YELLOW-BERRY IN HARD WINTER WHEAT

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In an earlier publication[1] of the Kansas Agricultural Experiment Station, data were presented to show that yellow-berry in wheat is heritable and that improvement in the ability of wheat to resist the disease can be accomplished by breeding. The investigations reported therein have been extended, and some studies pertaining to the physiological processes that result in yellow-berry have been made. It is the purpose of this paper to present the results of these later studies.[2]

THE NATURE OF YELLOW-BERRY

The yellow-berry problem has two aspects, the one practical, the other theoretical. The presence of yellow-berry in wheat causes it to grade lower and sell at a lower price than clear, hard wheat high in gluten. Furthermore, as Bailey says (*1, p. 18*):

> If the kernels are soft in texture, or represent what is termed the "yellow-berry" condition, the percentage of flour will be reduced, since it is mechanically impossible to free the bran from the floury portions so nearly as when the endosperm is hard and vitreous.

It is apparent that if the yellow-berry condition were eliminated from hard wheats, the practical interests of both the grower and the miller would be subserved.

The term yellow-berry has been defined by Roberts and Freeman (*6, p. 1*) as—

> the appearance [in hard, flinty wheats] of grains of a light yellow color, opaque, soft, and starchy. These opaque yellow grains, constituting what are called the "yellow berries," may have this character throughout; but sometime from a small fraction to half of a grain will be yellow and starchy, while the remainder of the kernel will be hard, flinty, and translucent. The difference in color between the flinty grains and the "yellow berries" is due to differences in the structure and contents of the cells of the endosperm.

The cause of yellow-berry in wheat has been the subject of some investigation. It appears to have been reported first by Bolley (*2, p. 35–36*), who held that the opaque, yellow spotting of the kernels was due not to heredity but to climatic factors, and that—

> this peculiar mottling is due to the action of moisture, air, and sun upon the grain while it is yet in the chaff. If the weather action is long continued, the grains become evenly bleached over the entire surface. The color and hardness of the grain can be maintained by proper care in harvesting and curing.

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[1] Reference is made by number (italic) to "Literature cited," p. 169.

[2] Credit is due the Department of Chemistry for the chemical analyses reported herein.

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Lyon and Keyser (*5, p. 25–29*) came to the conclusion that—

there is quite a definite relation between the per cent of yellow berries in the crop and the character of the season in so far as the latter affects the date of ripening, the composition, and the yield of wheat.

From experimental data they find that—

the amount of "yellow-berry" increases with the lateness of ripening,

and that—

crops of large yield and low nitrogen content contain more "yellow-berries" than do crops of the opposite kind.

They conclude that—

since it has been shown that the amount of yellow-berry increases as the ripeness of the grain increases, and also with the length of time the cut grain is exposed to the weather, it is impossible to lessen the loss by cutting the grain rather early and stacking as soon as sufficiently dry.

Roberts and Freeman (*6, p. 21–35*) found that in two successive years there was a diminution in the amount of yellow-berry corresponding to the shortening of the fall growing period on account of late planting. No relation was found to exist between the spring growing period and the percentage of yellow-berry, except that, in general, late ripening increased it. Higher mean temperatures for the three weeks before ripening were found to be correlated with low percentage of yellow-berry. Evidences of hereditary tendencies were found.

Headden (*4, p. 30–37*) studied the effects of different commercial fertilizers on yellow-berry. His results may be summarized in his own words, as follows:

In our case it is evidently the ratio between the potassium and nitrogen which determines the presence of yellow-berry. . . . The degree of mealiness or starchiness, the yellow-berry, . . . depends upon the relative available supply of these two elements. . . . The application of nitrogen, which was in the form of sodic nitrate, greatly reduced the amount of yellow-berry, in some cases preventing it altogether.

Headden does not find that climatic conditions, the soil, or the amount of available phosphorus affects the development of yellow-berry, but states that—

it can be greatly intensified or increased by the application of available potassium,

and that—

yellow-berry indicates that potassium is present in excess of what is necessary to form such a ratio to the available nitrogen present as to be advantageous to the formation of a hard, flinty kernel. . . . I do not think that there can be any question of the identity of this affection of our wheat with that of Kansas, Nebraska, or South Dakota, and almost no question but that the opaque wheats of California and the Pacific Coast States in general are identical in their character with extreme cases of yellow-berry in Colorado and have the same cause.

This last phase of the question has not yet received much attention. The fact that yellow-berry is produced under apparently the same conditions as the flinty kernels, not merely in the same field, but on the same

plant or in the same head, indicates that yellow-berry is actually different from ordinary soft wheat.

Roberts and Freeman (*6*) suggested that heredity is a strong factor in determining the occurrence of yellow-berry in wheat and that pure varieties could probably be isolated that would produce little or no yellow-berry. To establish the correctness or incorrectness of this view a large number of pure strains of winter wheat were examined by the writer, and the percentage by weight of yellow-berry was determined in each.

The method pursued was as follows: From each strain of wheat, 100 cc. of grain were taken and weighed. The yellow-berry kernels were then separated and weighed. The starchy spots in the kernel almost invariably begin to appear around the germ or embryo—that is to say, at the lower end of the kernel as it stands in the glumes—and spread from there upward. In no case do the starchy spots begin to appear at the brush or tip end of the kernel. The area of the starchy spots may vary from minute dots to the entire grain. Since the opaque, starchy spots in a flinty, translucent wheat kernel may be large or small, the separation of the yellow-berry kernels must be made according to an arbitrary standard. It was decided to include as yellow-berry all kernels of which one-half or more of the grain was opaque and starchy. The starchy kernels were separated on this basis and weighed. The flinty kernels—those showing no opaque spots at all—were also separated and weighed, and the residue, if any, was designated as "neutral grains."

The separating and weighing of the kernels was done by two persons, designated in the table by their initials, "L," and "A," who by long experience became very expert in making the analyses of the samples. By having a part of the samples which were analyzed by one checked by the other it was found that very little difference resulted from the different individual judgments of "L," who did the earlier, and "A," who did the later work. It is therefore concluded that the percentage of error due to the personal equation is negligible, and that it is completely overshadowed by the positive differences in the samples themselves.

In all, 164 lots of wheat were studied, of which 77 were pure strains and 87 were checks or controls. The pure strains were grown in single rows alternately with the controls. All the rows were of the same length, 66 feet, and stood 8 inches apart. The variety used for the control rows was not a pure line but was, nevertheless, an unusually pure race of Kharkov, a standard variety long and successfully grown here. All the rows, whether of pure-line wheats or controls, contained 250 grains each, planted equidistant in the rows. The wheat was all grown in the same field, which was divided lengthwise into blocks, and each block into plots separated by narrow alleyways. The plots were all 100 by 100 feet in size. In Table I the rows are grouped according to dates of harvesting in 1908. The control row following each pure strain is given

the number of that same strain, followed by the letter "C" to indicate that it is a control. Thus, 1104 is followed by 1104 C. In cases where the numbering is not consecutive, as where a control of a different number follows a pure strain, or where no control at all is given after a pure strain, the reason lies in the fact that the omitted rows did not have the same harvesting date, or else, either through accident or winterkilling, they had been eliminated. The results of this study are given in Table I and summarized in Table II. The percentage of yellow-berry in each strain in 1907 is included in Table I so far as this information is available.

TABLE I.—*Yellow-berry in different strains and varieties of hard winter wheat*

Row No.	Date of harvest, 1908.	Plot No.	Percentage of yellow-berry.	
			1907.	1908.
1152 (A)	June 24	7	3.0	4.8
1149 (A)	...do....	7	17.0	17.3
1126 (L)	...do....	7	5.0	40.4
1125 (A)	...do....	7	1.0	33.8
1066 (A)	June 25	5	5.0	6.8
1068-4 (L)	...do....	5	.....	30.8
1068-5 (L)	...do....	5	49.0	34.0
1081-C (A)	...do....	5	.....	11.9
1122-C (A)	...do....	6	.....	27.6
1124-C (L)	...do....	6	.....	32.4
1125-C (A)	...do....	6	.....	32.8
1126-C (L)	...do....	6	.....	33.0
1128 (A)	...do....	6	9.0	24.1
1131 (L)	...do....	6	4.0	34.2
1135-C (L)	...do....	6	.....	28.2
1142-C (A)	...do....	7	.....	45.3
1145-C (L)	...do....	7	.....	32.8
1157 (A)	...do....	7	1.0	4.6
1157-C (A)	...do....	7	.....	6.8
1161 (A)	...do....	7	7.0	4.8
990 (L)	June 26	3	1.0	11.1
991 (L)	...do....	3	.....	18.0
1000 (L)	...do....	3	2.0	16.5
1003-C (L)	...do....	3	.....	19.5
1008 (A)	...do....	4	5.0	20.5
1008-C (A)	...do....	4	.....	26.2
1069 (A)	...do....	5	5.0	5.2
1074-C (A)	...do....	5	.....	21.2
1075 (L)	...do....	5	5.0	22.2
1080 (A)	...do....	5	5.0	1.8
1080-C (A)	...do....	5	.....	19.8
1081 (A)	...do....	5	5.0	15.8
1093-C (L)	...do....	5	.....	40.7
1094 (L)	...do....	5	.....	70.4
1094-C (L)	...do....	5	10.0	28.2
1095-C (L)	...do....	5	.....	22.6
1103 (A)	...do....	6	11.0	29.7
1098 (A)	June 27	6	.....	37.1
990-C	June 30	3	.....	17.9
991-C (L)	...do....	3	.....	27.0
994-C (L)	...do....	3	.....	21.0
1000-C (L)	...do....	3	.....	13.0
996-C (L)	July 1	3	.....	29.5

TABLE I.—*Yellow-berry in different strains and varieties of hard winter wheat*—Con.

Row No.	Date of harvest, 1908.	Plot No.	Percentage of yellow-berry.	
			1907.	1908.
1004-C (A)	July 1	3	.....	13.6
1035-C (A)	...do.....	4	.....	14.0
1036 (A)	...do.....	4	10.0	56.8
1036-C (A)	...do.....	4	.....	19.0
1038 (L)	...do.....	4	20.0	62.1
1038-C (L)	...do.....	4	.....	36.0
1058-1-C (L)	...do.....	4	.....	40.1
1059-3-C (L)	...do.....	4	.....	43.3
1059-4 (A)	...do.....	4	5.0	23.3
1059-4-C (A)	...do.....	4	.....	23.0
1064-C (A)	...do.....	4	.....	6.2
1066-C (A)	...do.....	5	.....	12.8
1068-C (L)	...do.....	5	.....	33.9
1068-5-C (L)	...do.....	5	.....	38.0
1069-C (A)	...do.....	5	.....	12.8
1070-C (A)	...do.....	5	.....	10.1
1071 (A)	...do.....	5	.....	16.2
1071-C (A)	...do.....	5	.....	24.6
1072 (L)	...do.....	5	.....	47.0
1072-C (L)	...do.....	5	1.0	44.2
1073 (A)	...do.....	5	.....	22.2
1073-C (A)	...do.....	5	11.0	13.4
1075-C (L)	...do.....	5	.....	49.7
1076 (A)	...do.....	5	.....	50.9
1077 (L)	...do.....	5	16.0	50.4
1077-C (L)	...do.....	5	28.0	44.5
1093 (L)	...do.....	5	.....	44.9
1076-C (A)	...do.....	5	4.0	18.8
1098-C (A)	...do.....	6	.....	20.2
1102 (A)	...do.....	6	21.0	45.8
1103-C (A)	...do.....	6	.....	15.0
1104 (A)	...do.....	6	10.0	16.7
1104-C (A)	...do.....	6	.....	11.9
1105-C (A)	...do.....	6	.....	28.9
1106 (A)	...do.....	6	9.0	14.8
1106-C (A)	...do.....	6	.....	32.3
1107 (A)	...do.....	6	3.0	26.8
1107-C (A)	...do.....	6	.....	19.0
1108 (A)	...do.....	6	1.0	37.2
1108-C (A)	...do.....	6	.....	16.4
1109 (A)	...do.....	6	2.0	37.4
1110 (A)	...do.....	6	2.0	50.9
1110-C (A)	...do.....	6	.....	25.5
1111-C (A)	...do.....	6	.....	27.0
1113 (A)	...do.....	6	.....	10.0
1113-C (A)	...do.....	6	.....	26.4
1114 (A)	...do.....	6	.....	9.6
1114-C (A)	...do.....	6	.....	31.2
1115 (A)	...do.....	6	1.0	29.8
1115-C (A)	...do.....	6	.....	32.3
1116 (A)	...do.....	6	7.0	40.5
1116-C (A)	...do.....	6	.....	32.9
1124 (L)	...do.....	6	2.0	16.5
1128-C (A)	...do.....	6	.....	16.9
1130 (A)	...do.....	6	.....	43.5
1130-C (A)	...do.....	6	.....	24.0
1132 (L)	...do.....	6	20.0	80.4

TABLE I.—*Yellow-berry in different strains and varieties of hard winter wheat*—Con.

Row No.	Date of harvest, 1908.	Plot No.	Percentage of yellow-berry.	
			1907.	1908.
1132–C (L)	July 1	6	.....	69. 0
1135 (L)	...do.....	6	21. 0	86. 0
1140 (L)	...do.....	6	2. 0	94. 5
1140–C (L)	...do.....	6	.....	66. 9
1145 (L)	...do.....	7	25. 0	99. 0
1150–C (A)	...do.....	7	.....	10. 3
1151 (A)	...do.....	7	1. 0	8. 8
1151–C (A)	...do.....	7	.....	12. 9
1152–C (A)	...do.....	7	.....	11. 4
1154 (L)	...do.....	7	6. 0	75. 3
1154–C (L)	...do.....	7	.....	41. 7
1160 (L)	...do.....	7	.....	49. 0
1161–C (A)	...do.....	7	.....	10. 3
1162 (A)	...do.....	7	5. 0	62. 4
1162–C (A)	...do.....	7	.....	11. 4
1163 (L)	...do.....	7	12. 0	69. 1
1163–C (L)	...do.....	7	.....	28. 3
1164–1 (L)	...do.....	7	23. 0	45. 3
1164–1–C (L)	...do.....	7	.....	34. 6
1164–2 (L)	...do.....	7	30. 0	64. 8
1372–1 (A)	...do.....	7	2. 0	40. 3
1372–1–C (A)	...do.....	7	.....	15. 2
1372–8–C (A)	...do.....	7	.....	14. 1
1117–C (L)	...do.....	7	.....	25. 8
1160 (L)	July 3	7	30. 0	61. 5
1164–2–C (L)	...do.....	7	.....	52. 6
1058–6 (L)	...do.....	8	.....	26. 7
1058–6–C (L)	...do.....	8	.....	29. 2
1117 (L)	...do.....	8	.....	53. 0
1138–C (A)	...do.....	8	.....	8. 1
1059–7 (L)	...do.....	1	.....	45. 4
1059–7–C (L)	...do.....	1	.....	45. 2
1067 (L)	...do.....	1	17. 0	87. 0
1067–C (L)	...do.....	1	.....	41. 5
1091 (L)	...do.....	1	.....	90. 2
1091–C (L)	...do.....	1	.....	43. 4
1146 (L)	...do.....	1	32. 0	90. 4
1146–C (L)	...do.....	1	.....	59. 7
1147–C (L)	...do.....	1	.....	78. 4
1003 (L)	July 6...	3	10. 0	15. 0
1004 (A)	...do.....	3	.....	59. 8
1058–1 (L)	...do.....	4	.....	32. 5
1058–5 (A)	...do.....	4	1. 0	20. 3
1059–3 (L)	...do.....	4	1. 0	38. 9
1059–6 (L)	July 10	1	.....	30. 0
1059–6–C (L)	...do.....	1	.....	38. 0
1002–C (A)	...do.....	1	.....	33. 7
1039 (L)	...do.....	1	.....	67. 9
1039–C (L)	...do.....	1	.....	63. 0
1068–1–C (A)	...do.....	1	.....	26. 4
1096–C (A)	...do.....	1	.....	28. 3
1139 (L)	...do.....	1	.....	92. 2
1139–C (L)	...do.....	1	.....	79. 5
1147 (L)	...do.....	1	4. 0	94. 4
1158 (L)	July 12	7	1. 0	65. 5
1158–C (L)	...do.....	7	.....	38. 8

TABLE II.—*Summary of yellow-berry in hard winter wheat, 1908*

Date of harvesting, 1908.	Total number of cases.	Number of pure strains.	Percentage of yellow-berry.	Number of controls.	Percentage of yellow-berry.	Average percentage of yellow-berry.
June 25	16	7	20	9	28	24
26	17	10	21	7	25	23
30	4	0	.....	4	20	20
July 1	82	33	45	49	26	34
3	15	7	65	8	45	54
6	5	5	33	0	.....	33
10	10	4	71	6	45	55

Tables I and II give the results for 73 pure strains and 83 controls out of the total number of 77 and 87, respectively, that were originally planted. The average percentage of yellow-berry in the control plots is given in Table III.

TABLE III.—*Average percentage of yellow-berry in control plots, 1908*

Plot No.	Number of rows.	Percentage of yellow-berry.
3	7	20. 2
4	8	26. 0
5	17	26. 3
6	22	29. 5
7	15	24. 5
8	3	21. 0
Average	.....	26. 1

From this table it appears that the control rows were quite constant in their tendency to produce yellow-berry. However, as shown in figure 1, there is considerable variation in the amount of yellow-berry in individual rows. The general trend of the percentage of yellow-berry in the pure strains follows that of the controls. This indicates that the differences depend upon the same causes in the pure strains as in the controls, and that the changing conditions in different parts of the plot had more influence in causing an increase or a decrease in yellow-berry than did any hereditary factors.

The yield per row presents a similar phenomenon. There is a greater variability in the yield of the individual rows in the pure strains than in the control rows, but the general upward and downward trend of the two curves coincides very closely. This would indicate that external conditions in the plots were more important than varietal characteristics in determining both the yield and the percentage of yellow-berry.

An inspection of Table I shows that there are a number of cases in which there is apparent coincidence between the percentage of yellow-berry produced in one season and the percentage produced by the same strain the following season. However, a correlation table between yellow-berry percentages for the two successive seasons plotted for 56 strains that were planted and harvested on the same date gives a correlation coefficient of only 0.078 ± 0.005. This extremely low correlation indicates that the external conditions are the determining factors to a degree which the hereditary tendencies of the plant have little power to modify. On the other hand, a graph showing the percentage of yellow-berry in 1907 and 1908 for those strains having 10 per cent or more of yellow-berry indicates that there is a hereditary relation; and were the number of cases larger, distinct indications of inheritance would be seen.

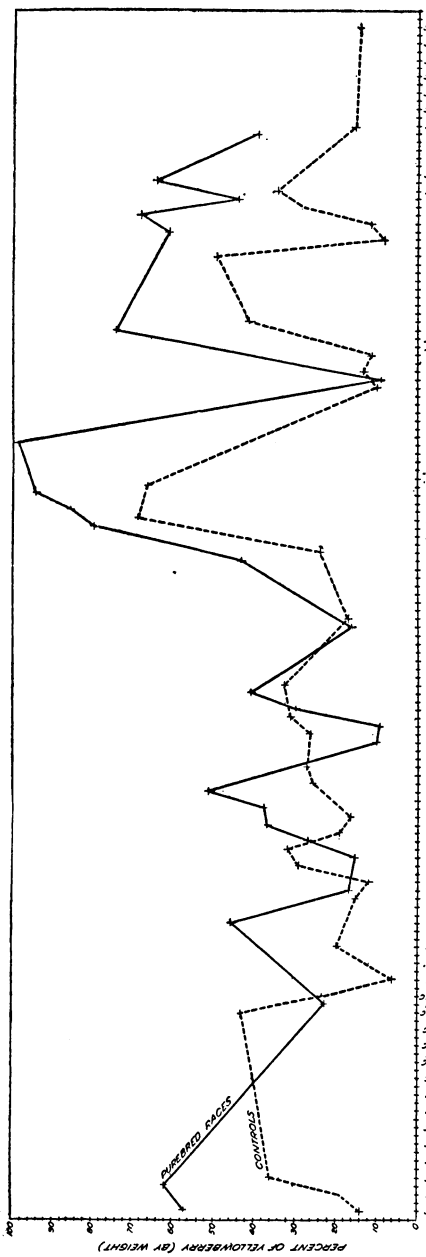

FIG. 1.—Percentage by weight of yellow-berry kernels in pure-bred wheats and their controls, 1908.

The relation between date of harvesting and the percentage of yellow-berry is indicated in figure 2. It is evident that from June 25 to July 1 there was an increase in the percentage of yellow-berry. The total number of rows harvested July 3 and 10 are not sufficient to permit definite conclusions with respect to these dates. It appears, however, that in the season of 1908 there was a close relation between the percentages of

yellow-berry and the date of ripening. This is in harmony with the general assumption that a longer growing and a slower ripening period produces yellow-berry.

PHYSICAL CHARACTERS OF YELLOW-BERRY

Lyon and Keyser (*5, p. 32*) cite Nowacki to the effect that—

the difference between mealy and horny wheat kernels is due to the presence in the former of a larger volume of air spaces than in the latter. He urges that the vacuoles

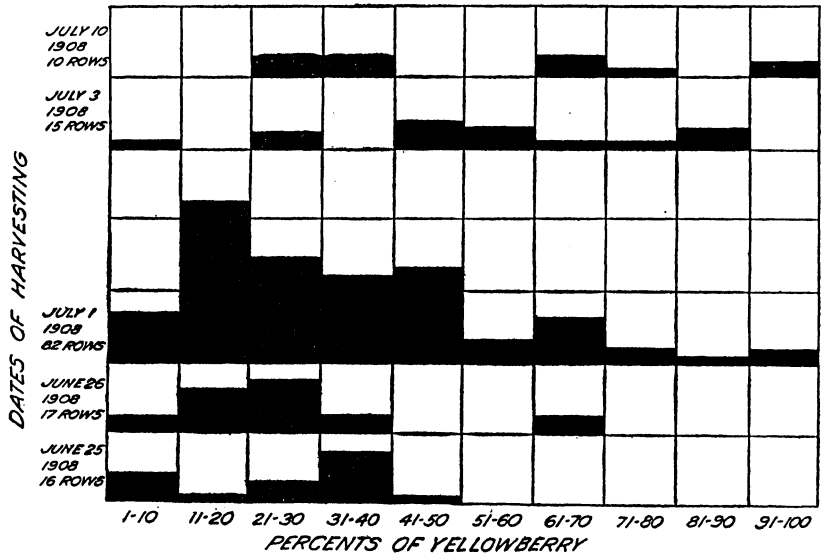

FIG. 2.—Relation between date of harvesting and percentage of yellow-berry.

that occur in the protoplasm of the cell decrease in size and number as the endosperm develops, and that the more protoplasm, the smaller and fewer the vacuoles.

Lyon and Keyser (*5, p. 34*) found that—

a typical mealy wheat like the soft, white Sonora of California contained starchy granules measuring from 0.02817 millimeters in diameter for the larger, to 0.005634 millimeters for the smaller. A typical horny Turkish Red kernel contained starch grains varying between the extremes of 0.014085 and 0.002817 millimeters in diameter. A typical yellow-berry Turkish Red kernel showed larger starch granules, 0.017042 millimeters for the larger, and 0.003081 millimeters for the smaller sizes.

Cobb (*3, p. 512*) found that—

it is noticeable that when the grain is rich in nitrogenous matter the number of large starch granules is smaller. As we pass in such grains in our examination from the center to the outside, we note a gradual decrease in the size of the starch granules, and even at some little distance from the aleuron layer the cells are filled with small granules only.

Lyon and Keyser's examination (*5, p. 35*) of horny and starchy kernels revealed more numerous and larger vacuoles in the latter, with only an

occasional vacuole in the former. It is stated that large starch granules and large or numerous vacuoles are associated in starchy kernels, and that—

> the difference in structure between the horny and the yellow kernels is also accompanied by a difference in composition, the yellow kernels containing less nitrogen.

The size of the starch granules in yellow-berry and in hard, flinty wheat was studied by the writer. Yellow-berry kernels were taken from a number of pure wheats, and samples of the opaque or yellow portions of the endosperm were removed from these by means of a dental drill. Samples were taken from 10 kernels to get a fair average. Similar samples were taken from the horny or flinty portion of the same 10 kernels, the drill being burned off each time after use.

The yellow-berry endosperm samples were shaken up in alcohol, stained with iodin in potassium iodid, and mounted for measurement with a Bausch and Lomb filar micrometer. Five hundred measurements were made for each 10-grain sample of each strain of wheat used. In all cases, the largest starch granules visible in any given field were the ones chosen for measurement. The results of this study are given in Table IV.

TABLE IV.—*Measurements of starch grains from yellow-berry and from hard kernels of 10 pure lines of wheat*

Sample No.	Measurement of starch granules in—		Difference between soft and hard grains.
	Hard grains.	Soft grains.	
	Mm.	*Mm.*	*Mm.*
951	0.030726	0.024819	−0.005907
1094	.024999	.029095	+ .004096
1119	.025910	.023940	− .001970
1126	.027315	.024977	− .002338
1150	.032587	.027981	− .004606
1516–8	.027873	.028878	+ .001005
1592–6	.028234	.028969	+ .000735
1687–4	.029413	.027965	− .001448
1687–8	.031869	.023822	− .008047
1687–10	.033200	.028519	− .004681
Average	.029212	.026897	.002315

These results show that in 7 out of 10 cases the average diameter of the starch grains in the hard portions of the kernels was greater than in the soft or yellow-berry portions, while in 3 cases it was less. These results are exactly the reverse of those obtained by Lyon and Keyser (*5, p. 23–26*).

The writer is unable to account for the discrepancy in the two sets of data. It would seem, however, that since in the present case an average of 500 measurements was taken and the largest starch grains in each

microscopic field were measured, fairly uniform and accurate results have been obtained.

Table V shows the frequency of distribution of the starch grains with respect to size, expressed in micromillimeters (microns) in nine of the races or pure strains just considered. From this table it appears that, in both the hard kernels and the yellow grains, the greatest number of individual cases (the mode) falls into the class of 25 to 29.9 micromillimeters diameter, although the average size of the starch grains in the hard kernels was about 2.3 microns greater than in the yellow-berry kernels.

TABLE V.—*Distribution of starch grains of yellow-berry and hard kernels with respect to size*

[Diameter of starch grains expressed in micromillimeters $\left(\frac{\text{mm.}}{1000}\right)$]

Pedigree No.	Number of starch grains having diameter of—												
	14.9	19.9	24.9	29.9	34.9	39.9	44.9	49.9	54.9	59.9	64.9	69.9	74.9
951 h	....	26	118	121	90	78	31	22	14	....	....	....	....
951 y	....	46	235	172	40	5	1	....	....	....	....	....	....
1094 h	1	63	207	167	46	16	7	1	....	....	....	....	....
1094 y	....	9	87	198	154	45	7	....	....	....	....	....	....
1119 h	....	36	197	174	74	19	....	....	....	....	....	....	....
1119 y	....	69	259	136	33	2	1	....	....	....	....	....	....
1126 h	....	7	133	245	97	18	3	....	....	....	....	....	....
1126 y	....	46	209	196	46	3	....	....	....	....	....	....	....
1516–8 h	....	5	124	224	118	26	3	....	....	....	....	....	....
1516–8 y	....	6	72	218	180	23	1	....	....	....	....	....	....
1592–6 h	....	15	127	179	124	47	....	....	....	....	....	....	....
1592–6 y	....	6	71	227	162	29	5	....	....	....	....	....	....
1687–4 h	5	32	88	147	117	68	22	8	2	0	1	....	....
1687–4 y	5	46	119	166	90	14	23	6	2	....	....	....	....
1687–8 h	17	42	57	93	83	71	79	23	5	2	1	1	1
1687–8 y	2	115	220	127	46	13	2	....	....	....	....	....	....
1687–10 h	9	27	64	99	108	83	51	25	19	7	3	3	2
1687–10 y	10	39	104	150	108	61	20	6	2	....	....	....	....
Total, hard	32	253	1,125	1,449	857	426	193	79	40	9	5	4	3
Total, yellow	17	382	1,376	1,590	859	224	60	12	4	....	....	....	....

Other physical characteristics of the yellow-berry and hard kernels—for example, specific gravity, average kernel-weight, and volume-weight, are given in Table VI for 10 strains of wheat used for the study of the size of starch granules. The volume-weight, the test weight per bushel, and the average weight per kernel is higher for the yellow-berry than for the hard kernels. The specific gravity is somewhat higher in the hard wheat. These results agree in general with those previously reported by the writer (*6*), except that in the earlier investigation the average weight per kernel was higher for the hard wheat.

Snyder (*7*, *8*) has investigated the comparative weight of light and dark seeds taken from the same samples of varieties from 31 miscellaneous

sources, and of 32 varieties grown from selected seed. Most of these were Minnesota-grown. The average weight per kernel was higher for the dark grains in one case and for the light grains in the other.

TABLE VI.—*Specific gravity, kernel-weight, and volume-weight of hard (h) and yellow-berry (y) wheat*

Sample No.	Specific gravity.	Average weight per kernel.	Volume weight.	Test weight.
		Gm.	*Gm. per 100 cc.*	*Pounds.*
951 y	1.368	.....	.....	.....
	1.367	0.029	83.42	64.76
951 h	1.387	.....	.....	.....
	1.378	.027	80.85	62.80
1094 y	1.351	.....	.....	.....
	1.362	.031	80.00	62.15
1094 h	1.395	.....	.....	.....
	1.385	.027	79.63	61.86
1119 y	1.380	.....	.....	.....
	1.373	.....	.....	.....
1119 h	1.399	.....	.....	.....
	1.399	.031	79.00	61.37
1126 y	1.388	.....	.....	.....
	1.360	.025	83.72	64.59
1126 h	1.406	.....	.....	.....
	1.411	.028	82.22	63.44
1150 y	1.379	.....	.....	.....
	1.379	.033	79.12	61.46
1150 h	1.376	.....	.....	.....
	1.376	.033	77.12	60.33
1516–8 y	1.370	.....	.....	.....
	1.367	.029	82.88	63.95
1516–8 h	1.387	.....	.....	.....
	1.390	.031	78.66	60.69
1592–6 y	1.345	.....	.....	.....
	1.347	.026	77.04	59.44
1592–6 h	1.368	.....	.....	.....
	1.381	.022	77.23	59.59
1687–4 y	1.378	.....	.....	.....
	1.370	.030	82.05	63.31
1687–4 h	1.404	.....	.....	.....
	1.404	.032	79.29	61.18
1687–8 y	1.372	.....	.....	.....
	1.378	.029	79.40	61.68
1687–8 h	1.396	.....	.....	.....
	1.395	.029	78.88	61.28
1687–10 y	1.377	.....	.....	.....
	1.370	.028	80.00	62.15
1687–10 h	1.391	.....	.....	.....
	1.386	.027	75.15	58.38
Average, y	1.369	.0291	80.66	62.49
Average, h	1.392	.0287	78.73	61.00

Stewart and Hirst (*10*) and Stewart and Greaves (*9*), of the Utah Agricultural Experiment Station, found in comparing the average weight of kernels of a considerable number of hard winter wheats, semihard winter wheats, and soft winter wheats, that soft wheat varieties had the heaviest kernels and hard wheats the lightest.

THE CHEMICAL COMPOSITION OF YELLOW-BERRY WHEAT

The chemical composition of yellow-berry, especially as related to protein content, has been the subject of several investigations. Snyder, of the Minnesota Experiment Station (7, *8*), in comparing 63 light (starchy) and 30 dark (flinty) lots of grain, found a slight difference in the protein content in favor of the hard grain. The chief differences in chemical composition of yellow-berry and hard kernels of the same sample found by the writer are a higher moisture content, a lower protein content, and a higher starch content in the yellow-berry kernels as compared with the hard kernels. The data secured in this investigation are given in Tables VII and VIII.

TABLE VII.—*Analyses of yellow-berry wheat*

Chemistry laboratory No.	Botany laboratory No.	Moisture.	Ash.	Crude protein.	Crude fiber.	Nitrogen-free extract.	Pentosans.	Starch.	Ether extract.
		Per cent	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*
603	951	8.47	1.83	10.36	2.51	74.99	7.60	69.34	1.84
605	1094	8.42	1.86	10.48	2.22	75.08	7.66	67.65	1.94
607	1119	8.59	1.71	10.44	2.19	75.29	7.27	64.50	1.78
609	1126	7.37	1.64	9.72	2.10	77.04	7.68	67.33	2.13
611	1150	7.72	1.96	10.76	2.05	75.61	7.99	66.17	1.90
613	1516–8	7.71	1.57	10.80	2.19	75.68	7.08	70.62	2.05
615	1592–6	7.73	1.71	10.04	2.53	76.04	8.03	63.47	1.95
617	1687–4	7.21	1.87	10.80	2.15	75.92	7.85	63.58	2.05
619	1687–8	6.71	1.94	10.79	2.30	76.16	7.73	69.26	2.10
621	1687–10	8.07	1.79	10.96	2.22	74.96	7.67	68.18	2.00
Total		78.46	17.88	105.15	22.46	756.77	75.56	670.10	19.74
Average		7.846	1.788	10.515	2.246	75.677	7.556	67.01	1.974

TABLE VIII.—*Analyses of hard, flinty wheat*

Chemistry laboratory No.	Botany laboratory No.	Moisture.	Ash.	Crude protein.	Crude fiber.	Nitrogen-free extract.	Pentosans.	Starch.	Ether extract.
		Per cent.	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*
604	951	8.20	1.99	12.00	2.65	73.31	8.17	68.82	1.85
606	1094	8.63	2.02	12.00	2.50	73.02	7.86	60.92	1.83
608	1119	7.97	2.06	12.00	2.36	73.96	7.32	66.95	1.65
610	1126	7.41	1.91	11.32	2.33	75.10	7.87	63.96	1.93
612	1150	7.68	2.03	12.30	2.11	74.06	8.37	64.60	1.82
614	1516–8	7.22	1.87	12.08	2.18	74.55	7.85	65.79	2.10
616	1592–6	7.20	1.90	12.04	2.50	74.51	8.52	62.01	1.85
618	1687–4	6.98	1.82	12.12	2.19	74.96	7.66	62.09	1.95
620	1687–8	7.24	2.02	12.08	2.35	74.34	7.58	65.67	1.97
622	1687–10	7.83	2.04	11.96	2.49	73.80	7.63	66.81	1.88
Total		76.34	19.66	119.90	23.66	741.61	78.83	647.62	18.83
Average		7.634	1.966	11.99	2.366	74.161	7.883	64.762	1.883

The results show a higher percentage of starch in the yellow-berry wheat than in the flinty kernels, the average percentages being 67.01 and 64.762, respectively. They show also an average starch ratio of 6.37 for the yellow-berry kernels and of only 5.40 for the flinty kernels. It appears probable that the smaller amount of protein in the starchy grains is not only fully compensated for by an equivalent deposition of starch but more than compensated for, since the percentage of protein is 1.475 less and the percentage of starch 2.248 greater in the starchy than in the flinty kernels.

SUMMARY

(1) This investigation is a continuation of the work reported in Kansas Agricultural Experiment Station Bulletin 156.

(2) The opaque, starchy spots in wheat kernels which give them the designation of yellow-berry kernels almost invariably begin to appear in the neighborhood of the germ or embryo, the lower end of the kernel as it stands on the plant, and spread from there upward.

(3) One hundred and sixty-four lots of wheat were investigated to determine the relation of yellow-berry to field conditions, especially the period between first heading and ripening. Seventy-seven of these lots were pure strains or pure lines, and 87 were checks or controls.

(4) In determining the percentage of yellow-berry, an arbitrary standard was adopted. If one-half or more of a kernel was opaque it was weighed as a yellow-berry kernel. The flinty kernels free from opaque portions were weighed separately, and the residue of the kernels were designated as neutral grains.

(5) The variation in yellow-berry percentages in the yields of the control rows was closely followed by that of the pure-line rows alternating with them. The general trend of the whole series of the pure lines follows that of the controls.

(6) The conclusion from the field tests is that the operation of common causes for the production of yellow-berry overshadowed any differences that may have been due to hereditary tendencies, and precludes a definite statement regarding the relation of hereditary tendencies in hard winter wheats toward the production of yellow-berry. That some isolated pure strains of wheat are freer from yellow-berry than others growing in the same field and under apparently identical conditions of soil and climate is, however, possible.

(7) With respect to the relation of yellow-berry to date of ripening, the experiment shows a higher percentage of yellow-berry with the later dates of ripening.

(8) The comparative size of the starch granules in yellow-berry and in flinty grains was investigated, 500 measurements of starch grains being made from hard and from yellow-berry samples of 10 strains of of pure-line wheats. The largest starch grains in the yellow-berry portions of the kernel were found to be smaller on the average than the largest starch grains in the flinty portions of the same kernels. These results seem to contradict those of Cobb and of Lyon and Keyser.

(9) In respect to the average kernel-weight, the yellow-berry kernels were found to weigh on the average 0.4 mg. more than the flinty kernels, based on the average weight (air-dried at 100° C.) of 100 kernels. In an earlier study the flinty kernels were on the average 1.4 mg. heavier.

(10) In specific gravity the flinty kernels were found to be 0.0230 heavier than the yellow-berry kernels.

(11) The yellow-berry kernels were found to be higher in moisture and starch content and lower in protein and ash than the hard, flinty kernels.

LITERATURE CITED

(1) BAILEY, C. H.
1913. MINNESOTA WHEAT INVESTIGATIONS. SERIES I. MILLING, BAKING, AND CHEMICAL TESTS. CROP OF 1911. Minn. Agr. Exp. Sta. Bul. 131, 42 p., 6 fig.

(2) BOLLEY, H. L.
1913. WHEAT: SOIL TROUBLES AND DETERIORATION; CAUSES OF SOIL SICKNESS IN WHEAT LANDS; POSSIBLE METHODS OF CONTROL; CROPPING METHODS WITH WHEAT. N. Dak. Agr. Exp. Sta. Bul. 107, 96 p., 45 fig.

(3) COBB, N. A.
1904. UNIVERSAL NOMENCLATURE FOR WHEAT. *In* Agr. Gaz. N. S. Wales, v. 15, pt. 6, p. 509–513, 1 fig., pl. 13–15. Continued article. Reprinted as Dept. Agr. N. S. Wales Misc. Pub. 539, 75 p., 74 fig., 15 pl. (partly col.). 1905.

(4) HEADDEN, William P.
1915. YELLOW-BERRY IN WHEAT, ITS CAUSE AND PREVENTION. Colo. Agr. Exp. Sta. Bul. 205, 38 p., 1 pl.

(5) LYON, T. L., and KEYSER, Alvin.
1905. NATURE AND CAUSES OF "YELLOW-BERRY" IN HARD WINTER WHEAT. *In* Nebr. Agr. Exp. Sta. Bul. 89, p. 23–36.

(6) ROBERTS, H. F., and FREEMAN, G. F.
1908. THE YELLOW-BERRY PROBLEM IN KANSAS HARD WINTER WHEATS. Kans. Agr. Exp. Sta. Bul. 156, 35 p.

(7) SNYDER, Harry.
1904. WHEAT AND FLOUR INVESTIGATIONS. Minn. Agr. Exp. Sta. Bul. 85, p. 179–224, fig. 120–130.

(8) ———
1905. GLUTINOUS AND STARCHY GRAINS. *In* Minn. Agr. Exp. Sta. Bul. 90, p. 219–225, fig. 182.

(9) STEWART, Robert, and GREAVES, Joseph E.
1908. THE MILLING QUALITIES OF WHEAT. Utah Agr. Exp. Sta. Bul. 103, p. 241–276, 3 illus.

(10) ——— and HIRST, C. T.
1913. THE CHEMICAL, MILLING, AND BAKING VALUE OF UTAH WHEATS. Utah Agr. Exp. Sta. Bul. 125, p. 113–150.