FACTORS AFFECTING THE POPPING QUALITY OF POP CORN [1]

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INTRODUCTION

Only during the last half century has corn popping developed into an industry of commercial importance. The resulting demand for pop corn has given the stimulus necessary to the growing of the crop in a large way and has expanded the acreage very considerably.

The quality of pop corn depends upon its palatability or flavor and upon its popping expansion. Although it is commonly recognized that great differences exist in the "poppability" of different varieties and in various lots of the same variety, the matter seems not to have been studied in a critical way.

All starchy corns may be placed in one of the four classes— pop corn, flint corn, dent corn, or flour corn—on the basis of
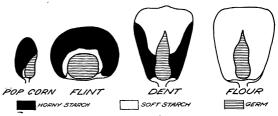

FIG. 1.—Diagrammatic representation of location and relative proportions of horny starch and soft starch in the four main classes of starchy corn

distribution and relative proportions of hard and soft starch in the endosperm. The endosperm of the best strains of pop corn is corneous throughout or contains only a small core of soft starch near the center. (Fig. 1.) In flint corn the endosperm consists of a small quantity of soft starch, near the embryo, completely surrounded by corneous starch. In dent corn the corneous starch is confined mainly to the sides of the kernels, soft starch constituting a larger proportion than in flint corn. In flour corn the endosperm is entirely of soft starch except for vestigial traces of hard starch.

The popping properties of the various types of corn follow rather closely the relative proportions of hard or corneous starch in the endosperm. Pop corn, with the greatest proportion of hard starch of any of the four types, is far better than the others in poppability. Flint corn may pop poorly to fairly well, depending on the strain. Dent corn rarely will pop at all, though occasionally a few kernels will pop feebly. Flour corn will not pop at all.

It is generally conceded that the popping process is due to the sudden liberation of pressure produced by steam generated within the kernel.[2] The source of the steam is the moisture contained in

the kernel and perhaps to a limited extent, also, water of constitution produced by partial breaking down of the starch molecule when heated.[3] The confining structure, according to Weatherwax, is the colloidal matrix in which the starch grains are embedded within the cell. The success of the explosion in expanding the kernel and completely disrupting its original structure to produce a uniform and tender product depends upon three conditions: (1) Optimum moisture content, (2) an elastic and tenacious confining structure, and (3) proper application of heat.

The first and third of these conditions, viz, optimum moisture content and proper application of heat, may be controlled at the time of popping. The second condition, however, is a property of the endosperm and varies with the sample. It is believed that differences in the poppability of various strains are definitely inherited and that the properties of endosperm structure have a genetic factorial basis, although the mode of inheritance is undoubtedly complicated. As a preliminary step in testing the possibilities of pop corn improvement through breeding, this paper is concerned chiefly with a study of the degree of association between certain morphological kernel characters and popping yield.

EXPERIMENTAL METHODS

With the exception of tests covering the influence of moisture content on poppability, all of the corn used in these experiments was of uniform and probably nearly optimum moisture content. The popping trials were conducted at Washington, D. C., during the winter months. Until the time of popping the samples were stored in an outside shelter protected from direct precipitation but subject to continuous free circulation of air.

The popping trials were made in a wire popper over a gas burner. A wire gauze over the burner helped to give a more uniform distribution of heat. The flame was adjusted so that popping would commence in about one and one-half minutes, which time had previously been found to give the best results. A wire swing for the popper assured a constant distance between the corn and the source of heat.

The index of poppability used in this paper is the ratio of the volume after popping to the volume of the unpopped corn, and for convenience is termed "expansion." Glass graduates were used to measure volumes both before and after popping. A uniform sample 20 cubic centimeters in volume was used throughout for popping, and, except where otherwise stated, the expansion is based on duplicate determinations. The expansion was determined only to the nearest whole number. Besides expansion, six characters of the unpopped kernels were considered, viz, percentage of soft starch, weight of 100 kernels, size as measured inversely by the number of kernels in 25 cubic centimeters, length of kernels, breadth of kernels, and thickness of kernels.

The proportion of soft starch in the endosperm did not lend itself to any simple exact measurement and therefore was estimated. Ten random kernels from each ear were split lengthwise and the halves glued to cardboard. The percentage of soft starch then was esti-

[3] CARR, R. H., and RIPLEY, E. F. WHAT PUTS "POP" IN POP CORN? Ind. Acad. Sci. Proc. 1920: 261–270, illus. 1921.

mated for each kernel separately, and the average of the 10 estimates was taken as the soft-starch content for the ear as a whole. The final ratings were not made until after a preliminary survey had given an intimate acquaintance with the material and had fixed the standards firmly in mind, so that it is thought that the estimates present a very fair basis for purposes of comparison.

Weight of kernels was obtained by weighing 100 kernels from each ear. Another measurement which is highly correlated negatively with weight was also taken, namely, the number of kernels in a measured volume of 25 cubic centimeters. Length of kernel was measured by laying 10 kernels end to end in a groove and dividing the total length in millimeters by 10. Breadth of kernel and thickness of kernel (from germinal to abgerminal face) were obtained similarly.

INFLUENCE OF MOISTURE CONTENT ON POPPABILITY

It is well recognized that the moisture content of pop corn has an important influence on its poppability. Carr and Ripley,[4] however, state that within comparatively wide ranges the moisture content has little effect on popping expansion. Weatherwax,[5] taking a similar view, expresses the opinion that, although maximum, minimum, and optimum moisture contents are indicated, the range is wide. In an exhaustive study on the effect of moisture content and other factors on popping, Stewart[6] concludes that "a moisture content of 13 to 15 per cent appears to be the most favorable for maximum popping yield." He states also that, under New York conditions, outside storage from October to April will give a moisture content approaching the optimum.

TABLE 1.—*Expansion of successive 12-ear samples of White Rice pop corn taken while drying, showing relation between moisture content and poppability*

Sample No.	Moisture (per cent)	Expansion (volumes)	Sample No.	Moisture (per cent)	Expansion (volumes)	Sample No.	Moisture (per cent)	Expansion (volumes)
1	17.0	2	11	11.9	18	21	9.1	11
2	15.6	7	12	11.9	17	22	8.3	9
3	15.6	5	13	11.9	16	23	8.1	6
4	14.2	12	14	10.6	16	24	7.4	7
5	13.6	15	15	10.5	15	25	7.4	8
6	13.6	14	16	10.1	16	26	7.2	6
7	12.7	17	17	10.1	14	27	6.9	8
8	12.7	16	18	9.6	10	28	6.3	7
9	12.6	17	19	9.5	12			
10	12.6	16	20	9.2	11			

A stock of White Rice pop corn grown at Oconomowoc, Wis., was divided into a number of samples of 12 ears each, and successive moisture and popping determinations were made as the samples were drying. Each sample of 12 ears was shelled and thoroughly mixed before testing. The data for these tests are given in Table 1

4 CARR, R. H., and RIPLEY, E. F. Op. cit.
5 WEATHERWAX, P. Op. cit.
6 STEWART, F. C. THE RELATION OF MOISTURE CONTENT AND CERTAIN OTHER FACTORS TO THE POPPING OF POP CORN. N. Y. State Agr. Expt. Sta. Bul. 505, 70 p., illus. 1923.

and are shown graphically in Figure 2. Each value for expansion is the mean of several determinations made from a given 12-ear sample. About 12 per cent appears to be the optimum moisture content for greatest expansion in this sample.

RELATION OF KERNEL CHARACTERS TO POPPABILITY IN WHITE RICE POP CORN

One hundred ears of White Rice pop corn grown, harvested, and cured under as nearly identical conditions as possible formed the material for a preliminary study of the relation of kernel characters to poppability. Data were obtained for the weight of 100 kernels, the number of kernels in a 25 cubic centimeter volume, the percentage
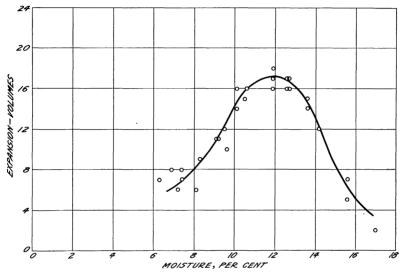

Fig. 2.—Relation between moisture content and popping expansion in White Rice pop corn

of soft starch, and the expansion for each ear. The expansion on popping ranged from 5 to 25 volumes. The ears were grouped into seven classes according to expansion, and the average obtained in each group for the various characters noted is shown in Table 2.

There is a distinct tendency for the size of the kernels to decrease as the expansion increases. In other words, the ears giving the greater increase in volume on popping tend on the average to have smaller kernels. This is true when kernel size is measured either by the weight of 100 kernels or by the number of kernels in 25 cubic centimeters. In group A the average expansion is 6.0, the average weight of 100 kernels is 15.5 gms., and the average number of kernels in 25 cubic centimeters is 130. At the other extreme, in group G, with an average expansion of 24.2, the weight of 100 kernels is only 11.6 gms. and the average number of kernels in 25 cubic centimeters is 177.4.

TABLE 2.—*Relation between certain kernel characters and popping quality of White Rice pop corn, as shown by the mean values of these characters when a population is grouped on the basis of expansion*

[Correlation of expansion with weight of 100 kernels, −0.57±0.046; with number of kernels in 25 c. c., 0.56 ±0.046; and with per cent of soft starch, −0.55±0.047]

Group	Range of expansion (volumes)	Number of ears	Average			
			Weight of 100 kernels (grams)	Number of kernels in 25 cubic centimeters	Percentage of soft starch	Expansion (volumes)
A	5–7	12	15.5	130	11.2	6.0
B	8–10	14	15.2	136	9.9	9.4
C	11–13	20	14.0	148	7.8	12.0
D	14–16	20	14.1	145	8.2	15.0
E	17–19	11	12.9	158	7.2	17.9
F	20–22	13	11.4	180	3.8	20.5
G	23–25	10	11.6	177	2.6	24.2

The relation of percentage of soft starch to poppability also is pronounced. Group A has an average soft-starch content of 11.2 per cent, whereas group G, with the largest popping expansion, has an average soft-starch content of only 2.6 per cent. There is a consistent decrease in the soft-starch content from group to group when the groups are arranged in ascending order on the basis of expansion.

The tendencies shown in these groupings suggest at once the probability of significant correlations between expansion and the three kernel characters measured. The correlation coefficients were calculated and are shown in Table 2. These coefficients are all about twelve times their probable errors and are of undoubted significance.

INFLUENCE OF KERNEL CHARACTERS ON POPPABILITY IN YELLOW PEARL POP CORN

In order to verify and amplify the results of the preliminary studies, a second experiment was planned, in which a larger number of ears of another variety was used, and the scope of the work was extended to include three additional kernel measurements. A sample of 394 ears of Yellow Pearl, which had uniform conditions for growth and curing, was used as the experimental material. The weight of 100 kernels, number of kernels in 25 cubic centimeters, percentage of soft starch, and expansion were determined as before. In an attempt to analyze further the relation between kernel size and expansion, the three additional measurements of length, breadth, and thickness of kernels were also taken.

TABLE 3.—*The means, standard deviations, and coefficients of variability of the various characters studied in a group of 394 ears of Yellow Pearl pop corn*

Symbol	Character	Mean	Standard deviation	Coefficient of variability
V	Expansion_____volumes	24.20±0.078	2.29±0.055	9.45±0.229
S	Percentage of soft starch_____	8.09±.139	4.09±.098	50.59±1.495
W	Weight of 100 kernels_____grams	15.05±.060	1.77±.043	11.78±.287
N	Number of kernels in 25 cubic centimeters	143.10±.574	16.90±.406	11.81±.288
L	Length of kernel_____millimeters	8.08±.015	.45±.011	5.52±.133
B	Breadth of kernel_____do	5.70±.011	.33±.008	5.72±.138
T	Thickness of kernel_____do	3.48±.009	.28±.007	8.01±.194

The ordinary statistical constants of the various measurements, together with the symbols used hereafter for the various characters, are shown in Table 3.

<div align="center">GROSS CORRELATIONS</div>

The coefficients of correlation between expansion and each of the kernel characters and also those between the various combinations of kernel characters, are given in Table 4.

TABLE 4.—*Gross correlations between all possible combinations of the various characters studied in a sample of 394 ears of Yellow Pearl pop corn*

Character	Expansion (volumes) V	Percentage of soft starch S	Weight of 100 kernels (grams) W	Number of kernels in 25 cubic centimeters N
Expansion...............V..		−0. 59±0. 022	−0.31±0.031	0. 38±0. 029
Percentage of soft starch.............S..	−0. 59±0. 022		.42± .028	−.47± .026
Weight 100 kernels.................W..	−. 31± .031	.42± .028		−.84± .010
Number of kernels in 25 cubic centimeters.......................N..	.38± .029	−.47± .026	−.84± .010	
Length of kernels....................L..	−.44± .028	.19± .033	.09± .034	−.12± .033
Breadth of kernels..................B..	−.29± .031	.15± .033	.16± .033	−.18± .033
Thickness of kernels..................T..	−.17± .033	.17± .033	.08± .034	−.13± .033

Character	Length of kernels (millimeters) L	Breadth of kernels (millimeters) B	Thickness of kernels (millimeters) T
Expansion........................... V..	−0. 44±0. 028	−0. 29±0. 031	−0.17±0.033
Percentage of soft starch.............................S..	.19± .033	.15± .033	.17± .033
Weight 100 kernels..................................W..	.09± .034	.16± .033	.08± .034
Number of kernels in 25 cubic centimeters...........N..	−.12± .033	−.18± .033	−.13± .033
Length of kernels...................................L..		.19± .033	.07± .034
Breadth of kernels.................................B..	.19± .033		.09± .034
Thickness of kernels.............................T..	.07± .034	.09± .034	

The correlations between expansion and the first three kernel characters confirm the results of the preliminary study on White Rice pop corn, although the coefficients for weight of kernel and for number of kernels in a given volume are somewhat lower. The correlations involving expansion all show that within this sample those ears with the smaller kernels and those with kernels containing the least proportion of soft starch, in general, give the greatest increase in volume on popping. The percentage of soft starch in the endosperm had the greatest influence on popping yield of any of the kernel characters considered in this study, the coefficient of correlation in this case being −0.59 and 27 times its probable error. The conclusion that ears with the most horny and vitreous kernels tend to give the largest popping yields appears to be fully warranted.

The further analysis of the various relations shows that length, breadth, and thickness of kernel are all negatively correlated with the expansion. This would be expected, as these measurements largely determine the size of the kernel. The correlation of expansion is greatest with length of kernel and least with thickness of kernel. All of these correlation coefficients are statistically significant.

Considering the correlations of kernel characters among themselves, the greatest is between number of kernels per given volume and

weight of kernels and, of course, is negative. Interesting points brought out in Table 4 are the relatively high correlations between weight and starchiness (0.42 ± 0.028) and between size of kernels (as measured by number of kernels in 25 c. c.) and starchiness (-0.47 ± 0.026). These values indicate that large kernels are much more likely than small ones to have a large proportion of soft starch and suggest that one reason for the relatively poor popping quality of the ears with the larger kernels may be the associated higher percentage of soft starch which they contain.

The remaining correlations among the kernel characters are comparatively small. Those coefficients of 0.11 or more are over three times their probable errors and may be considered as probably significant. It is rather surprising that the correlations between weight of kernel and length, breadth, and thickness of kernel are not higher. Length and thickness are more highly correlated with starchiness than with weight, and breadth is correlated about equally with starchiness and with weight.

MULTIPLE CORRELATIONS

In the gross correlations considered in the previous paragraphs, the tendencies toward concomitant variation between poppability and certain individual kernel characters have been pointed out. These kernel characters, in turn, have been shown to be more or less highly correlated among themselves. In order to ascertain the relationships between expansion and the combined effect of all the other characters reported, or various groups of them, the method of multiple correlations was used. The coefficients of multiple correlations of expansion with various combinations of kernel characters are given in Table 5.

TABLE 5.—*Coefficients of multiple correlation between expansion and various combinations of kernel characters, ranked according to their numerical value*

[For explanation of symbols, see Table 3]

Characters	Coefficient (R)	Characters	Coefficient (R)	Characters	Coefficient (R)	Characters	Coefficient (R)
$V(SWNLBT)$	0.731	$V(SL)$	0.678	$V(SW)$	0.597	$V(WNBT)$	0..478
$V(SWNLB)$	.729	$V(SWNBT)$	.674	$V(WNLBT)$	.589	$V(NBT)$	.458
$V(SNLBT)$	.718	$V(SWNB)$	.673	$V(WNLB)$	.587	$V(LT)$	.457
$V(SWNLT)$	.715	$V(SWNT)$	.644	$V(NLBT)$	.587	$V(WNB)$	.445
$V(SWNL)$	.714	$V(SWN)$	.643	$V(NLB)$	.578	$V(WNT)$	.417
$V(SNLB)$	.701	$V(SNBT)$	.635	$V(WNLT)$	.564	$V(WBT)$	.416
$V(SWLBT)$	.697	$V(SNB)$	.633	$V(WNL)$	.561	$V(NB)$	.410
$V(SLBT)$	.696	$V(SWBT)$	.630	$V(NLT)$	.557	$V(NT)$	.402
$V(SWLB)$	.695	$V(SB)$	.629	$V(WLBT)$	.553	$V(WB)$	.395
$V(SLB)$	.694	$V(SWB)$	.628	$V(NL)$	.548	$V(WN)$	.355
$V(SNLT)$	.688	$V(SB)$	.626	$V(WLB)$	.541	$V(WT)$	.344
$V(SNL)$	.686	$V(SNT)$	.608	$V(WLT)$	.528	$V(BT)$	.325
$V(SWLT)$	.684	$V(SN)$	.604	$V(WL)$	.513		
$V(SWL)$	.681	$V(SWT)$	.601	$V(LBT)$	² .499		
$V(SLT)$	.681	$V(ST)$	.597	$V(LB)$	.482		

When all six kernel characters are considered with expansion, $R = 0.731$. This value for R may be substituted in the formula $100 (1 - \sqrt{1 - R^2})$ to find the proportion of variability in expansion directly associated with the kernel characters studied. The value obtained, 31.8 per cent, indicates that approximately one-third of this variability is accounted for by variations having to do with size

and starchiness of the unpopped kernels. Other factors, such, perhaps, as the size of the starch grains or the tenacity or elasticity of the surrounding matrix, may play an important part in determining the degree of expansion.

In the sample studied, however, fairly reliable predictions of poppability could be made on the basis of the size and soft-starch content of the kernels, two easily observable characters.

The importance of the influence of starchiness on popping quality may be noted from the fact that the correlation between expansion and percentage of soft starch ($r_{vs} = -0.593$, Table 4) is slightly greater than the multiple correlation between expansion and all the kernel characters studied other than starchiness (R_v ($_{WNLBT}$) = 0.589, Table 5).

PARTIAL CORRELATIONS

The partial correlation method is especially valuable for purposes of analysis in a study of this kind, in which several related characters are more or less highly correlated among themselves.

The various partial correlations resulting from the study are given in Table 6. In each case the first two letters indicate the variables for which the correlation is calculated with the characters indicated by the subsequent letters held constant. The coefficients, therefore, measure the correlation between expansion and one of the kernel characters, the influence of various combinations of the other characters being eliminated. The coefficients for any two characters are arranged in order of their magnitude.

The partial correlation coefficients for expansion and percentage of soft starch are high throughout, irrespective of what combinations of other characters are held constant. Of all the kernel characters studied, the proportion of soft starch seems to be most closely associated with popping expansion and to be most nearly free from influence by the other characters studied.

The partial correlations of expansion with weight of kernel present an interesting situation. The coefficients are all negative when the number of kernels is variable, but all positive in those combinations in which number of kernels is held constant. In other words, the popping expansion is highest in general in the lightest kernels, but in the case of kernels of a given size the popping expansion is slightly greater in the heavier ones. This suggests at once that probably there is a positive relation between popping expansion and specific gravity. The fact that pop corn has a considerably higher test weight per measured bushel than does field corn lends support to this hypothesis. No determinations of kernel density were made on the ears studied.

The partial coefficients for expansion with number of kernels per 25 cubic centimeters are all positive. There is a decided drop in those coefficients, however, in which starchiness is held constant. The smaller coefficients in every instance are combinations which contain starchiness as one of the constant factors.

The correlations of expansion with length of kernel are negative and are all of undoubted significance, the smallest coefficient being thirteen times its probable error. These coefficients differ little, irrespective of what characters are held constant.

TABLE 6.—*Partial correlations of expansion with each kernel character studied when various combinations of the other characters are held constant*

[For explanation of symbols see Table 3]

Characters	r	Characters	r	Characters	r	Characters	r
VS. T	−0.58	VW. NT	0.01	VL. T	−0.43	VB. WL	−0.20
VS. B	−.58	VW. NLBT	.01	VL. W	−.43	VB. SL	−.20
VS. L	−.58	VW. NL	.01	VL. WT	−.43	VB. SLT	−.20
VS. LB	−.57	VW. NBT	.02	VL. N	−.42	VB. WLT	−.19
VS. BT	−.57	VW. N	.02	VL. WN	−.42	VB. SWL	−.19
VS. LT	−.57	VW. NLB	.02	VL. NT	−.42	VB. WNL	−.19
VS. LBT	−.56	VW. NB	.03	VL. WNT	−.42	VB. NL	−.19
VS. W	−.54	VW. NSLT	.04	VL. SW	−.41	VB. SWLT	−.19
VS. WB	−.53	VW. NSL	.05	VL. S	−.41	VB. SWNL	−.19
VS. WT	−.52	VW. NST	.05	VL. SN	−.41	VB. WNLT	−.19
VS. WL	−.52	VW. NSLBT	.05	VL. SWT	−.41	VB. NLT	−.19
VS. WBT	−.52	VW. NSLB	.05	VL. SWN	−.41	VB. SWNLT	−.19
VS. WLB	−.52	VW. NS	.05	VL. ST	−.41	VB. SNLT	−.18
VS. WLT	−.51	VW. NSBT	.05	VL. SNT	−.41	VB. SNL	−.18
VS. WLBT	−.51	VW. NSB	.06	VL. SWNT	−.41	VT. L	−.16
VS. NW	−.51	VN. L	.37	VL. B	−.40	VT. W	−.16
VS. N	−.51	VN. T	.37	VL. WB	−.40	VT. B	−.15
VS. NWB	−.50	VN. LT	.36	VL. BT	−.40	VT. LB	−.15
VS. NB	−.50	VN. B	.35	VL. WBT	−.40	VT. WL	−.14
VS. NWT	−.50	VN. LB	.35	VL. NB	−.40	VT. WB	−.14
VS. NT	−.50	VN. BT	.34	VL. WNB	−.40	VT. WLB	−.13
VS. NWBT	−.50	VN. LBT	.34	VL. NBT	−.40	VT. N	−.13
VS. NWL	−.50	VN. W	.24	VL. WNBT	−.40	VT. WN	−.13
VS. NBT	−.50	VN. WL	.22	VL. SWB	−.39	VT. NL	−.12
VS. NWLB	−.49	VN. WB	.22	VL. SWNB	−.38	VT. WNL	−.12
VS. NL	−.49	VN. WT	.22	VL. SNBT	−.38	VT. NB	−.12
VS. NLB	−.49	VN. WLB	.22	VL. SWBT	−.38	VT. WNB	−.12
VS. NWLT	−.49	VN. WLT	.21	VL. SB	−.38	VT. NLB	−.11
VS. NWLBT	−.49	VN. WBT	.21	VL. SWNBT	−.38	VT. WNLB	−.11
VS. NLT	−.49	VN. WLBT	.20	VL. SBT	−.38	VT. S	−.09
VS. NLBT	−.49	VN. S	.15	VB. T	−.28	VT. SW	−.09
VW. T	−.30	VN. SL	.14	VB. W	−.26	VT. SL	−.08
VW. L	−.30	VN. ST	.14	VB. S	−.25	VT. SN	−.08
VW. LT	−.30	VN. SLT	.14	VB. WT	−.25	VT. SWL	−.08
VW. B	−.28	VN. SW	.13	VB. WN	−.25	VT. SWN	−.08
VW. LB	−.28	VN. SWL	.12	VB. N	−.25	VT. SWB	−.08
VW. BT	−.27	VN. SWT	.12	VB. SW	−.24	VT. SB	−.08
VW. LBT	−.27	VN. SLB	.12	VB. WNT	−.24	VT. SNL	−.07
VW. SL	−.09	VN. SLBT	.12	VB. NT	−.24	VT. SWLB	−.07
VW. SLT	−.09	VN. SB	.12	VB. SWT	−.24	VT. SLB	−.07
VW. S	−.09	VN. SWB	.12	VB. SWN	−.24	VT. SWNL	−.07
VW. ST	−.09	VN. SWLT	.12	VB. SN	−.24	VT. SNB	−.07
VW. SLBT	−.07	VN. SBT	.12	VB. SWNT	−.23	VT. SWLB	−.07
VW. SLB	−.07	VN. SWLB	.12	VB. SNT	−.23	VT. SNLB	−.07
VW. SBT	−.06	VN. SWBT	.11	VB. L	−.23	VT. SWNLB	−.06
VW. SB	−.06	VN. SWLBT	.11	VB. LT	−.22		
VW. NLT	.01	VL. SNB	−.43				

Correlations of 0.11 are more than three times their probable errors, those of 0.14 more than four times, those of 0.17 more than five times, those of 0.31 more than ten times, those of 0.43 more than fifteen times, and correlations of more than 0.51 are more than twenty times their probable errors.

The correlations between expansion and breadth of kernel and between expansion and thickness of kernel are all small, particularly those of the latter group.

DISCUSSION

Of the characters studied, the proportion of soft starch seems to be the outstanding determining influence. Sectioning kernels from each individual ear is rather tedious, and it requires experience to estimate with accuracy the relative amounts of soft starch. The high correlation between starchiness and size of kernel, however, may serve as a rough guide to eliminate many of the ears having the softest kernels. Growers frequently have a tendency to select large seed ears, which usually have kernels above the average in size and starchiness and may represent a more or less distant contamination with field corn. This practice should be avoided if quality is to be maintained.

The fact that the results of the two experiments here reported, made with samples from different varieties, confirm each other so closely lends support to the view that the relationships are of a general nature and are not limited to the varieties here considered. It should not be overlooked, however, that although some of the correlations are high the multiple correlation between expansion and all the kernel characters combined was only 0.731.   The associations between kernel characters and popping expansion should be a valuable aid in selection of pop corn for seed, but they can not entirely replace a popping test of prospective seed ears as a means of crop improvement.

SUMMARY

In pop corn a moisture content of about 12 per cent is optimum for greatest expansion in popping.

Within a given variety, those ears bearing kernels with the least soft starch are likely, on the average, to give the largest expansion in popping.

Similarly, those ears having smaller kernels are more likely to give a higher expansion on popping than those with larger kernels.

Study of these kernel characters should be a valuable aid in selecting seed to maintain and improve the popping quality of a strain of pop corn, although it can not wholly supplant an actual popping test of individual ears.