .0239	.4449± .0192	− .2061± .0229
		133	.5605± .0186	.0833± .0269	.7361± .0124	----------	.4228± .0223	− .0756± .0269	.4283± .0221	− .0405± .0271
F	Weight of cob	77	.6376± .0114	.3861± .0163	.4377± .0155	.3911± .0163	----------	− .7608± .0081	.1302± .0189	.1171± .0189
		119	.5727± .0182	.3958± .0229	.3284± .0242	.2878± .0249	----------	− .6775± .0147	.1178± .0267	.1457± .0265
		120	.6207± .0147	.4336± .0194	.3171± .0215	.2821± .0220	----------	− .8064± .0084	.1064± .0236	.1089± .0236
		133	.6344± .0162	.3983± .0228	.4576± .0214	.4228± .0223	----------	− .7256± .0128	.0848± .0269	.1252± .0267
G	Percentage of grain	77	− .0502± .0192	− .0285± .0192	− .0664± .0191	− .0838± .0191	− .7608± .0081	----------	.1057± .0190	.1478± .0188
		119	.0533± .0270	− .0253± .0271	.0259± .0271	.0140± .0271	− .6775± .0147	----------	.1072± .0268	.1274± .0267
		120	− .1061± .0236	− .1493± .0234	− .0636± .0238	− .0309± .0239	− .8064± .0084	----------	.0465± .0238	.0687± .0238
		133	.0193± .0271	.0191± .0271	− .0892± .0269	− .0756± .0269	− .7256± .0128	----------	.1096± .0268	.1416± .0266
H	Number of rows	77	.3549± .0168	− .0205± .0192	.5164± .0141	.4769± .0148	.1302± .0189	.1057± .0190	----------	− .0835± .0191
		119	.3232± .0243	− .0630± .0270	.4814± .0208	.4465± .0217	.1178± .0267	.1072± .0268	----------	− .0571± .0270
		120	.2383± .0225	− .1414± .0234	.5043± .0178	.4449± .0192	.1064± .0236	.0465± .0238	----------	− .2128± .0228
		133	.2358± .0256	− .0388± .0271	.4294± .0221	.4283± .0221	.0848± .0269	.1096± .0268	----------	− .1125± .0268
I	Number of kernels per row	77	.3788± .0164	.5527± .0134	− .0022± .0192	− .0749± .0191	.1171± .0189	.1478± .0188	− .0835± .0191	----------
		119	.4169± .0224	.5795± .0180	− .0273± .0271	− .0545± .0270	.1457± .0265	.1274± .0267	− .0571± .0270	----------
		120	.3329± .0213	.5445± .0168	− .1982± .0230	− .2061± 0229	.1089± .0236	.0687± .0238	− .2128± .0228	----------
		133	.3813± .0232	.5552± .0187	.0005± .0271	− .0405± .0271	.1252± .0267	.1416± .0266	− .1125± .0268	----------

TABLE 7.—*Coefficients of partial correlation between some of the ear characters studied*

Designation of coefficient	C. I. No. 77	C. I. No. 119	C. I. No. 120	C. I. No. 133
$r_{BH \cdot D}$	0.0398±0.0192	0.0630±0.0270	−0.0017±0.0239	−0.0252±0.0271
$r_{DI \cdot C}$	.0665± .0191	.1037± .0268	.0054± .0239	.0614± .0270
$r_{HI \cdot CD}$	−.0832± .0191	−.0188± .0271	−.0963± .0238	−.0877± .0269
$r_{BF \cdot CD}$	.3486± .0169	.2946± .0247	.3291± .0213	.3527± .0237
$r_{GH \cdot D}$	.1638± .0187	.1081± .0268	.0912± .0237	.1644± .0264
$r_{GI \cdot C}$	.1963± .0185	.1744± .0263	.1809± .0231	.1575± .0264

Considering the data in Tables 6 and 7 together, the correlations indicate three natural groups of characters: (1) Weight of ear with its component elements, length of ear, circumference of ear at butt and tip, and weight of cob; (2) percentage of grain; and (3) the number of rows of kernels and the number of kernels per row.

Number of rows and number of kernels per row are correlated negligibly with weight of ear when circumference and length of ear are made constant. Weight of cob, on the other hand, has a direct relation to weight of ear apart from the length and circumference of the ear. Finally, the number of rows and number of kernels per unit of circumference or length do not seem to have as important a relation to the percentage of grain as might be expected from the emphasis that formerly was placed on tight-fitting kernels.

CORRELATIONS BETWEEN THE EAR CHARACTERS AND YIELD

COEFFICIENTS OF THE ZERO AND FIRST ORDERS

The coefficients of correlation of the zero and first orders for yield with each of the eight characters of seed ears are shown in Table 8. Coefficients more than three times their respective probable errors are printed in boldfaced type and will be referred to as significant. Coefficients less than three times their errors will be referred to as nonsignificant. The smallest of the significant coefficients, that of −0.0583 between yield and butt circumference for constant weight of cob in C. I. No. 77, is equivalent to one of 0.18+ on the basis of interpretation already discussed. On the same basis the largest coefficient, that of 0.2088 between yield and weight of cob for constant percentage of grain in C. I. No. 77, is equivalent to one of 0.66+.

Yield is correlated positively with weight of ear regardless of what other character may be constant, except weight of cob in C. I. No. 77. Making weight of ear constant decreases the positive and increases the negative significant correlations between yield and the other characters except weight of cob in C. I. No. 77.

The relations between yield and length of ear are much like those between yield and weight of ear, but somewhat less important. This is true particularly in C. I. No. 133 when butt circumference is constant. The similarity in the relations of yield with weight and length of ear extends to the effect that making each constant has upon the correlations with other characters. That length is less important than weight of ear is shown by the smaller coefficients between yield and length and particularly by the smaller correlations of yield with length for constant weight of ear than of yield with weight for constant length of ear.

TABLE 8.—*The correlations of the zero and first orders between yield and each of eight characters of seed ears*

Variable associated with yield	Symbol	C. I. No.	Total correlation between yield (A) and the variable given in column 1	Partial correlation of the first order between yield (A) and the variables designated in column 1 when each of the variables is made constant as stated — Constant variables: B Weight of ear	C Length of ear	D Butt circumference	E Tip circumference	F Weight of cob	G Percentage of grain	H Number of rows	I Number of kernels per row
1	2	3	4	5	6	7	8	9	10	11	12
Weight of ear	r_{AB}	77	0.0279±0.0192	-------	0.0284±0.0192	0.0355±0.0192	0.0179±0.0192	−0.0642±0.0191	0.0289±0.0192	0.0641±0.0191	0.0726±0.0191
		119	.1605±.0264	-------	.0914±.0269	.1594±.0264	.1897±.0261	.1539±.0265	.1579±.0264	.2013±.0260	.1642±.0264
		120	.1526±.0233	-------	.0849±.0237	.1524±.0233	.1621±.0233	.0817±.0237	.1467±.0234	.1554±.0233	.1391±.0234
		133	.1014±.0269	-------	.0617±.0270	.0512±.0270	.0840±.0269	.0526±.0270	.1021±.0268	.1129±.0268	.1042±.0268
Length of ear	r_{AC}	77	.0087±.0192	−0.0103±0.0192	-------	.0087±.0192	.0092±.0192	−.0414±.0192	.0093±.0192	.0069±.0192	.0790±.0191
		119	.1466±.0265	.0633±.0270	-------	.1480±.0265	.1463±.0265	.1339±.0266	.1484±.0265	.1418±.0266	.1606±.0264
		120	.1417±.0234	.0628±.0238	-------	.1472±.0234	.1461±.0234	.0890±.0237	.1336±.0235	.1441±.0234	.1268±.0235
		133	.0861±.0269	.0303±.0271	-------	.0761±.0269	.0818±.0269	.0524±.0270	.0868±.0269	.0849±.0269	.0947±.0269
Butt circumference	r_{AD}	77	.0008±.0192	−.0220±.0192	.0004±.0192	-------	−.0250±.0192	−.0583±.0191	.0021±.0192	.0552±.0191	.0006±.0192
		119	.0529±.0270	−.0494±.0270	.0566±.0270	-------	.0933±.0269	.0351±.0271	.0515±.0270	.1105±.0268	.0537±.0270
		120	.0391±.0239	−.0384±.0239	.0562±.0238	-------	.0361±.0239	−.0069±.0239	.0350±.0239	.0412±.0239	.0532±.0238
		133	.1020±.0268	.0524±.0270	.0938±.0269	-------	.0888±.0269	.0656±.0270	.0994±.0268	.1297±.0266	.1020±.0268
Tip circumference	r_{AE}	77	.0234±.0192	.0094±.0192	.0236±.0192	.0342±.0192	-------	−.0261±.0192	.0251±.0192	.0755±.0191	.0158±.0192
		119	−.0101±.0271	−.1029±.0268	.0039±.0271	−.0776±.0269	-------	−.0287±.0271	−.0109±.0271	.0340±.0271	−.0086±.0271
		120	.0204±.0239	−.0589±.0238	.0414±.0239	−.0138±.0239	-------	−.0212±.0239	.0184±.0239	.0193±.0239	.0347±.0239
		133	.0570±.0270	.0002±.0271	.0502±.0270	−.0269±.0271	-------	.0182±.0271	.0546±.0270	.0797±.0269	.0576±.0270
Weight of cob	r_{AF}	77	.1208±.0190	.1338±.0189	.1273±.0189	.1340±.0189	.1213±.0189	-------	.2038±.0184	.1341±.0189	.1345±.0189
		119	.0603±.0270	−.0391±.0271	.0025±.0271	.0455±.0270	.0660±.0270	-------	.0282±.0271	.0718±.0270	.0570±.0270
		120	.1437±.0234	.0632±.0238	.0922±.0237	.1386±.0234	.1438±.0234	-------	.1533±.0233	.1438±.0234	.1377±.0234
		133	.0960±.0268	.0412±.0271	.0675±.0270	.0558±.0270	.0795±.0269	-------	.1037±.0268	.0994±.0268	.0951±.0269
Percentage of grain	r_{AG}	77	.0193±.0192	.0207±.0192	.0196±.0192	.0194±.0192	.0213±.0192	.1726±.0186	-------	.0290±.0192	.0350±.0192
		119	.0584±.0270	.0506±.0270	.0628±.0270	.0571±.0270	.0585±.0270	.0239±.0271	-------	.0688±.0270	.0554±.0270
		120	−.0660±.0238	−.0507±.0238	−.0458±.0238	−.0637±.0238	−.0654±.0238	.0852±.0237	-------	−.0664±.0238	−.0708±.0238
		133	−.0340±.0271	−.0362±.0271	−.0358±.0271	−.0251±.0271	−.0298±.0271	.0521±.0270	-------	−.0304±.0271	−.0363±.0271
Number of rows	r_{AH}	77	−.0896±.0190	−.1065±.0190	−.0894±.0190	−.1051±.0190	−.1147±.0189	−.1070±.0190	−.0922±.0190	-------	−.0990±.0190
		119	−.0905±.0269	−.1524±.0265	−.0823±.0269	−.1325±.0266	−.0961±.0268	−.0985±.0268	−.0975±.0268	-------	−.0891±.0269
		120	.0070±.0239	−.0306±.0239	.0276±.0239	−.0147±.0239	−.0023±.0239	−.0084±.0239	.0101±.0239	-------	.0210±.0239
		133	−.0350±.0271	−.0609±.0270	−.0318±.0271	−.0877±.0269	−.0659±.0270	−.0435±.0270	−.0315±.0271	-------	−.0337±.0271
Number of kernels per row	r_{AI}	77	−.1027±.0190	−.1224±.0189	−.1290±.0189	−.1027±.0190	−.1013±.0190	−.1185±.0189	−.1067±.0190	−.1110±.0190	-------
		119	.0272±.0271	−.0443±.0270	−.0716±.0270	.0287±.0271	.0267±.0271	.0186±.0271	.0200±.0271	.0222±.0271	-------
		120	.0653±.0238	.0156±.0239	−.0143±.0239	.0746±.0238	.0710±.0238	.0505±.0238	.0702±.0238	.0670±.0238	-------
		133	.0133±.0271	−.0276±.0271	−.0416±.0271	.0133±.0271	.0156±.0271	.0013±.0271	.0183±.0271	.0094±.0271	-------

The total correlations between yield and butt circumference are positive, but only that in C. I. No. 133 is significant. The varietal difference indicated extends through the partial correlations, larger butt circumference apparently being desirable in C. I. No. 133. All of the correlations between yield and butt circumference for constant number of rows are positive and are the largest between this character and yield. In spite of the fact that only two are significant, this indicates that a larger butt circumference is more desirable when it is unaccompanied by an increase in the number of rows of kernels. One interesting correlation is that between yield and butt circumference for constant tip circumference in C. I. No. 119. Inasmuch as butt and tip circumference are correlated positively, this positive partial correlation indicates that the less cylindrical ears perhaps were the more productive in C. I. No. 119.

Only two of the correlations between yield and tip circumference are significant. That for constant weight of ear in C. I. No. 119 is negative, and that for constant number of rows in C. I. No. 77 is positive. There is nothing in the data to show any particular relation between yield and tip circumference.

The correlations between yield and weight of cob are much like those for yield with weight and length of ear. The total correlations between yield and weight of cob are perhaps the most consistent of any in the varieties as a whole. Only in C. I. No. 119 is the coefficient nonsignificant. In C. I. No. 77 the only positive correlation between yield and any character when weight of cob is constant is that with percentage of grain. In this variety, therefore, weight of cob is more important in relation to yield than weight of ear or any of its other factors. In the other varieties weight of ear apparently is more important.

The correlations between yield and percentage of grain are neither significant nor consistent except when weight of cob is constant. The data do not indicate any important relation between yield and percentage of grain, as such.

The total correlations between yield and number of kernel rows are negative in three varieties, being significant in two. The coefficient for this relation in C. I. No. 120, which had a mean of only 13 rows, is negligible. With the exception of C. I. No. 120 the correlations between yield and number of rows are negative throughout. When butt circumference is made constant the correlations are negative in all four varieties and significant in three of them. In connection with the positive correlations between yield and butt circumference for constant number of rows there is every indication that larger numbers of kernel rows are unfavorable to yield but that this is offset to some extent by the fact that a larger circumference, which usually accompanies an increase in the number of rows, is favorable to yield. That the correlations in C. I. No. 120 are nonsignificant throughout indicates that the relation between yield and number of rows is not rectilinear and that the number of rows in C. I. No. 120 is near the lower limit for this relation.

The relations between yield and number of kernels per row are much the same as those between yield and number of rows. The total correlations mean little because the number of kernels per row is strongly correlated with length of ear, a character apparently favorable to yield. When length of ear is made constant, the correlations between yield and number of kernels per row are negative in every case, though significant only in C. I. No. 77. The fact that the total correlation in this variety is negative and significant probably is only a reflection of the negligible correlation between yield and length of ear.

The correlations between yield and number of rows for constant butt circumference and for yield and number of kernels per row for constant length of ear indicate in a general way a positive relation of breadth and thickness of kernel to yield. This is not absolute, because other factors also are involved in determining the number of kernels per unit of circumference or length. The negative coefficients for these relations, however, indicate that the ears with wider, thicker kernels were more productive.

COEFFICIENTS OF MULTIPLE CORRELATION

The coefficients of multiple correlation between yield and various combinations of seed-ear characters are shown in Table 9. Perhaps the most striking difference is in the extent to which any characters were correlated with yield in the different varieties. The squares of these coefficients measure the degree to which variation in yield is a function of variation in the seed-ear characters considered. Thus, 2.5 per cent of the total variation in yield of C. I. No. 133 was a function of variation in seven characters of the seed ears and could be predicted from the multiple regression equation involving these characters. Similarly 6.7 per cent of the total variation in yield in C. I. No. 119 could be predicted from the equation for the same characters.

TABLE 9.—*Coefficients of multiple correlation between yield and various combinations of ear characters, ranked according to their relative importance*

Average rank	Designation of coefficient	C. I. No. 77		C. I. No. 119		C. I. No. 120		C. I. No. 133	
		R	Rank	R	Rank	R	Rank	R	Rank
1	$R_{A(BCDEFHI)}$	0.2114	1	0.2590	1	0.1771	1	0.1582	1
2	$R_{A(BCDEHI)}$	.1913	2	.2501	2	.1684	2	.1577	2
3	$R_{A(BCDHI)}$	.1905	3	.2389	5	.1657	4	.1565	3
4	$R_{A(BCEHI)}$	.1903	4	.2466	4	.1681	3	.1328	7
5	$R_{A(BDEHI)}$	.1888	7	.2487	3	.1640	7	.1462	4
6	$R_{A(BCHI)}$	.1900	5	.2388	6	.1657	5	.1306	8
7	$R_{A(BDEH)}$	.1215	9	.2324	8	.1636	8	.1446	5
8	$R_{A(BHI)}$	.1894	6	.2339	7	.1557	10	.1254	9
9	$R_{A(BCI)}$	.1345	8	.1901	10	.1653	6	.1151	11
10	$R_{A(DEH)}$	.1172	10	.1545	11	.0435	11	.1346	6
11	$R_{A(BDE)}$	.0458	11	.1917	9	.1633	9	.1206	10

The coefficients of multiple correlation do not show whether the relations between yield and the independent variables are positive or negative. This may be determined, however, from the regression equations. In the regression equations involving all seven ear characters, yield is related to the different characters as shown in Table 10.

Yield is related positively to weight of ear and length of ear and negatively to number of rows and number of kernels per row in all of the varieties. Similarly, the relation of yield to butt circumference and weight of cob is positive and to tip circumference is negative in three of the four varieties.

TABLE 10.—*Direction of the relations between yield and seven characters of seed ears, as determined from the multiple regression equations for yield on these characters*

Variety	Positive relations	Negative relations
C. I. No. 77	*B C E F*	*H I D*
C. I. No. 119	*B C D*	*H I E F*
C. I. No. 120	*B C D F*	*H I E*
C. I. No. 133	*B C D F*	*H I E*

The differences between the multiple correlation coefficients involving different combinations of characters provide a measure of the relative importance of the different characters. It is evident that only a few ear characters contribute significantly to the relations shown by the higher order coefficients. On the basis of this information the following additional coefficients have been computed. In C. I. No. 77 $R_{A(FHI)}$ is 0.2062, in C. I. No. 119 $R_{(ABH)}$ is 0.2201, and in C. I. No. 133 $R_{A(BDH)}$ is 0.1427. In C. I. No. 120 weight of ear is the one important factor ($r_{AB}=0.1526$), and there is little gain from including any other characters in the regression equation.

DISCUSSION

Considering the data as a whole and bearing in mind the varietal differences, several rather general tendencies are apparent. A positive relation between yield and weight of ear and negative relations between yield and number of rows per unit of circumference and number of kernels per unit of length are the most important of these. Positive relations between yield and length of ear, weight of cob, and butt circumference are less important or consistent. Of the variation in yield other than that due to experimental fluctuation, from 20.4 per cent in C. I. No. 133 to 48.4 per cent in C. I. No. 119 could be predicted from regression equations involving one to three ear characters on the basis of the previous interpretation. Disregarding this interpretation, from 2.04 to 4.84 per cent of the total variation in yield was a function of variation in one to three characters of the seed ears.

Perhaps the fact of greatest interest from the breeder's point of view is the negative relation between yield and number of rows. Relatively few rows certainly mean relatively wide kernels, but it is far from certain that this is the fundamental connection between number of rows and yield. The volume of an ear increases with the square of the diameter and only directly with the length. It therefore should be possible to increase yield more readily by adding to the circumference than to the length of the ear. Kyle and Stoneberg (*4*) have shown that this is true, in fact, when only the bearing plants were considered. When all plants were considered, the larger numbers of barren plants in the many-rowed strains were enough to result in larger yields from ears of smaller circumference. Their data (*4*) on the greater smut susceptibility, barrenness, chlorophyl abnormalities, and general undesirability in selfed strains with the relatively larger numbers of rows are highly suggestive in this connection. If few-rowedness be looked upon as a more primitive, less specialized condition, it is easy to understand why the more complex mechanism should break down more frequently. Unfortunately, the basic data in the present case were not suitable for differentiating between the effects of kernel size and number of rows. This possible negative relation between yield and number of rows per se is one that should be kept in mind.

There is nothing in the data to indicate that selection on the basis of seed-ear characters could be used as a method of breeding. At the same time, the tendencies shown are of interest in connection with the mass selection of seed corn. The ears studied represented a carefully selected population, already above the average of the varieties in length, circumference, and weight. The positive correlations between yield and weight of ear in this selected population indicate that the selection of larger ears for seed is worth while. They also seem to warrant the recommendation to select the longer, heavier ears with proportionately heavy cobs and with relatively few rows of wide, thick kernels. This is in substantial agreement with most of the results of comparisons made by other investigators (*7*). Larger butt circumference seems more desirable if unaccompanied by an increase in the number of rows, but whether it is desirable in any event appears to depend upon the variety. It should be noted that, with the possible exception of number of kernel rows, the relations indicated are of size rather than form and that the kind of ear indicated as better may be described as a large ear with large kernels and a proportionately heavy cob.

SUMMARY

Data from ear-to-row plats in four varieties of corn, comprising 3,265 ears in all and extending over 47 crop years, were studied as to possible relations between productiveness and some physical characters of the seed ears.

(1) Accidental variation in soil and experimental conditions was responsible for a large part, possibly 90 per cent, of the total variation in yield.

(2) From 2.5 to 6.7 per cent of the total variation in yield in the different varieties was a function of variation in the ear characters studied.

(3) On the basis of the multiple regression equations involving seven ear characters, yield was related positively to weight of ear and length of ear and negatively to number of rows and number of kernels per row in each of the four varieties. Similarly, yield was related positively to butt circumference and weight of cob and negatively to tip circumference in each of three varieties, the relations being reversed in the fourth variety.

(4) The use of weight of ear, number of rows, and number of kernels per row in a multiple regression equation gave almost as good a predicting equation in each of the varieties as the inclusion of the four other characters and was the best general predicting equation involving only three characters.

(5) Because of varietal differences, the substitution of weight of cob for weight of ear in C. I. No. 77 and butt circumference for number of kernels per row in C. I. No. 133 gave a better three-character predicting equation in these varieties than that mentioned in paragraph 4.

(6) Selecting longer, heavier ears with proportionately heavy cobs and with relatively few rows of wide, thick kernels is warranted as a means of obtaining a supply of good seed for general planting.

(7) Selection from among good seed ears on the basis of ear characters as a method of corn breeding is not warranted.

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