T H E S I S

THE HARDNESS OF WHEAT AND ITS RELATION TO THE MOISTURE CONTENT.

by

O. A. Stevens.

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Outline.

THE HARDNESS OF WHEAT AND ITS RELATION TO THE MOISTURE CONTENT.

I. Hardness, its Characters, etc:

General Characters.

Affected by Climate and Conditions.

Desiribility.

II. Methods of Testing Hardness:

Hand separation, according to color.

Machine used at the Ky. Expt. Station.

Machine used at the New South Wales Station.

Machine used at the Kans. Expt. Station.

III. Relation to the Moisture Content

Comparative tests of three wheats;

Hard red.

Soft red.

White.

Similar tests of the hard and soft grains

of the first named.

Conclusions:

THE HARDNESS OF WHEAT AND ITS RELATION TO THE MOISTURE CONTENT.

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Hardness, Its Characters and Value.

The terms "hard"and "soft" as commonly applied to wheats, are probably rather loosely used, with but a general and indefinite meaning. Certain red wheats are commonly referred to as hard, others as soft. On closer investigation it is foud,as does not seem at all unreasonable, that the degree of hardness varies in different varieties, in the same variety under different conditions, and in the grains of the same variety under any one condition. The common indication of hardness is found in the color of the grain. This varies in the red wheats from a clear reddish amber to an opaque red, yellow or whitish, the clear grain being "hard", the others "soft". By cutting the grains transversely with a knife the clear ones are found to hard and flinty, while the others are soft, white, and mealy. The grains of certain varieties may be characteristically of one type or the other, but in any given variety under ordinary conditions it is possible to select a perfect series of kernels showing all degrees from the entirely clear and flinty to the opaque and mealy. It may be and has been repeatedly shown that the flinty grains are considerably harder than the others. For instance in the following experiment the kernels of a certain sample which were entirely flinty or nearly so, were found to be 23.6 per cent harder than those which were not all, or only slightly flinty.

The reasons for the presence of the varying per cents of hard or soft grains appear to be assignable to climatic conditions. In New South Wales, Cobb tested a number of wheats for three consecutive years (Ag'i.Gaz. New South Wales, 1896, pp279 -- 298). He found that the relative hardness of the various varieties was quite constant for three seasons, but that the hardness of any given wheat varies greatly, being softer in the drier, more unfavorable season. It seems, also, that allowing the grain to be exposed to the weather after it is ripe, reduces the hardness. In an experiment at the Nebraska Experiment Station (Bul. 89) one half of the product of one plot was cured in a dry room and the other half left in the field for about forty days. The grain of the first contained 75% of flinty kernels , while that of the second only 2.8%. In a second trial the change was not so great, but still very noticeable. In a somewhat similar experiment at this Station, part of a number of wheats was taken inside to cure, immediately after cutting and the remainder was left in the field thru the usual period. In nearly all cases the second lots contained many more "yellow" or soft grains and were more or less bleached. A test of the hardness of sixteen of the varieties showed an average decrease of 14.1 per cent, the percents varying from 0 to 24.7. In all but three there was a marked decrease. These three showed practically no change. The following table shows the per cents of hard grains and the hardness

test of several of the wheats. The hardness test was made by the crushing machine described later, one hundred grains being used for an average:

Wheat	Crushing test.		Dif.	Per cent hard grains.		
	Unweathered	Weather-ed	Dif.	Unweather-ed.	Weath-ered	Diff.
257	10,207	10,239	+ 32	79,5	31.3	- 48.2
460	7,840	7,726	- 114	71.4	73.2	+ 1.8
556	10,871	9,510	- 1362	71.5	28.0	- 43.5
619	9,695	8,398	- 1297	76.2	28.8	- 47.4
608	10,640	8,010	- 2630	90.6	21.4	- 69.2
610	11,689	9,447	- 2242	99.0	8.8 v	- 90.2

Showing in general the great decrease of the flinty grains and proportinate decrease in the crushing test.

Concering the reasons for the kernels appearing clear and flinty, or opaque and mealy. Hackel, in Naturlichen Pflanzenfamilien, says: " If the albumenoids so fill up the intervals between the starch grains that the latter seems to be imbeded in cement the albumen appearstranslucent and the fruit is called corneous, but if the union is less intiniate there appear numerous small air cavities and the albumen is opaque and the fruit is mealy." It has been found by different investigators that in a given wheat the hard flinty grain contains the greater per cent of protien. (Minn Bulletin No. 85, Neb. Bul. 89, Ky. Bul. 113, Examining and grading Grains, by Lyon & Montgomery, Neb.)

The Ky. Station for example, found the difference to be from 1.00 % to 5.88 %, with an average of 3.20 %.

If this then is true, it is obvious that the hard kernels are the more valuable from the standpoint of nutrition which is, of course, the purpose of the wheat grain. The Neb. Station, l, c, sent a list of questions concerning causes and effects of, and remedial measures for"yellow berry" in wheat, to a number of prominent millers and grain dealers of the state. On most of the questions the answers were varied and not entirly concordant, but on the effect on the value all agreed that the presence of "yellow berry" lessened the value per bushel, the amount given by different answers being from one to four cents. If, then, the difference is two or three cents per bushel, considering the magnitude of the wheat industry, it does not require the mathetidian 's figures to show that this is a question of great economic importance. We have, then, before us the necessity for an accurate method of testing the hardness of the grain, and the various details and factors attending such tests, the subject proper of this discussion.

Methods of Testing Hardness.

In a rough way the hardness of a wheat may be judged by the external appearance, that is, the color. As has been said, the hard grains are clear, red, amber in color; while the soft ones are opaque, red to to white. There is of course no exact line of separation, but one passes imperceptibly into the other. Not infrequently the hard or nearly

hard kernels have two yellow spots on the cheeks of the grain, one on each side of the furrow. These vary greatly in size, and one may be entirely absent, but seems to be a rather common occurrence in the grains which are partly hard and partly soft. The hard and the soft grains are fairly easily distinguished by the eye, but with much greater difficulty in samples discolored by exposure to weather or otherwise. By cutting the grain transversely with a sharp knife a rough classification might be made as; hard, semi-hard, and soft. In this case of course arises the difficulty of deciding where the lines separating the three groups shall be drawn. If a large number of semi-hard grains be almost hard enough to be classed as hard, the average hardness of the sample would be considerably higher than in another sample in which a large percent of the same were nearly soft enough to be classed as soft, and yet the figures would show no difference.

In the semi hard grain, more or less of the center is usually opaque and mealy, and the outer part clear and flinty. Since it has been shown the flinty grains contain more protein, this would seem to be in agreement with Cobb's experiment to determine the percent of protein in the outer part of the grain compared with the inner. For this experiment the grains were sawn in two transversely, the cut end laid off in concentric rings of equal width, the flour re-

moved from each division separately and analyzed. In the first experiment three divisions were made and the per cent of protein was found to be 6.7, 10.0, and 16.4 for the inner, middle and outer, parts, respectively. In a second experiment five divisions were made with the results: 7.4 %, 8.6 %, 9.5 %, 13.9 %, and 16.5 % in the same order.

An instrument to measure pressure required to cut the grains was devised by Harper of the Kentucky Station. This consisted simply of a knife attached to a vertical beam upon which pressure was applied by means of weights. In his experiment (Bulletin 113) he appears to have placed a certain weight upon the knife and to have recorded simply the per cent cut by this weight. Such results give but a general result and not a correct average, since there is no means of knowing how much more pressure would have been necessary to cut the grain not cut by the given weight, and how much less for the other. Two other factors which must be considered are: The sharpness of the knife and the length of time which it was allowed to rest upon the grain. It is self evident that the sharper the less weight would required, and that it would be impossible to have it equally sharp for a large number of tests. It is also true, and has been found so by me in trials with a somewhat different machine described a little later, that a grain would resist a greater weight for a very short time than it would for a longer period. This difficulty, however, would exist with any such machine, and would be largely overcome by giving uniform treatment, thus

making the error comparative.

Harper remarks upon the results as follows: "The flinty grains are distinctly harder than the starchy ones in the same variety, and some varieties are much harder than others, but in comparing different varieties, there appears to be no definite relation between the percentage of protein and the pressure required to cut the grain in two". While it is not difficult to see that this might be true in wheat of different types, it is scarcely clear why it should hold with those of the same type grown under the same condition.

A machine devised and used by N. A. Cobb, in New South Wales, gave somewhat more of a crushing test. In this the grain was placed between the jaws of a pair of nippers, these having been dull by filing until they were a half millimeter wide. The jaws were then brought together by a spring balance attached to the handles, this being operated by winding an attached ribbon upon an axel by turning a crank. The test was then found by reading the balance, multiplied by the lever factor of the nippers. The writer mentions that a uniform winding of the ribbon was secured by timing the turn of the crank with a pendulum. But since the diameter of the axle would be increased by the accumulating ribbon, an accelerated motion would be producted; that is, unless the diameter of the axle was comparatively large, (He does not mention this and from the figure it appears quite small .)

In preparing the wheat for the test the samples were graded by a series of sieves of half round parallel wires, the spaces

between the wires being from 2.00 mm. to 3.25 mm., and the grains were used only from the grade containing the greatest per cent of the samples, or from the two largest in case two grades were represented by a larger per cent. The number of grains used for a test for an average was 40. The writer remarked that a larger number would probably have been better. The readings on the balance were made to 1-2 oz. and the results appeared therefore in ounces. The results exhibit great variations between different wh wheats, between samples of the same wheat grown in different years, and between grains in the same sample. Some of these variations are shown in the tables below.

Table II. Showing different variations for different seasons.

Name of wheat.	Crop of 1893	Crop of 1894.	Crop of 1895.
White Fife	155.65	117.12	82.56
Fultz	161.75	145.49	82.15
White Velvet	177.71	165.41	115.29
Pringle's Definace	217.47	203.64	132.47
Poland	365.19	290.56	197.13
Medeah	393.15	326.66	197.03

The climatic conditions for these years were:

1893 -- Favorable to growth.
1894 -- Favorable spring, followed by drought when grain was forming.
1895 -- Dry throughout.

Showing that the drier season produced the softer grain.

The following shows the variation in grains of the same sample. The figures 10-12, 12-14, etc., refers to the reading of the balance and the numbers in the colums to the number of grains broken at their points. To correspond with the preceding table they must be multiplied by 10.167, the lever factor of the machine.

Table III. Crop of 1894.

Wheat	below 10	10 to 12	12 to 14	14 to 16	16 to 18	18 to 20	20 to 22	22 to 24	24 to 26	26 to 28	28 to 30	30 to 32	32 to 34	34 to 36	36 to 38	38 to 40	40 to 42	42 to 44	44 to 46	Av.
White fife.		6	18	12	4															11.52
Fultz.		1	5	17	19	4	1	1	2											14.31
White Velvet.			2	4	9	15	9	1												16.27
Pringle's Definace					3	9	10	7	4	5	0	2								20.03
Poland									3	8	10	6	3	2	2	2	1	2		28.58
Medeah										3	5	2	6	9	9	2	1	1	1	32.13

From the first table it would seem that the variations of the same wheat in the different seasons is very great. So much so that the test overlaps to a considerable extent. The relative hardnessses, however, is seen to remain fairly constant. The second table shows the variation in grains of the same sample to be quite large, much more so in the harder wheat.

This instrument should give a fairly good average test, since the resistance of each grain is determined with considerable accuracy.

A machine similar to the last in general principles but somewhat different in application, was recently devised by Prof. Roberts and Freeman of the Botanical Department of this Station and constructed by one of the best known makers of scientific instruments, It consisted of a stand bearing a rotaty block on which the grains are placed, and a graduated beam, supported at the rear upon a knife edge and bearing at the outer end a steel pin which rests upon the grain. From the latter end a weight is suspended. A car which may bear any desired weight, is also provided to be moved by a rack and pinion along the beam. By this means a steadily increasing weight is applied until the grain breaks. The test is then calculated from the suspended weight, the weight on the car and its position on the beam; by means of a graduation on the face of the disk, moving the car, the reading may be made to one gram . The grains are placed with the cheeks down.

It will be seen that the effect of the machine is much the same as Cobb's Biting apparatus, but that the record is more accurate. Since a grain that is broken by a certain weight, will be broken by a lighter weight acting for a longer time, this may be offered as an objection. But the trouble seems difficult if not quite impossible to avoid,

and is at any rate only a comparative error, since it enters into all the work. It will be remembered that it was present in a like manner in the two instruments previously described.

Thus far no results have been obtained with wheat of different years, and only a limited amount with different varieties. In grains of the same sample the variations appear to be rather greater than in Cobb's experiment. (Such comparisons is hardly proper as in these tests the samples were not graded as in the former, weeviled, broken or otherwise injured only, being removed.) The following tables gives some idea of the result and of the variations in one-hundred grains of a sample. The numbers in the column headed 6 to 7, 7 to 8, etc., indicate the number of grains in one-hundred broken by a weight of between 6000 and 7000 g. etc.

Table IV.

Wheat	under 5	5 to 6	6 to 7	7 to 8	8 to 9	9 to 10	10 to 11	11 to 12	12 to 13	13 to 14	14 to 15	15 to 16	16 to 17	Average.
No.252	0	1	11	20	18	15	14	8	9	2	1			9312
No.1455	11	20	28	17	13	3	5	0	1					6820
No.1968	0	12	16	22	14	15	12	6	1	0	1			8235

Showing an extreme variation of nearly 10000 gms. between grains of the same sample. There was also a considerable variation in the averages of 100egrain lots, a shown below in five such tests of the same wheats.

Table V.

Wheat No.	Tests					Average.
	first	second	third	fourth	fifth	
252	9,407	9,346	9,312	9,065	8,958	9,218
1455	6,900	6,713	6,854	6,820	6,746	6,806
1968	8,122	8,497	8,075	8,235	8,295	8,245

Showing an extreme variation in the averages from one sample of between four hundred and five hundred grams. It will be seen from this that a large number of tests would be required to obtain an accurate average. This difference, however, we might expect to be considerably diminsihed in pure samples. These lots were selected from the available material as comparatively pure and uniform. No. 252 is an ordinary hard, red, wheat, grown at this Station; grains small to medium sixe, rather long, weighing 30.31 g. per thousand. No. 1455 is a soft red wheat from the Indiana Station; grains plump and short, small to medium size, weighing 33.795 g. per thousand. No. 1968 is a white but rather hard wheat from Oregon; grains plump, medium size, weighing 36.493 g. per thousand. No. 252 contained about 34 % of flinty grains. A comparison of the hardness of these and of the softness is shown below.

Table VI.

Table VI.

Wheat	5 to 6	6 to 7	7 to 8	8 to 9	9 to 10	10 to 11	11 to 12	12 to 13	13 to 14	14 to 15	15 to 16	16	Average.
Hard	1	5	5	9	8	15	15	16	12	5	7	1	11,249
Soft	0	14	29	21	15	11	6	2	0	1			8,586

Showing the flinty grains to be much harder and to show more variation.

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Relation to the moisture content.

In making such comparative test, one question suggested is: What difference does the moisture content of the grain make? The following experiment constitutes an attempt to throw some light upon this point. The wheats used were the three mentioned above. They had been stored for several months previous in a dry room.

To determine the per cent of moisture in the samples in this condition, a 30 gram sample of each was reduced to dryness, partly by a sulphuric acid dessicator, later by a drying oven. The original samples were comparatively clean, but for this, as well as for all subsequent tests, the grain used was carefully examined and all trash, broken, weevviled or badly shriveled grains removed. In the dessicator the samples were spread out in one hald of an ordinary Petri dish, the exposed surface being about 65 sq. cm. and the depth 6 mm. or less. Weighings were made every twelve hours for the first

few days; later at longer periods. The following table shows the rate of evaporation for successive periods.

Table VII. Evaporation in dessicator - 30 g. used.

Wheat	Time	14	1-2	11	12	12	1-2	12	12	12	12	12	12	12	12	12	12	24.
252	Loss in weight, mg.	412		221	172	150		120	103	86	86	81	76	69	64	62	57	46	94
1455		233		177	127	149		121	94	89	80	79	76	73	66	65	52	55	100
1968		147		128	120	118		105	92	83	87	77	79	67	72	60	50	49	97

Wheat	Time hrs.	*24	24	24	24	24	36	36	54	Total 452.
252	Loss in weight, mg.	*29	47	33	25	23	39	41	67	2200 = 8.30 %
1455		*28	42	35	20	25	43	40	72	1940 = 7.27 %
1968		*25	42	38	25	20	50	41	75	1547 = 5.73 %

*This small loss is probably accounted for by the fact that other samples were placed in the dessicator with these at this time. The others showed a proportional decrease.

The drying was completed in an over at about 100° C. In the first of the latter operation certain errors entered which make it impossible to give the exact time required to complete the drying. It might be noted, however, that 200 mg. were lost in the last 30 1-2 hours. The final results showed the following per cents:

No. 252 -- 13.18 %

No.1455 -- 12.40 %

No.1968 -- 11.08 %

In order to ascertain the hardness at different per

cents of moisture, another set of samples was started in the dessicator. One thousand grains were used in each case and five tests made at various stages, using two hundred grains to obtain an average. The table shows the result.

Table VIII. Change in hardness upon drying.

No. of wheat.	Normal.		1st test.		2nd test.		3rd test.	
	% moisture	Crushing test	% moisture	Crushing test.	% Moisture	Crushing test	% Moisture.	Crushing test.
252	13.18	9,218	11.90	9,727	9.73	10,215	8.44	9,826
1455	12.40	6,806	11,75	6,697	10.63	6,887	9.49	6,812
1968	11.08	8,245	10.53	8,427	9.38	8,619	7.75	8,486

No. of wheat (con.)	4th test		5th test.		6th test.	
	% Moisture.	Crushing test.	% Moisture.	Crushing test.	% Moisture.	Crushing test.
252	6.09	10,651	4.39	10,850	0	9,585
1455	7.11	6,954	5.42	6,810	0	5,414
1968	6.71	7,895	3.46	7,561	0	6,563

Showing, at least in the first, a considerable increase in the crushing test to a certain point, and then a decrease. The sixth test was made from the lots which had been in the oven(all others are from the dessicator), and it may be questioned whether any of the change is due to the different method of drying.

In order to secure results with a per cent of moisture

above normal, three samples of the same quantity as the last were exposed to saturated atmosphere of a moist chamber, and tests made at intervals as before. Absorption took place rapidly with a corresponding decrease in the crushing test as shown below.

Table IX. Absorption of moisture and crushing test.

No. of wheat.	Normal			First test.			Second test.	
	% of moisture	Crushing test.	Hours exposed.	% of moisture.	Crushing test.	Hours exposed.	% of moisture.	Crushing, test.
252	13.18	9,218	12	15.10	8,041	12	17.07	-----
1455	12.40	6,806	12	14.71	6,341	12	16.66	-----
1968	11.08	8,245	12	13.67	7,623	12	15.87	-----

It might be expected that a hard or dry grain would break with a more sharp, sudden, drop than a softer or less dry one. In the drying experiment the difference in the break was not great enough to be especially noticeable, but in this test the change for the first test was remarkable. The grains of the hard red (No. 252) broke much the same as those of a soft wheat would under ordinary conditions. With the others the results were quite unsatisfactory since in many cases there was no sudden drop, but only a gradual mashing. On this account and beeause the decrease was comparatively small, no further test was made with these. With the first sample another lot was taken and followed more closely. The periods of exposure were four hours each, and the per cents

absorbed were; 1.29 %, 1.40 %, 1.51 %, 1.22 %, and 1.74 %.

The change in the crushing test was as follows:

Table X. Change in crushing test in moist chamber.

Norof wheat	Normal		First test.		Second test.	
	% of moist-ure.	Crushing test.	% of moist-ure.	Crush-ing test.	% of moist-ure.	Crushing test.
252	13.18	9,218	14.37	8,299	15.77	7,601

(Continued)

No. of wheat.	Third test.		Fourth test.		Fifth test.	
	% of moist-ure.	Crush-ing test.	% of moist-ure.	Crush-ing test.	% of moist-ure.	Crushing test.
252	17.28	7,629	18.50	7,408	20.24	-----

A fifth test was begun but not completed because the grains were too soft to give satisfactory results. From these results it is seen that the grain absorbed water very rapidly and the crushing test dropped remarkably, expecially at first. This is rather surprising considering the small change which took place upon dessication. Since in these tests the grains were not allowed to remain for any length of time before testing at a given per cent of moisture, it might be interesting to see what would be the result if they were allowed to do so.

Another test now made, was a comparison of the hard and soft grains of No. 252. As has been said, this wheat contained

34% of grains which were clear and flinty, the remainder being opaque and mealy. A quantity of the sample was separated into the two lots and tests made as with the first three samples.

The hard grains were found to be somewhat heavier, the average of three lots of one thousand grains each being 31.167 g. for the hard, and 29.704 g. for the soft, a difference of about 4.7 %. In comparing the hard and soft grains of the same sample, the Kentucky Station (Bul.113) found the flinty ones contained more moisture, (.15 % as an average of nineteen tests.), and that the starchy ones absorbed moisture more rapidly in moist air. The Nebraska Station on the other hand, found (bul. 89) that the yellow berries contained more moisture, the average difference being .56%: also that the flinty kernels were in every case, heavier. The Minnesota Station (Bul. 85) found the flinty kernels heavier in some wheats and lighter in others.

In testing for moisture content as before, 30 g. of flinty grains lost in nine days, in the dessicator, 1.657 g. or 6.24 %. In the same time an equal weight of soft grains lost 1.656 g. or 6.23 %. The drying was continued in the oven with the three lots of the first test. The results at the conclusion of this test showed an original moisture content of 12.93 % for the hard, and 12.76 % for the soft.

Two samples of 1000 grains each dried in the dessicator and tested at five different points gave the following results:

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Curve showing relation of moisture and crushing point.

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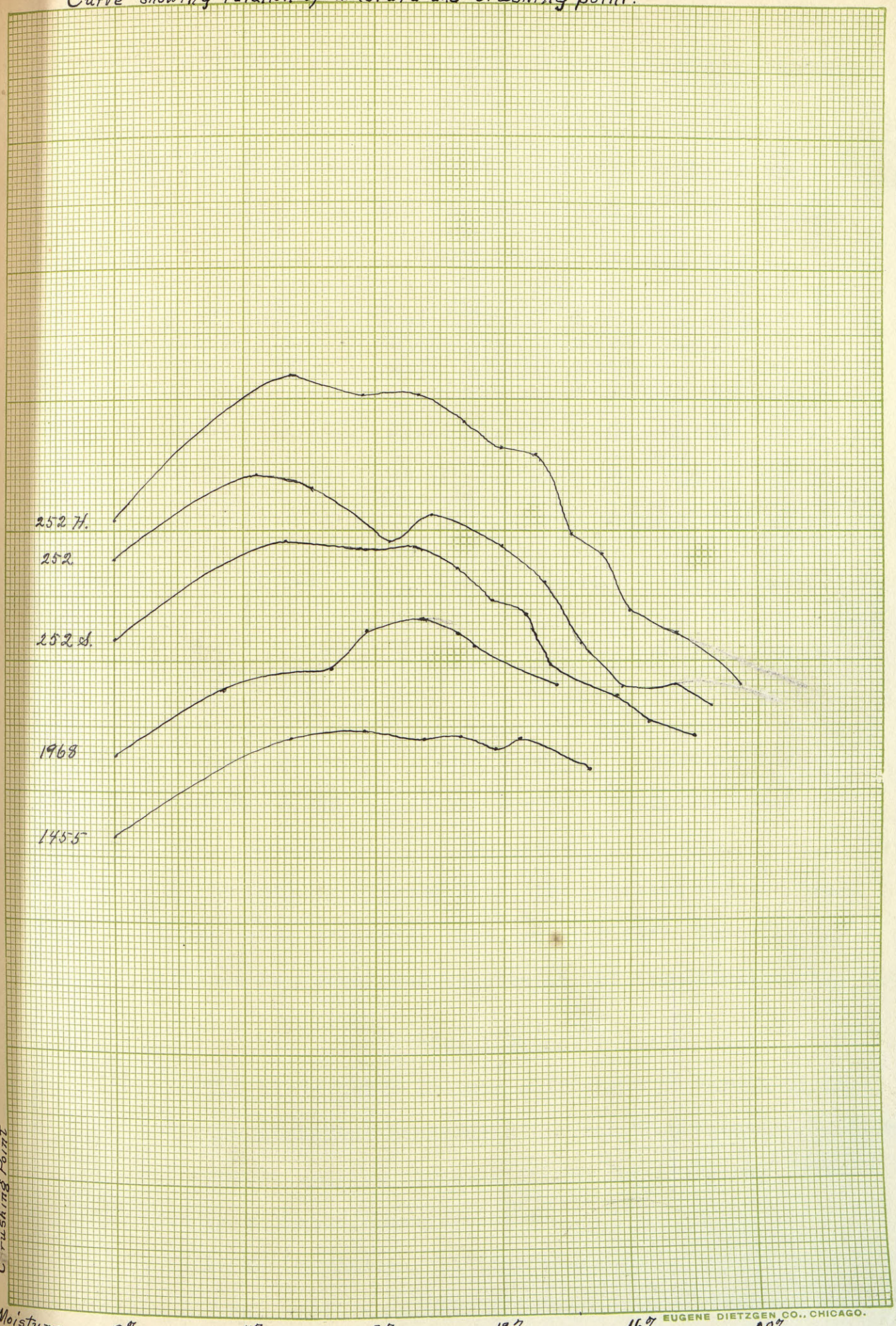

The following shows the crushing tests at these stages.

Table XII. Hard and soft grains in moist chamber.

Wheat	Normal		First test.		Second test.	
	% of moisture.	Crushing test	% of moisture.	Crushing test.	% of moisture.	Crushing test.
Hard	12.93	11,160	14.11	9,965	15.04	9,657
Soft	12.76	8,722	14,37	7,960	15,50	7,580

(continued)

Wheat	Third test		Fourth test.		Fifth test.	
	% of moisture.	Crushing test.	% of moisture.	Crushing test.	% of moisture.	Crushing test.
Hard	15.91	8,793	17.13	8,467	19.41	7,604
Soft	16.54	7,028	17.91	6,828	20.23	-----

As with the former lots, the character of the break changed with the first test, and the fifth test for the soft was not concluded because of the unsatifactory results.

Conclusions.

The above tests are not sufficient to permit of any definite statement concerning the relation between the moisture content and the hardness of the wheat grains. They seem to indicate, however, that:

1. The crushing point increases as the moisture content decreases, until a certain point is reached, after which the

crushing point decreases rather rapidly, this point being within about five per cent of dryness.

2. This variation is fairly constant with different varieties.

3. The change in moisture content does not change the variation between individual grains. (Space has not permitted data upon this point.).)

4. The variation of hard and soft grains of the same sample does not differ greatly as the moisture content changes.

5. The harder grains are heavier and contain a slightly greater per cent of moisture.

6. The softer grains absorb moisture more rapidly when placed in a moist atmosphere.

(end)

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