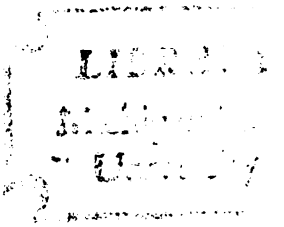

INVESTIGATIONS TO DETERMINE THE PROTEIN CONTENT OF STRAINS OF WHITE WHEAT

INVESTIGATIONS TO DETERMINE THE PROTEIN CONTENT OF STRAINS OF WHITE WHEAT

Thesis

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I - REASON FOR INVESTIGATIONS

White wheats, as grown in Michigan, have been found to contain "red" kernels in some years. Many of these "red" kernels are much more vitrous and translucent than the general run of the variety. Millers, supplying the demand for flour for the cracker and biscuit trade, consider that because these kernels are hard in texture that they are higher in protein content than the white grain. For this reason such white wheats are given a lower grade than they would receive if there were no red kernels in the lot.

These red grains are usually of three kinds:

(1) Those known by their shape and size not to belong to the white variety. This type is usually due to impure seed or to mechanical mixture during threshing and so is not considered in this thesis.

(2) Those which are red but have the same type of grain, as to shape and texture, as the variety. The question regarding these is, are these kernels due to crossing, or are they due to environmental conditions? This question will be discussed in this thesis.

(3) Those which are apparently red and have the shape of the white variety but they have a more vitrous texture than the common run of the variety. The questions with regard to these are, is the redness due to coloring or to a difference in translucency, or both? And, are these translucent grains harder

in texture and so higher in protein content than the non-translucent white kernels? These questions are discussed in this thesis.

The possibility of selecting strains of low protein content from among the white wheats used in this investigation is also discussed.

To answer these questions three methods have been followed. The first was to make plantings of the white chalky kernels and also of the apparently red kernels and to examine the progenies for segregations in color as well as vitrousness. The second line of attack was to develop a method of determining the hardness of the two types of kernels by a breaking or crushing machine. The third phase of the work was to make chemical analyses of the various kernel groups when classed according to the pressures needed to break them. This thesis deals in major part with the last two phases mentioned.

II - PREVIOUS INVESTIGATIONS

Roberts (1) tested the hardness of two strains of wheat by breaking samples containing 100, 150, 200, 250, and so on to 500 kernels. He took random samples and found that 350 kernels gave so small a probable error that it could be considered accurate. The kernels were broken by means of a machine which indicated the weight needed to crush each kernel. He dried the grains seven days at 100°C and kept them in a dessicator during the work. He found that soft wheats had a breaking pressure of about six

kilograms, semi-hard of nine kilograms and hard of twelve kilograms.

He (2) further determined the breaking pressure of ninety-four pure strains of wheat, but found no correlation between breaking pressure and protein content.

Shaw and Gaumnitz (3) used an apparatus made of a pair of pincers. They counted out five samples of 100 kernels each and by using different weights found how many kernels were crushed by each weight. They graded the kernels according to size and found within the variety the larger grains were harder to crush. They did not find any correlation between hardness and protein content.

Harper and Peters (4) devised a machine for cutting the grain by adding weights directly to a vertical piston and they considered this cutting method better than crushing. No correlation was found between breaking pressure and protein content.

Bryan and Pressley (5) found in a pedigreed strain of Early Baart wheat some grains of extremely hard and glossy texture. From 19 planted grains they obtained ten plants with hard seed only while the others had either soft grains or a mixture. The texture of the grain was the only noticeably differing character, so neither crossing nor mechanical mixture was the cause for this difference. They thus obtained ten hard grained lines which after four years growing under irrigation have kept the hardness unchanged. They are about two per cent higher in gluten and six per cent higher in absorption than the soft parent. Since Early Baart is considered

a pure strain for visible characters, this should mean that it would be possible to find different lines for certain characters within a variety already considered as a pure strain.

Freeman (6) found that some varieties at the Arizona station maintained their hardness while others softened. Hardness was judged by sight, that is, only translucent kernels were termed hard. He thinks the change in varietal texture was due to a natural sorting out and discarding of the less adapted strains in impure varieties. Also, that varieties considered pure for some characters, in reality are not necessarily pure strains for certain other characters.

According to the last two papers it also should be possible to find wheat strains of different hardness within a variety even if the variety is considered to be pure for some characters.

III - PRESENT INVESTIGATION

A. Material Used.

Three varieties of white wheat were chosen for this investigation - Early Windsor, O. A. C. No. 104, and American Banner. Early Windsor, O. A. C. No. 104, and one lot of American Banner were received from the Farm Crops Section of the local Experiment Station. Five samples of the latter variety were obtained through the Michigan Crop Improvement Association. The reasons for choosing these varieties are that they are the three best white wheats grown at this station and that they are also considered to be pure strains, as Early Windsor and American Banner are pure line

selections made at this station and O. A. C. No. 104 is a pure line selection coming from a cross made at the Ontario Agricultural College, Guelph, Canada. American Banner is the only one of the three varieties grown commercially in this state.

All lots of grain of the 1925 crop contained a varying amount of red and vitrous appearing kernels. From each of these samples 3000 of the most chalky and 3000 of the most vitrous kernels were picked for seed, breaking test and chemical analysis.

The source of material, variety name, accession number, number of red grains per kilogram of wheat, and the number of kernels used in the breaking test, are all shown in Table I.

TABLE I. Showing the source, variety name, accession number, number of red kernels per kilogram, and number of soft and hard kernels broken for analysis, for the bulk lots of grain, 1925 crop.

Source	Variety Name	Accession Number	No. of red kernels per kilogram	No. of kernels broken for analysis	
				Soft	Hard
Farm Crops Dept.	Early Windsor	6	235	100	100
" " "	O.A.C. No.104	407	25	100	100
" " "	American Banner	408	91	100	100
Clarence Heinline	" "	487	45	100	100
" "	" "	488	70	100	100
W. E. Eckerson	" "	489	120	100	100
Farley Bros.	" "	490	36	100	100
Orval Walker	" "	491	304	100	100

Individual head selections were also made from the station plats of the white varieties, in the summer of 1925, to determine whether strains of different protein content existed in these varieties. A sample of the 1926 crop of Red Rock, a medium hard red wheat, was included in order to compare the breaking pressure of a harder wheat with its protein content. These were threshed in such a way that the kernels from top, middle and base of the spike were kept separate, to see if differences in the color would appear within the spike. In some cases there was a tendency for more chalky kernels to appear in top and base, and the chalkier the appearance the smaller the grain, but the differences were too small to be considered of any importance. This material is given in Table II.

TABLE II. Giving for the material used in the head row planting, the source; variety name, number of heads threshed; numbers with red chaff, with red kernels; numbers and types of heads discarded; and the number of heads used in breaking test (five kernels per head were used in this test). 1925 crop.

Source	Variety Name	Number of heads					
		Threshed	With red: chaff	With red: kernels	Discarded for: poorly developed kernels	Discarded for: containing less than 25 kernels	Whose kernels were broken
Farm Crops Dept.	O.A.C. No.104	772	28	0	236	194	342
" " "	American Banner	567	all	0	138	205	224
" " "	Early Windsor	611	all	10	58	228	325

In O. A. C. No. 104 were found 28 heads with more reddish chaff than common but as there was no sharp distinction the difference was considered to be due to more or less weathering. In American Banner and Early Windsor some heads were found with kernels which were whiter and more chalky than common, while in Early Windsor ten heads were found having red kernels.

B. Methods.

The methods of attacking this problem may be divided into two groups, laboratory and field. The laboratory methods involved the breaking of grain and then chemically analysing that grain for its protein content. The field methods pertained to the rod row and to the head row materials. These methods will be discussed in the following order:

Laboratory:

1. Breaking technique.
2. Chemical analysis.

Field:

3. Rod row planting.
4. Head row planting.

1. The Breaking Technique.

The breaking was done with a tensile testing machine which was kindly loaned by Mr. B. B. Robinson of the Office of Fibre Investigations, U. S. Department of Agriculture, and which he uses in

his work on flax fiber. See Fig. 1.

The testing of 1925 material before planting that fall was done by crushing the kernels between two blocks of iron having smooth crushing surfaces. The kernels were always put in the same position, with the crease down, by using a pair of forceps to place the kernels in position.

By turning the wheel (a) the upper block (e) was pulled down and pressed upon the lower block (f) which was connected with the weight (d) and with a hand which indicated the increasing pressure in kilograms on the dial (b). When the kernel broke, the operator instantly stopped the wheel (a). The latch (c) kept this weight (d) in place and permitted reading the amount of pressure needed to crush the kernel. The latch had to be released by hand to put the scale in position for the next operation. As seen in the figure a couple of chutes of stiff paper were attached to the machine so that the broken grains were easily gathered into the envelope below, when pushed off the block. Kernels of as even size and shape as possible were selected for breaking because it was apparent from preliminary tests that differences in shape had a great deal to do with the pressure needed to crush the kernels.

For the breaking done on the 1926 crop the lower iron block was replaced by a wooden block and into the upper was inserted an Autostrop safety razor blade with the dull edge down, which cut the kernels instead of crushing them. It was found that if the sharp

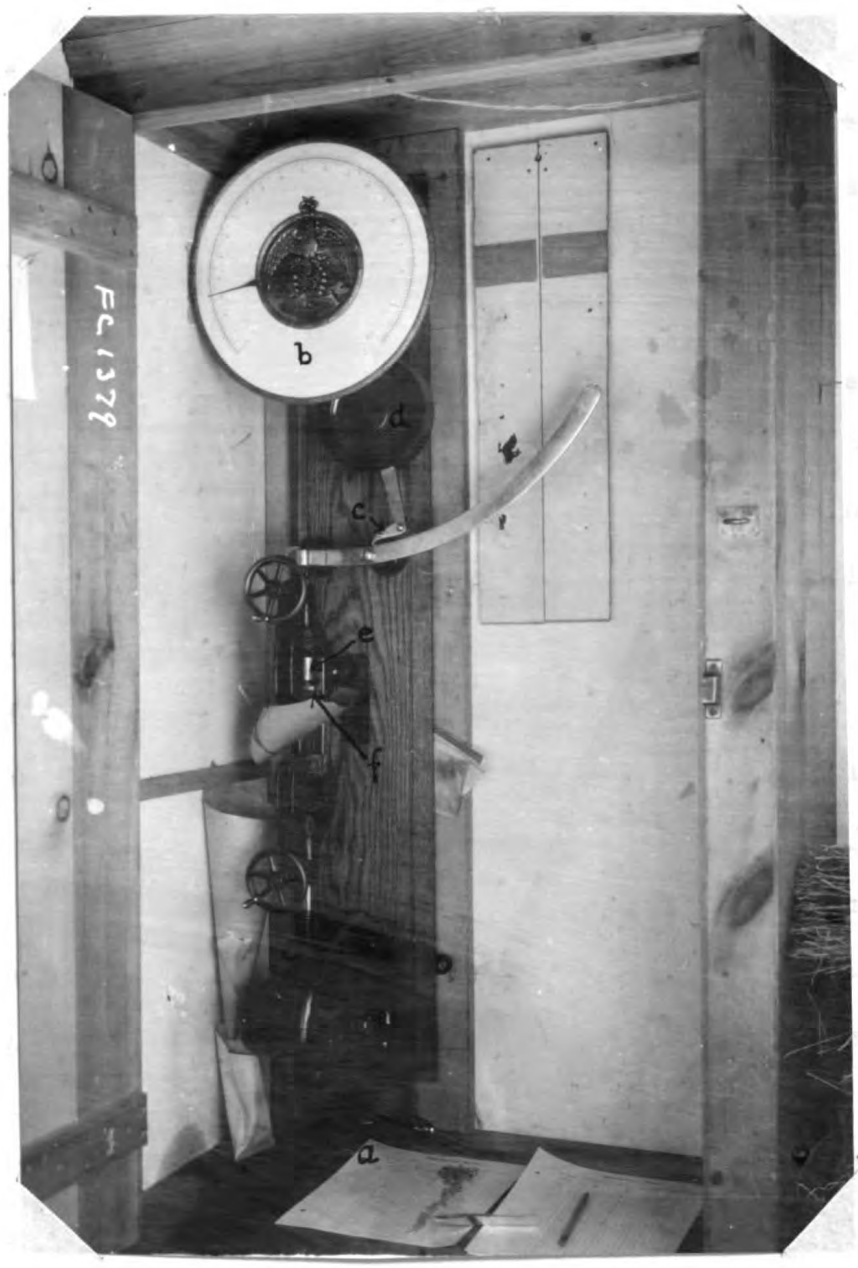


Fig. 1. Showing the tensile testing machine used for determining breaking pressure.

edge of the razor was used the pressure needed for cutting the majority of kernels was barely enought to cause any movement of the dial hand, while if the dull edge of the bladewas used, the pressure was sufficient to be recorded. It was also found that the pressure needed for cutting by this latter method was considerably less than that required when the grain was crushed between the broad surfaces of the iron blocks as was done in the first part of the work, but it was felt that, even so, the results were much more accurate because the shape of the kernel influences the crushing pressure more greatly than it does the cutting pressure. For convenience the author has used the term breaking pressure for both crushing pressure and cutting pressure.

For breaking the bulk material before planting 1925, 100 kernels were counted out of the sample, eliminating kernels of odd shape and taking only those of even size. The size was only judged by sight. The same kind of selection was made for the five grains broken from the head samples. When broken, the grains were pushed off the block and gathered into the envelope below, and the breaking pressure recorded for each grain.

For breaking done in 1926 some of the material was put in classes according to breaking pressure. This was done by placing, with the aid of a pair of forceps, the crushed kernels into envelopes marked with the breaking pressure for each class. The chutes were retained so that, even if a kernel should fall

off the block before being picked up, it was collected in the envelope below and could be put in its proper class. The breaking pressures for the single grains were not recorded for this group of measurements but the number of grains in each class was noted.

2. Chemical Analysis.

The chemical analysis of the 1925 material was done by the Experiment Station's Chemist while the analysis of the 1926 material was done by the author for whom space and material was made available in the station's chemical laboratory.

The five grain samples taken from the head selections and the 100 grain samples from the bulk seed in 1925 were ground in a mortar by hand, a long and tedious job, but all the 35, or more, grain samples of 1926 crop were ground on a mill operated by electricity. The 35 kernels needed only one minute's grinding in this machine for all material to pass through the 1/20 inch sieve required for analysis.

Kjeldahl's method was used for the chemical analysis of protein content of wheats.

3. Rod Row Material.

Plantings were made in rod rows of the most chalky kernels and in adjacent rows of the most translucent kernels from each of the lots of white wheats listed in Table I. See Fig. 2. The rows were made one foot apart and eighteen feet long with a two-foot alleyway at the end of the rows. The kernels were space planted two inches apart making 108 kernels to a row. The rows

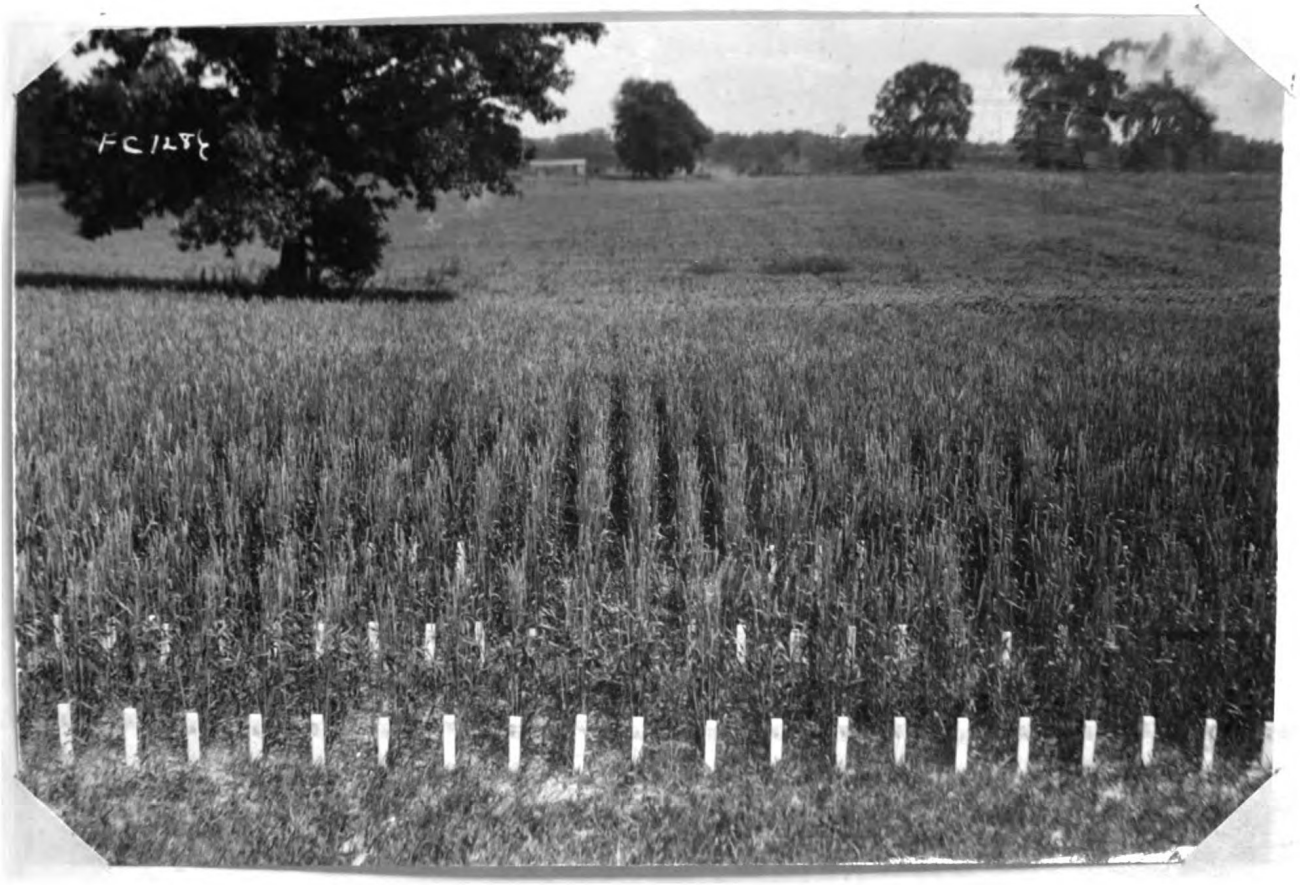


Fig. 2. Showing part of the research field. The rows are running north to south.

were covered with a rake. The material was replicated four times, making five rows of chalky and five rows of translucent selections. Every third row was a check. Each row was harvested and threshed as a whole.

4. The Head Row Material.

The material involved in this planting were the remnants from the heads used in the breaking test and reported in **Table II.** The rows were planted in sections three and one-half feet long with two and one-half foot alleyways between sections. The grain was planted in rows one foot apart, the kernels being two inches apart in the row, making 20 kernels to the row. Every second row was a check. O. A. C. No. 104 was used as a check throughout.

Each plant in the head row was harvested and threshed separately. All the plants in the checks were harvested and threshed together.

After harvest, which took place July 23rd-24th, the wheat from the rod row and head row plats were hung up in the laboratory where the temperature was 30° - 32°C, so that it dried fairly fast both in the straw and after being threshed while kept in bags and envelopes.

The distribution of the different varieties is shown in the figure on planting arrangement. At the end of each section were planted seven edge rows except on the east side of section III where the number of them was eight and the east side of section VIII where there was a larger number. On the north was planted

an extra section as a protection against birds because a large tree grew nearby.

C. The Season.

Before discussing the results of the various tests it seems advisable to give an outline of the growing season.

The wheat was planted in 1925 on September 23rd. This did not germinate very well, only about eighty per cent. However, the winter was favorable for the wheat on this plat, and only part of one section was covered with ice which lasted from the middle of December, 1925, until the snow went off during the middle of January, 1926. After that there was no more ice formed and only part of the most northern section was covered with snow. In the spring, some water stood over the edge rows on the west side and killed out most of these and had some affect on the nearest rows of the adjacent sections.

The wheat began to head out about June 5th, 1926, and to blossom about June 16th.

There was much smut in the American Banner from the farmers and some in the three varieties from this station. All plants were heavily rusted.

The harvesting was done July 23rd and 24th, 1926.

The last part of the growing season was rather dry and warm, which was fortunate, for such conditions are favorable to developing a crop of "red" translucent appearing kernels and hence would aid in the selection of soft chalky strains.

D. Results. - Breaking Pressure.

It was assured, when taking the first samples for the breaking tests, that weight of kernels would affect the breaking pressure. To prove this 200 kernels of O. A. C. No. 104 of the 1925 crop were taken at random and placed in classes according to their breaking pressure. The same was done with 1000 kernels of O. A. C. No. 104 of the 1926 crop. The results are given in Table III.

TABLE III. Showing classes for breaking pressure and number of grains, 1000 grain weight and per cent protein in each class for 200 kernels of O. A. C. No. 104 of 1925 crop and for 1000 kernels of the same variety of the 1926 crop.

200 Kernels O. A. C. No. 104 of 1925 crop thrown in classes of 1 kg. difference			1000 Kernels of O. A. C. No. 104 of 1926 crop thrown in classes of 1/2 kg. difference			
Classes for breaking pressure	-For the class- Number of kernels	1000 grain wt. in gram	Classes for breaking pressure	-For the class- Number of kernels	1000 grain wt. in gram	Per cent protein
2.0 - 2.9	12	25	2.0 - 2.4	23	19.5	14.42
3.0 - 3.9	146	36	2.5 - 2.9	58	19.8	15.56
4.0 - 4.9	31	40	3.0 - 3.4	319	27.1	14.88
5.0 - 5.9	7	49	3.5 - 3.9	434	34.7	14.19
6.0 - 6.9	4	53	4.0 - 4.4	85	39.8	14.08
			4.5 - 4.9	46	42.5	13.51
			5.0 - 5.4	25	43.2	14.36
			5.5 - 5.9	5	52.0	too small samples for accurate analysis
			6.0 - 6.4	2	50.0	
			6.5 - 6.9	1	50.0	

This table shows that there is quite a strong positive correlation between weight of kernels and breaking pressure.

Because of this relationship it seemed advisable to use only kernels of a standard size (cross section) in the future work. In order to find such a size, one kilogram each of American Banner and Red Rock was screened. Red Rock was included in these preliminary tests because it is harder than the three white wheats used and it was considered desirable to compare the results from a soft, with those from a semi-hard wheat. Combinations of two kinds of screen were tried. First the grains were put through screens with meshes three-quarters of an inch long but of different widths. This was done easily and conveniently. The sizes of grains obtained in this way were then put through screens with round holes of different diameters, and vice versa. But screens with round holes did not work well because the individual grains had to be put through the holes in the screen by hand, as they would not screen through readily enough to give a uniform sample. Table IV gives the sizes of screens used in this test. The diameters of the round hole mesh were the same as the widths of the oblong holes.

TABLE IV. Showing number and size of screens used to determine a standard size of kernels for analysis, and weight of kernels retained on each size out of 1000 grams of grain. All meshes were three-quarters of an inch long.

Left in Screen No.	Width of meshes in 64ths of an inch	Weight of kernels in grams- American Banner	Red Rock	
1	7½	16	48	
2	7	150	206	
3	6½	531	490	
4	6	69	84	
5	solid bottom	234	172	mostly shriveled kernels

In this screening test the screens were placed on top of each other, the one with largest holes (No. 1) on top and in order of decreasing size of meshes down to the solid bottom (No. 5). The screens were shaken till no more kernels went through. Since screen No. 3 retained by far the largest number of kernels, this size was chosen as the standard and all later testing was done with kernels of that size.

Kernels of poor appearance or of odd shape were omitted so that the breaking was always done with uniform looking kernels.

TABLE V. Showing number of kernels, 1000 grain weight and per cent protein for different classes of breaking pressure of O. A. C. #104 and Red Rock of standard size kernels (screen 3) when broken on different dates.

Variety	Classes of breaking pressure	Aug. 10 No. of kernels	Aug. 10 1000 grain wt. in grams	Aug. 10 Percent protein	Aug. 17 No. of kernels	Aug. 17 1000 grain wt. in grams	Aug. 17 Percent protein	Aug. 24 No. of kernels	Aug. 24 1000 grain wt. in grams	Aug. 24 Percent protein	Aug. 31 No. of kernels	Aug. 31 1000 grain wt. in grams	Aug. 31 Percent protein	Sept. 7 No. of kernels	Sept. 7 1000 grain wt. in grams	Sept. 7 Percent protein	Average → Percent protein
American Banner	2.0	5	40.														
" "	2.5	35	39.9	13.40	17	39.8	13.28	26	38.2	13.03	11	38.6	11.12	11	41.1	10.95	12.36
" "	3.0	134	43.2	13.17	124	42.7	13.37	131	42.1	13.08	91	42.3	13.45	108	42.7	12.88	13.19
" "	3.5	20	44.2	13.28	42	44.7	13.06	34	43.4	13.60	74	44.5	13.20	61	45.2	13.09	13.25
" "	4.0	6	46.7		12	41.3	12.54	9	44.3	13.97	16	46.0	13.49	20	46.4	12.40	13.10
" "	4.5				3	47.0	12.54				7						
" "	5.0				2						1						
Sum breaking pressure of 200 kernels			593.5			633.0			613.0			655.0			645.0		627.9
Sum weight in grams of 200 kernels			8.525			8.545			8.370			8.670			8.637		8.549
Average per cent protein			13.22			13.23			13.20			13.23			12.79		
Red Rock	2.5	13	37.5	13.59													13.59
" "	3.0	84	41.6	15.22	65	43.3	15.02	64	42.4	15.11	40	40.1	15.15	51	39.9	14.82	15.06
" "	3.5	66	42.9	15.05	62	44.2	15.11	61	44.6	15.22	56	42.1	15.77	69	42.2	15.08	15.25
" "	4.0	24	46.0	15.14	33	45.9	15.14	38	45.5	15.82	47	43.5	15.14	41	42.7	15.43	15.33
" "	4.5	13	46.4	15.02	25	46.8	15.11	22	47.5	15.82	32	44.7	15.00	25	46.1	15.08	15.21
" "	5.0				13	46.6	15.31	11	50.3	14.88	17	44.5	15.14	11	48.0	16.17	15.33
" "	5.5				1			2			7			3			
" "	6.0				1			2			1						
Sum breaking pressure of 200 kernels			670.0			711.0			734.5			777.5			741.0		726.8
Sum weight in grams of 200 kernels			8.545			8.975			8.985			8.555			8.515		8.715
Average per cent protein			15.08			15.10			15.35			15.37			15.15		

Table V shows samples broken at different times to see if the time after harvesting would affect the breaking pressure. Samples for this test were obtained from the regular variety series which were harvested about the same time and dried out of doors. The samples were kept in the laboratory during the work.

It is seen that for both varieties the first date, August 10th, has the lowest breaking pressure, while the others although with considerable variation might be said to run about the same. This should suggest that by handling the material as done, breaking test for comparison could be started about three to four weeks after harvest. If artificial drying were resorted to, one might be able to start earlier.

It should be noted that though breaking was done with standard sized kernels the protein content did not vary with the breaking pressure nor with the date when broken. The large variations in the lowest and highest classes of breaking pressure are in all probability due to inaccuracy in analysing such small samples.

The weights of the 200 kernel samples, under each date, indicate that the method of screening gives quite an even sample as judged by weight.

TABLE VI. Showing number of kernels, 1000 grain weight and per cent protein for different classes of breaking pressure of O. A. C. No. 104 and Red Rock of different sizes.

Variety	Classes after breaking pressure	Broken 200 kernels of each size left in screen No. 1			2			3			4			5			Average per cent protein
		No. of kernels	1000 grain wt. in grams	Per cent protein	No. of kernels	1000 grain wt. in grams	Per cent protein	No. of kernels	1000 grain wt. in grams	Per cent protein	No. of kernels	1000 grain wt. in grams	Per cent protein	No. of kernels	1000 grain wt. in grams	Per cent protein	
American Banner	2.0										3	28.3		17	28.8	10.55	10.55
" "	2.5	4	40.0					9	40.0		25	33.4	11.88	39	30.0	12.97	12.54
" "	3.0	93	44.4	13.51	74	47.9	13.28	91	41.3	13.20	118	36.7	12.94	120	33.0	12.51	13.04
" "	3.5	65	47.9	13.94	81	49.7	13.28	75	45.1	13.31	37	37.7	12.83	19	35.3	11.40	13.25
" "	4.0	27	50.2	13.91	30	51.7	13.22	23	45.2	13.14	17	40.3	12.37	5	37.0		13.24
" "	4.5	10	57.0	13.68	12	50.8	12.97	2	47.5								13.29
" "	5.0				3	50.0											
" "	5.5	1	60.0														
Sum wt. in grams of 200 kernels			9.386			9.880			8.635			7.330			6.470		
Sum breaking pressure in kg.			675.0			694.5			659.0			625.0			578.0		
Average per cent protein			13.72			13.25			13.24			12.74			12.32		
Red Rock	2.5	3	51.7					8	37.5		16	34.4	13.85	25	28.0	14.62	14.31
	3.0	46	51.7	15.08	60	47.7	15.02	63	40.2	14.59	103	36.1	14.68	103	30.9	14.96	14.81
	3.5	65	52.6	15.25	58	49.6	14.88	54	42.9	15.19	41	37.1	15.00	46	33.0	14.88	14.98
	4.0	41	53.2	16.14	30	49.5	15.39	41	42.7	14.59	27	37.6	14.85	20	34.3	14.31	15.15
	4.5	18	53.6	15.43	31	50.8	15.48	23	44.1	15.16	10	37.3	14.65	5	35.0		15.28
	5.0	16	55.3	15.15	9	53.3	16.25	7	46.4	15.12	3			1			15.27
	5.5	8	55.0	16.36	11	54.4	15.79	4									16.03
	6.0	2															
	6.5	1			1												
Sum wt. in grams of 200 kernels			10.590			9.925			8.425			7.285			6.270		
Sum breaking pressure in kg.			760.0			754.5			722.5			660.5			637.0		
Average per cent protein			15.45			15.17			14.76			14.70			14.75		

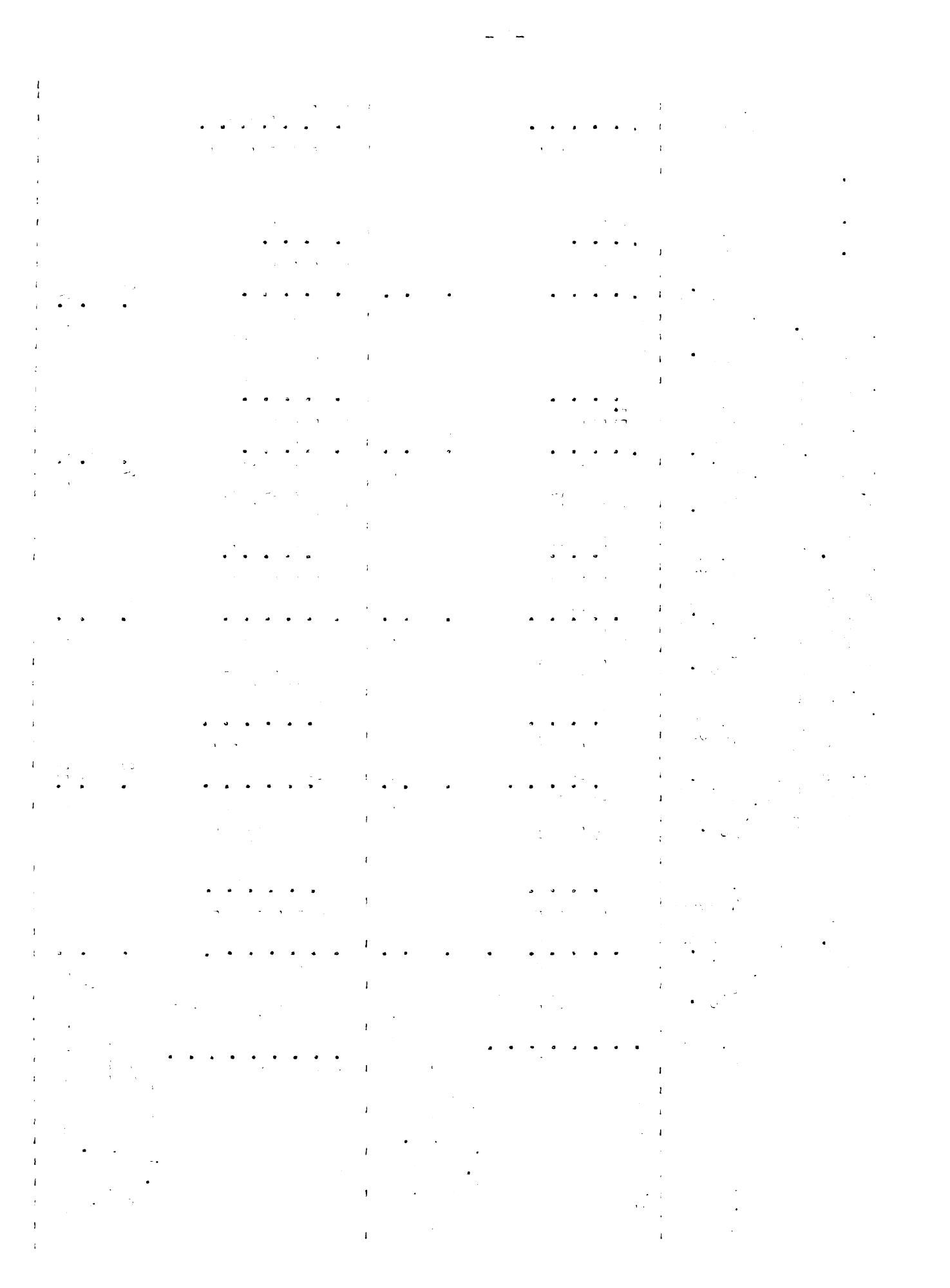


Table VI shows how the breaking pressure decreases with smaller size of kernels and shows, as in Table V, that there is a correlation between breaking pressure and the weight of kernels within the same size group. It is seen that the larger kernels have the higher protein percentage, but within the same size there is no correlation between breaking pressure and protein content.

The average protein percentage is obtained by multiplying the single protein analysis with the number of analyzed kernels, adding these products and dividing the sum by the total number of kernels. This applies to the averages within a size and the averages for each class of breaking pressure.

The column on the right gives the average per cent protein for each class of breaking pressure. The increase of average per cent protein with the increase of breaking pressure is due to the fact that the lower classes of breaking pressure contain most of the smaller sized kernels and the higher classes, greater numbers of the larger sized kernels, and only shows the same condition as does the average per cent protein of different kernel sizes. Compare with Table V for which all kernels were of the same size and in which no correlation is seen between breaking pressure and protein content.

It is seen from these tests that the higher the 1000 grain weight of even sized kernels, the denser the kernels and, hence as might be expected, the higher is the breaking pressure but, contrary to common belief, the denser kernels do not contain more protein than the less dense.

The Rod Row Material.

Each lot of seed was classified by sight into three groups, one containing only the hardest translucent kernels, the second containing the softest chalky kernels and the third all the intergrades. One hundred kernels of each extreme class were broken and analyzed for protein. The results are given in Table VII. Some of the remnant of each class were planted for progeny tests.

TABLE VII. Showing the analysis for the hard and soft groups for breaking pressure and protein content for parent 1925 material given in Table I and progeny 1926.

	Accession No.	Type	1925 crop: Ave. breaking pressure per grain in kgs.	1925 crop: Per cent protein content	1925 crop: Diff. in breaking pressure between hard & soft	1925 crop: Diff. in % protein between hard & soft	1926 crop: Average breaking pressure	1926 crop: Average per cent protein content
Early Windsor	6	soft	6.93	13.68	.25	1.82	434.1	12.45
		hard	7.18	15.50			435.7	12.12
O.A.C. No.104	407	s	7.64	10.72	1.78	4.16	486.1	12.46
		h	9.42	14.88			496.4	12.24
American Banner	409	s	7.17	12.48	1.49	2.34	464.5	12.54
		h	8.66	14.82			469.5	12.56
"	487	s	9.29	8.49	1.49	2.17	443.7	12.52
		h	10.72	10.66			448.8	12.45
"	486	s	9.17	7.92	1.25	1.43	449.5	12.72
		h	10.42	9.35			454.6*	12.71*
"	489	s	8.88	8.78	1.43	2.53	452.6	12.54
		h	10.31	11.29			458.0	12.53
"	490	s	7.90	9.92	1.07	1.42	455.5	12.43
		h	8.97	11.34			451.0	12.51
"	491	s	8.94	12.65	1.06	1.66	454.2	12.52
		h	10.00	14.31			468.2	12.53
Average		s	8.24	10.59	1.23	2.17	455.3	12.52
		h	9.47	12.76			460.3	12.46

*average of only four

The chalky kernels in all cases had the lower breaking pressure and protein content.

One hundred kernels of standard size and of the two extreme classes of texture were taken from each row of the progeny, and were analyzed for breaking pressure and protein content. The average of these tests are also given in Table VII. It is seen that the breaking pressure and per cent protein of hard and soft classes of kernels are practically equal. This indicates that this character is influenced to a very great extent by environmental causes, and that the selection of chalky or translucent-looking kernels does not necessarily determine the texture of the resulting progeny. The coefficient of correlation between breaking pressure and protein content was calculated on the check material, which was planted every third row, and was found to be $r = .129 \pm .105$; showing that no relationship exists between these characters.

There was a considerable variation in the protein content throughout the field as is shown by the coefficient of variability of the checks, it being $5.40 \pm .40\%$. This indicates that the growing conditions to a large extent determine the protein content. The coefficient of variability for the breaking pressure, $3.96 \pm .29\%$, was much lower than that for the protein content and gives further proof that one of these properties can not be used as an indication for the other, even within a variety.

The graphs of the check and soft and hard selections of the 1926 progeny are given in Fig. 3. The fluctuations in the soft

and hard selections follow the curves of the check.

The Head Row Material.

The head selections given in Table II were divided into classes according to their breaking pressure. Fifty heads with uniformly high and fifty with uniformly low breaking pressure were selected from American Banner and Early Windsor varieties. The same was done with O. A. C. No. 104 and in addition fifty heads with medium breaking pressure were selected, making 150 in all from this variety. The larger number was taken from O. A. C. No. 104 because it was developed from a cross and it seemed to offer the greatest possibility for selection of strains with different protein content. The range for the breaking pressure for the selected heads is given in Table VIII.

TABLE VIII. Showing range of breaking pressure of head selections used for seed 1925. Five kernels per head were broken and the remnants were planted.

Variety	Range of total breaking pressure in kilograms for five kernels-		
	soft	medium	hard
O. A. C. No. 104	35.6 - 45.8	46.0 - 52.6	55.1 - 67.0
American Banner	33.5 - 46.0		53.1 - 66.9
Early Windsor	35.6 - 41.6		51.7 - 63.4

Because of the size of the samples (five kernels) the protein content could not be accurately determined but it should serve as an indication of the protein content.

No correlation was found between breaking pressure and protein content as shown by the following coefficients of correlation:

O. A. C. No. 104	hard	$r = .180 \pm .17$
O. A. C. No. 104	soft	$r = .067 \pm .18$
American Banner	hard	$r = -.027 \pm .15$
American Banner	soft	$r = -.038 \pm .15$

Further analysis of this material was discontinued.

In examining the 1926 material by sight there were found some plants with partly chalky kernels but no plant was found with only chalky kernels. In mapping these plants it was found that the chalky kernels only appeared on certain spots in the field, see fig. 4, and just as much in the hard as in the soft selections. Two heads with extra chalky kernels ~~were~~ selected from the 1925 crop of Early Windsor and one from American Banner were planted, but these progenies had no chalky grains, only those with a translucent appearance. These facts seemed to indicate that the variation in the soil, to a large extent, is responsible for the variation in grain texture.

There proved to be such a large mass of material that the work had to be limited, and the series of O. A. C. No. 104 were chosen because this variety came from a cross and it was thought there might be more chances for segregation and thus for finding

Fig. 4. Map of the research field. The numbers to the right are numbers of the different sections. The edge rows are not given on this map. The red lines are the rows where chalky kernels appeared.

a constant soft white line.

Twenty-five kernels from each sample were used in the breaking test, and in order to get enough for a one-gram sample for protein analysis about ten kernels were added from the same plant. From each head row was taken one sample - single plant - for breaking test of the common translucent appearance and this was analyzed for protein. Where one or more plants of a progeny contained chalky kernels one of these, too, was broken and analyzed. For some rows, the whole progeny was broken and analyzed.

The coefficient of correlation between breaking pressure and protein content was calculated upon the check rows of this material and was found to be $r = .010 \pm .054$.

Correlations on the breaking pressure of parents, 1925, with that of progeny, 1926, of the 20 hardest and 20 softest selections were found to be -

for soft selection, $r = -.101 \pm .153$

for hard selection, $r = -.092 \pm .014$

Similar correlations of per cent protein of parents, 1925, with that of progeny, 1926, gave -

for the soft selection, $r = -.002 \pm .19$

for the hard selection, $r = .013 \pm .18$

These values show that there is no correlation either in breaking pressure or protein content between parents and progeny.

The graphs of the breaking pressure and protein content from the progeny of the check as well as the soft medium and hard selections are given in Fig. 5.

Summing up breaking pressure and protein content from the progeny of all soft, medium and hard selections, this was found.

	Average breaking pressure	Average per cent protein
Soft	113.4	12.54
Medium	114.8	12.56
Hard	111.6	12.21

The values for r between breaking pressure for 1925 (parent) and breaking pressure for 1926 (progeny) are as follows.

Soft selection $r = .070 \pm .091$

Medium selection $r = .060 \pm .095$

Hard selection $r = .112 \pm .094$

Between the breaking pressure 1925 (parent) and protein percentage 1926 (progeny):

Soft selection $r = -.145 \pm .093$

Medium selection $r = -.056 \pm .092$

Hard selection $r = -.040 \pm .094$

Between breaking pressure and per cent of protein of progeny:

Soft selection $r = .030 \pm .095$

Medium selection $r = -.015 \pm .095$

Hard selection $r = -.062 \pm .092$

These values show that the selection of hard, medium and soft kernels did not bring about any change in the progeny, and that there is no correlation whatsoever between breaking pressure of

parent 1925 and progeny 1926 or between breaking pressure 1925 and protein 1926 or between breaking pressure and protein of progeny (1926).

Table IX gives a comparison of 1926 plant selections, made by sight, from among the same progenies. In the first column, the 1925 classification according to the breaking pressure of the mother selection is given. In all cases the chalky appearing plants have the lower protein content. However, there is no relationship between the hard and soft selections of 1925 and the classifications of hard and soft made in 1926.

Table X gives the results on the breaking pressure and protein content of three typical progenies out of the nine of which 25 kernels from each plant in the progeny were tested. Plants not having enough seed for testing and a remnant for future planting were discarded from the progeny. There is no correlation between breaking pressure and protein content.

TABLE IA. Showing plant number, total breaking pressure and per cent protein from one translucent and one chalky plant of the progeny from a head row. The 1925 classification of the head is given.

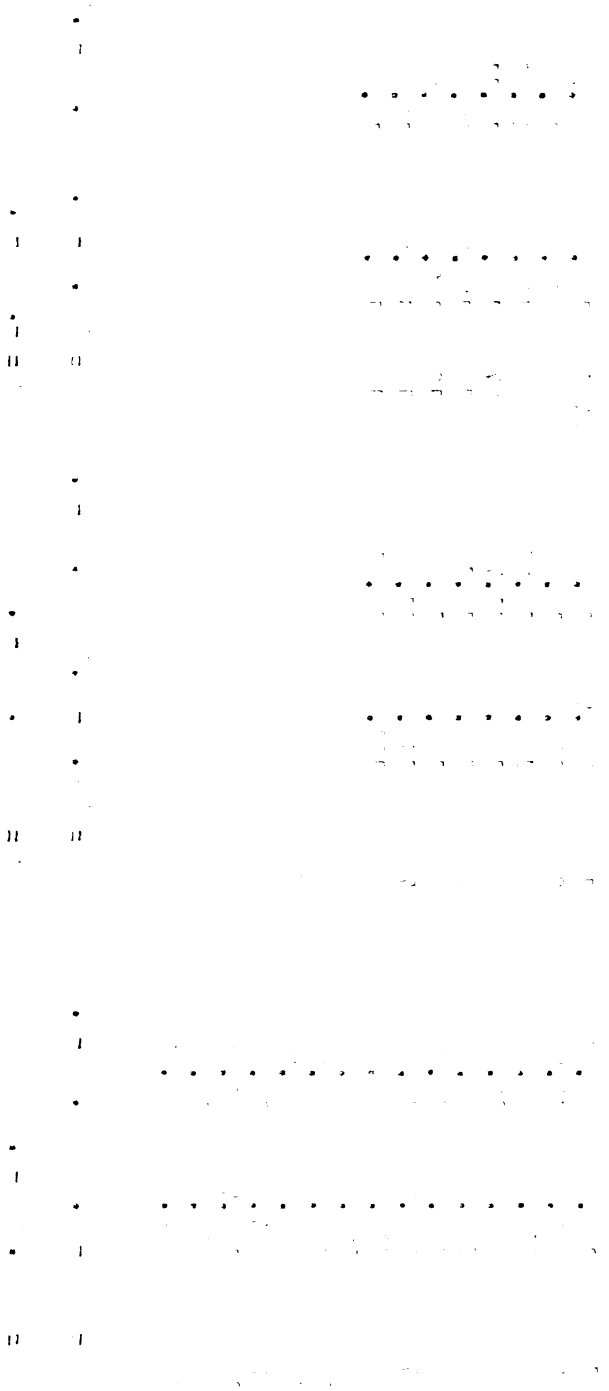
Head selections classified by breaking pressure 1925	Progeny 1926					
	Translucent appearing plant			Chalky appearing plant		
	Plant No.	Total breaking pressure	Per cent protein	Plant No.	Total breaking pressure	Per cent protein
hard	680102	105.0	13.28	681106	111.4	9.86
soft	83301	102.0	12.65	83314	122.5	10.08
hard	83701	103.2	12.54	83712	142.2	9.29
soft	83901	125.6	13.91	83910	125.8	11.29
medium	84101	106.4	13.45	84107	107.6	11.46
hard	90901	126.0	11.23	90906	131.5	10.49
medium	91301	126.1	12.46	91302	120.6	10.83
hard	93301	116.5	13.54	93309	104.1	9.51
soft	93502	111.1	11.12	93505	113.1	10.15
medium	93702	108.2	13.85	93704	106.6	11.91
soft	94101	130.2	11.63	94104	139.3	9.52
medium	94301	127.7	12.03	94305	106.1	9.06
hard	94501	135.1	12.65	94504	97.6	8.72
medium	103701	110.4	13.22	103713	136.8	9.75
hard	103901	118.7	10.55	103904	108.2	9.29
soft	104101	117.5	13.51	104110	111.7	9.75
hard	104501	121.2	11.46	104508	105.9	10.83
soft	104701	104.2	10.15	104705	117.5	10.03
medium	104901	120.1	11.51	104908	117.4	9.35

TABLE IX - continued.

Head selections classified by breaking pressure 1913	Translucent appearing plant			Mealy appearing plant		
	Plant No.	Total breaking pressure	Per cent protein	Plant No.	Total breaking pressure	Per cent protein
hard	105101	117.6	9.86	105111	103.5	8.95
soft	105501	121.5	11.31	105507	104.1	9.55
medium	105501	126.7	10.49	105503	110.1	9.55
medium	105701	125.6	11.51	105710	114.1	9.52
hard	105901	123.3	11.74	105903	125.2	10.26
Average soft, 7 plants		116.0	12.04		119.1	10.03
Average medium, 8 plants		129.2	12.32		113.7	10.15
Average hard, 9 plants		118.7	11.76		114.4	9.69
Average of all, 24 plants		118.1	12.03		115.5	9.94

TABLE X. Showing selection number, breaking pressure and protein analysis for the progenies of three head rows all of whose plants, having sufficient seed, were analyzed.

Soft Selection 1925			Medium Selection 1925			Hard Selection 1925		
Selection number	Breaking pressure	Percent protein	Selection number	Breaking pressure	Percent protein	Selection number	Breaking pressure	Percent protein
683901	125.6	13.91	683501	124.7	14.08	683701	103.2	12.54
02	112.0	11.74	02	117.9	13.74	05	143.9	12.54
03	110.6	12.43	03	100.3	13.28	06	119.0	11.51
04	114.8	12.88	04	105.9	11.74	07	126.0	13.11
05	109.5	12.14	05	106.3	12.14	10	124.2	12.34
06	121.0	12.65	06	104.9	13.45	12	142.2	9.29
07	111.7	12.03	07	113.0	11.69	13	109.8	11.34
08	114.6	12.94	08	111.8	12.31	14	143.4	12.43
09	120.7	12.94						
10	125.8	11.29						
11	108.7	11.29						
12	117.2	12.54						
13	120.7	11.69						
14	119.4	12.26						
15	113.5	10.72						
m =	118 ± 1.58	12.20 ± .068	m =	110.6 ± 2.16	12.80 ± .26	m =	126.1 ± 3.77	11.18 ± .40
r =	.167 ± .169		r =	.010 ± .238		r =	-.009 ± .237	



Since these head selections failed to transmit either their hardness, chalky appearance or protein content, the expression of these characters may not be considered to be due primarily to hereditary differences because this variety has been grown so long that, even if it consisted of several strains, the single plants should represent pure lines.

The differences within the progeny from a single head, as seen from the table, can, at present, only be attributed to environmental differences. However, it is possible that segregations or mutations might have taken place, and so it may be worth while to plant the low protein selections for further investigation.

The Red Material.

Table I shows that all the lots of seed used contained a number of kernels that were classified as red. The red might have been due to mechanical mixture of red kernels among the white, to crosses, or to the results of environmental conditions causing the soft starch to become hard thereby giving the kernel a red appearance.

Twenty red-appearing kernels were planted from each source of seed. The results from these kernels are shown in Table XI-a. The germination was low and varied considerably. The number of plants classified is given in the last column. This table shows that 36 of the 108 red-appearing kernels produced white offspring, indicating that many of the red-appearing kernels, having the same general shape and size as the variety in which they appeared, were the result of

environmental conditions. This percentage will vary with the variety.

In the Early Windsor head selections, it was possible to find ten heads having red kernels. The four best samples were planted. The other six did not have enough well developed kernels for one row each and so were discarded.

Three of the progenies segregated for bearded and beardless heads, and one of these for red and white kernels, showing that they were the result of crosses. This shows the possibility that some of the red kernels appearing in white wheats are the result of crosses.

Table XI-a. Showing name, accession number and classification of the progeny, of the red kernels from the bald and white grained varieties O. A. C. No. 104, American Banner and Early Windsor. The two latter having red chaff, the first white. (w is white grains, r is red grains.)

Name of Variety	Accession Number	Bearded				Not bearded				Number of plants harvested
		white chaff		red chaff		white chaff		red chaff		
		r		w	r	w	r	w	r	
Early Windsor	6	2			2	3	4			11
O. A. C. No.104	407				3			2	9	14
American Banner	406				3		1	1	7	12
" "	487			2			2	4	7	15
" "	488				2		3	2	10	17
" "	489				3		2	6	5	16
" "	490							4	4	8
" "	491						1	12	2	15
Total		2		2	13	3	13	31	44	108

Table XI-b. Showing selection number of heads with red kernels from Early Windsor and the segregation of the progeny; Early Windsor being a bearded white wheat with red chaff.

Selection Number	Accession Number	Bearded		Not bearded		Number of plants harvested
		Red chaff		Red Chaff		
		w	r	w	r	
148701-11	6				11	11
148901-20	6		6		14	20
149101-20	6	1	6	1	12	20
149301-15	6		7		8	15

V - CONCLUSIONS

1. There is a close positive relationship between breaking pressure, size (cross section) and 1000 grain weight of the kernels.
2. Breaking pressure and protein content are not correlated, so breaking pressure, as obtained by the method employed, can not be used as a means of determining protein content.
3. The kernels of lower protein content could be picked out by their more chalky appearance.
4. So far as can be seen now, textural appearance is due to environmental conditions and not to hereditary properties.
5. The two classes of red kernels used in this investigation proved

to be due to three causes.

1. Environmental conditions. These kernels are translucent but this condition is not transmitted to the offspring.

2. Mixture of red wheat. These will continue to breed true for red kernels.

3. Crossing of white wheats with red. The F_1 of such a cross is red. The heterozygous red kernels will continue to segregate.

6. This investigation has not proceeded far enough to determine the possibility of selecting strains of white wheats with lower protein content than the present varieties.

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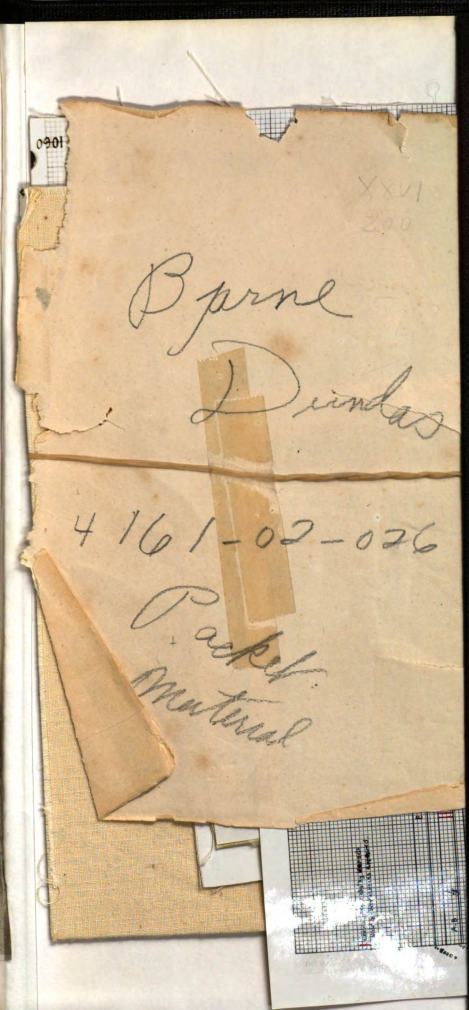
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