12-1919

The Influence of Length of Wheat Heads on Resulting Crops

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The Influence of Length of Wheat Heads on Resulting Crops

The Correlation Between the Length of Parent Head and Yield of Progeny in Successive Generation of Bluestem Wheat. (Minn. 169)

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EXPERIMENT FARMS

Brookings	Brookings County
Cottonwood	Jackson County
Eureka	McPherson County
Highmore	Hyde County
Vivian	Lyman County

SUMMARY OF BULLETIN

(1) Practically, it would be helpful in wheat breeding to know whether one could depend on picking out the relatively longest (and accordingly finest appearing) heads, as a method for securing the highest yielding strains. Page 140.

(2) The results of the present experiment indicate that relatively long heads did yield slightly higher than similar heads on other plants, in the first generation after the selection of mother heads. Table 1, page 142.

(3) Whatever may have caused the slight increased yield in the first generation, it failed to persist in following generations; which were produced from seed tracing back to the original mother heads, but without additional selection. Tables 2-5.

(4) At any rate so far as one may generalize at all, the plant may be used as a unit of selection, and the length of central spike, cannot be considered as an indicator of the fitness of a given plant to serve as the mother plant of a line of progeny. Page 149.

(5) References. Page 156.

THE CORRELATION BETWEEN THE LENGTH OF PARENT HEAD AND YIELD OF PROGENY, IN SUCCESSIVE GENERATIONS OF BLUESTEM WHEAT (Minn. 169)

By

A. N. Hume, Manley Champlin and Matthew Fowlds

The question of the present thesis, empirically stated is: Will the selection and use of either longer or shorter heads of wheat for seed have any influence over relative yield in the resulting crop; and if so will such influence persist through successive generations? The present report is intended in the main to set down the facts of given trials. Conclusions drawn therefrom may be tentative, and the facts serve for comparison with those from similar trials, carried out elsewhere, with somewhat different sets of conditions.

The outline of the experiment reported herein, consisted very briefly in first securing a number of longer heads (spikes) of Bluestem (Minn. 169) wheat and an equal number of relatively shorter heads, from separate plants, which plants however were produced under nearly identical conditions of growth. The several heads thus secured were planted in "head-rows," alternating long and short. In following years the progeny of these rows were planted in corresponding head rows; thus giving successive generations of yield from seed, tracing directly back to a given "mother plant," however without any persistent plant selection in successive years. It is well to state at this point that the several tables of correlation which were made from the data of mother-plant selections and head-row yields contained herein were finally computed by Prof. W. E. Lattin of the Department of Mathematics of South Dakota State College.

The work was begun in 1912, by first producing twelve hundred plants, under as nearly identical conditions of growth as might be possible. These were produced by planting twelve hundred separate seeds of uniform quality in rows that were

twelve inches apart, with plants three inches apart in the rows. Two hundred and sixty plants were selected out of the total twelve hundred, the former having as nearly the same number of stools as possible; the hypothesis being that stooling differences should be eliminated as a factor if possible. Thus apparently, the chief visible difference between individual plants among these two hundred sixty selected consisted in variation in length of spike. Moreover the mother-heads selected in the summer of 1912, from the foregoing plants were always taken from central spikes of the plants in question, thus avoiding variations in length of head, due to differences in position of the plant.

Twenty seeds were selected at random from each of these heads. In 1913 the twenty seeds from each head were planted in individual head rows, the rows being twelve inches apart and the seeds three inches apart in the row, care being taken to pair the relatively long and relatively short heads in alternote rows.

The season of 1913 was favorable and the head-rows came into harvest without having growth unduly interfered with either by unfavorable weather or by plant diseases. The rows were harvested, separately, and record kept of the weight of grain from each one, to be correlated with the length of spike (in centimeters) from whence it grew.

The following Correlation Table No. 1 expresses the degree of relation that existed in 1913 between the yields of head rows in grams and the lengths of the mother heads from whence they grew.

TABLE

RELATION BETWEEN LENGTH IN CENTIMETERS OF MOTHER SPIKE AND

(r=0.17

Weight of grain in grams.	8.9	9.1	9.3	9.5	9.7	9.9	10.1	10.3	10.5	10.7	10.9	11.1	11.3	11.5	11.7	11.9	12.1	12.3
20	1												1					
25																		
30																		
35										1						1		
40				1						3				1	1			
45	1						1			5				3	1		1	
50					1				2	1	3			4	2		2	
55									1	5				2	2	2	3	
60		1			1		1			2				4	1	2	1	
65					1		2							10	1	4	2	
70				1			2			4				4	4	6	1	
75				1			3			7				4	1	2	1	
80					1					1	2			3	1	1		
85							1		2					1	1		1	
90														3		3	1	
95										2						1		
100																2		
105										1						2		
110										1						1		
115																		
120																		
125																1		
130																		
135																		
140														1			1	
Totals	3	3	....	3	4	....	10	....	5	33	5	....	1	40	15	28	14	....

It may be seen with examining the foregoing Table 1, that a comparatively slight positive correlation appears, between the lengths of spike serving as a source of seed for head-rows and yields produced therefrom the year they were seeded, namely 1913. This degree of correlation is expressed by $r=0.17+0.04$. It is an appreciable correlation, but by no means is there any very pronounced degree of relationship.

The fact that there is this slight degree of correlation corresponds with the following: The average yield of grain from the long head progeny rows was 71.8 grams as compared with 65.3 grams for the progeny of short heads. Likewise the average straw yield of the long head progeny was higher than that of the short head progeny by 13.0 grams.

The percentage of grain of total weight of plant was 2.6 per cent higher as an average in the progeny of the long heads than that of the short heads for this first year.

NO. 1

DIRECT YIELD THEREFROM, EXPRESSED IN GRAMS PER HEAD ROW ±0.04.)

12.5	12.7	12.9	13.1	13.3	13.5	13.7	13.9	14.1	14.3	14.5	14.7	14.9	15.1	15.3			Totals
																	2
																	0
	1																1
	3																5
	2	1		2													11
	2																14
	1			2			2										20
	4				1		1		1								22
	3	1		1	2		3		1								24
1	3	1		2			1										28
	4			4													30
	4	1		2	1		1		1								29
	4			5			1										19
	5			2	3		1										18
	3	1							1		1						14
	3				1												8
		1															3
	1																4
																	2
														1			1
				1													1
																	1
																	0
																	0
																	2
1	43	6	....	21	8	....	10	....	4	....	1	....	....	1	....	....	259

Granted that there is actually some positive correlation between greater length in mother head and higher yield, in this first year the question remains whether seed selected in turn from these progeny rows will show a similar correlation in the year or years following. Accordingly seed was preserved from the head-rows of 1913 and put out in similar head-rows in 1914, the expectation being that the resulting yields could be correlated in turn with the lengths of the original mother heads of 1912 to which they could be traced. Not much need be said relative to these head rows of 1914 except that the growing plants were so devastated by rust (Puccinia graminis) that it seemed useless to harvest the plants.

Sufficient seed of all the head-row strains produced in 1913 remained so that it was practicable to replant in 1915. The following Table 2, reports the degree of correlation that existed between the lengths of the original mother-heads and the yields of the progeny in 1915:

TABLE

RELATION BETWEEN LENGTH IN CENTIMETERS OF MOTHER SPIKES, (SE
(PLANTED FROM CORRESPONDING PR

Weight of grain in grams.	8.9	9.1	9.3	9.5	9.7	9.9	10.1	10.3	10.5	10.7	10.9	11.1	11.3	11.5	11.7	11.9	12.1	12.3
30	....	....	....	....	....	....	....	....	....	....	....	....	....	1	....	....	....	....
35	....	....	....	....	....	....	....	....	....	4	....	....	....	2	1	....	....	....
40	....	....	....	....	....	....	....	....	....	2	1	....	....	3	2	1	1	....
45	....	....	....	....	....	....	....	....	1	4	....	....	....	5	....	4	1	....
50	1	....	....	....	....	....	2	....	1	11	....	....	....	7	3	3	2	....
55	....	1	1	1	1	....	4	....	....	3	1	....	....	4	2	7	3	....
60	1	....	1	....	1	....	3	....	....	3	1	....	....	7	4	6	2	....
65	....	....	....	....	1	....	....	....	1	4	2	....	....	5	....	2	2	....
70	1	1	....	....	....	....	....	....	1	1	1	....	....	....	3	1	1	....
75	....	1	....	....	....	....	....	....	....	1	....	....	....	2	....	2	....	....
80	....	....	....	....	....	....	....	....	....	....	....	....	....	2	....	2	2	....
85	....	....	....	....	....	....	1	....	....	....	....	....	....	1	....	....	....	....
90	....	....	....	....	....	....	1	....	....	....	....	....	....	1	....	....	....	....
95	....	....	....	....	....	....	....	....	....	....	....	....	....	2	....	....	....	....
100	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....
105	....	....	....	....	....	....	....	....	....	1	....	....	....	....	....	....	....	....
Totals	3	3	2	1	3	0	11	0	4	34	6	0	0	42	15	28	14	0

It becomes sufficiently clear from examining the foregoing Table 2, that no correlation is shown between length of original mother heads, as selected in 1912, and the yields of progeny produced in 1915.

The head rows of 1915 were carefully harvested and the weights recorded in connection with securing data for Table

TABLE

RELATION BETWEEN LENGTH IN CENTIMETERS OF MOTHER SPIKES, (SE
RESPONDING PROGENY RO

Weight of grain in grams.	8.9	9.1	9.3	9.5	9.7	9.9	10.1	10.3	10.5	10.7	10.9	11.1	11.3	11.5	11.7	11.9	12.1	12.3
10	....	....	....	....	....	....	....	....	....	1	....	....	....	....	....	....	....	....
15	1	1	....	....	1	....	4	....	....	3	1	....	....	10	3	....	8	3
20	1	....	....	....	2	....	3	....	....	8	1	....	....	9	4	....	7	4
25	....	....	....	....	....	....	....	....	....	2	....	....	....	1	....	....	1	....
Totals	2	1	....	....	3	....	7	....	....	14	2	....	....	20	7	....	16	7

NO. 2

LECTED IN 1912, AND PLANTED IN 1913) AND YIELDS OF PROGENY IN 1915 OGENY ROWS OF 1913) ($r=0.02\pm0.04$)

12.5	12.7	12.9	13.1	13.3	13.5	13.7	13.9	14.1	14.3	14.5	14.7	14.9	15.1	15.3			Totals
	2																3
									1								8
	2	1		1	1						1						16
	4			2	1		2										24
1	7	2		3	1	1	1			1							47
	6			2	1		5		1								43
1	4	2		2			1										39
	5	1		6			1							1			31
	3			2	2				2								19
	3			3	1												13
	3																9
																	2
	2																4
																	2
																	0
																	1
2	41	6	0	21	7	1	10	0	4	1	1	0	0	1	....	....	261

2 and likewise sufficient seed was preserved from these head-rows of 1915 to plant another set of head-rows in 1916. It will be noted that the number of rows employed was reduced from 261 in 1915 to 130 in 1916. Following Table 3, sets down the distribution of yields in grams of progeny rows for 1916 and length of original mother heads in centimeters:

NO. 3

LECTED IN 1912) AND YIELDS OF PROGENY IN 1916 (PLANTED FROM COR-WS OF 1915) ($r=0.03\pm0.06$)

12.5	12.7	12.9	13.1	13.3	13.5	13.7	13.9	14.1	14.3	14.5	14.7	14.9	15.1	15.3	15.5		Totals
	2																3
1	4	1		5	1			2	1					1			51
1	16	2		5	1			4	2		1						71
				1													5
2	22	3	....	11	2	....	....	6	3	....	1	....	....	....	....	....	130

The foregoing Table 3 with the correlation coefficient put down above supplies evidence that there was no correlation in 1915 between yields of progeny and length of original mother heads selected in 1912. The probable error is greater than the slight apparent correlation.

Again, in the season of 1917, seed that had been preserved from the corresponding head-rows of 1916 was planted. The plan for planting was the same as that employed in preceding years, so that the progeny from the several head rows

TABLE

RELATION BETWEEN LENGTH IN CENTIMETERS OF MOTHER SPIKES (SE
RESPONDING PROGENY ROWS

Weight of grain in grams.	8.9	9.1	9.3	9.5	9.7	9.9	10.1	10.3	10.5	10.7	10.9	11.1	11.3	11.5	11.7	11.9	12.1	12.3
15	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....
20	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	1	....
25	....	....	....	....	....	....	1	....	....	....	....	....	....	2	....	....	1	....
30	....	....	....	....	....	....	4	....	....	....	....	....	....	7	3	....	2	1
35	1	....	....	....	1	....	1	....	....	10	....	....	....	4	1	....	5	1
40	....	1	....	....	1	....	....	....	....	2	....	....	....	2	2	....	2	1
45	1	....	....	....	....	....	....	....	....	1	....	....	....	2	1	....	2	....
50	....	....	....	....	1	....	....	....	....	....	....	....	....	2	....	....	3	3
55	....	....	....	....	....	....	....	....	....	....	1	....	....	....	....	....	....	....
60	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....
65	....	....	....	....	....	....	1	....	....	....	....	....	....	....	....	....	....	1
70	....	....	....	....	....	....	....	....	....	1	....	....	....	....	....	....	....	....
75	....	....	....	....	....	....	....	....	....	....	1	....	....	1	....	....	....	....
80	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....
85	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....
90	....	....	....	....	....	....	....	....	....	....	....	....	....	1	....	....	....	....
Totals	2	1	0	0	3	0	7	0	0	14	2	0	0	21	7	0	16	7

of the year in question would trace directly back through the several generations to the original mother heads selected in 1912. The question again is whether any correlation in yield, in grams per head row, and length in centimeters of these original mother heads will appear.

The following Table 4, puts down the array which summarized the degree of correlation and at the top of the table is also put down the mathematical coefficient:

NO. 4

LECTED IN 1912) AND YIELDS OF PROGENY IN 1917 (PLANTED FROM COR-OF 1916) (r=0.03±0.06)

12.5	12.7	12.9	13.1	13.3	13.5	13.7	13.9	14.1	14.3	14.5	14.7	14.9	15.1	15.3	15.5		Totals
....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	0
....	1	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	2
....	....	1	....	....	....	....	....	1	....	....	....	....	....	....	....	....	6
....	8	....	....	2	2	....	....	1	....	....	....	....	....	....	....	....	30
....	4	1	....	3	....	....	....	....	....	....	....	....	....	....	....	....	32
2	5	....	....	2	....	....	....	1	1	....	....	....	....	....	....	....	22
....	1	....	....	2	....	....	....	2	1	....	....	....	....	1	....	....	14
....	1	....	....	2	....	....	....	....	....	....	....	....	....	....	....	....	12
....	3	....	....	....	....	....	....	....	1	....	1	....	....	....	....	....	6
....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	0
....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	2
....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	1
....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	2
....	1	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	1
....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	0
....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	1
2	24	2	0	11	2	0	0	5	3	0	1	0	0	1	0	....	131

Examination of the foregoing correlation Table 4, shows that the general result for the years 1917 was similar to that for all years calculated after the first, so far as finding any correlation between the length of original mother head and yield of progeny, in following generations is concerned.

Following is the similar table, Table 5, arranged to summarize results secured from head rows of 1918:

TABLE
RELATION BETWEEN LENGTH IN CENTIMETERS OF MOTHER SPIKES (SEL
OUT OF CORRESPONDING PROGE

Weight o grain in grams.	8.9	9.1	9.3	9.5	9.7	9.9	10.1	10.3	10.5	10.7	10.9	11.1	11.3	11.5	11.7	11.9	12.1	12.3
10	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....
15	....	....	....	....	....	....	1	....	....	2	....	....	....	1	1	....	2	1
20	1	....	....	....	1	....	2	....	....	4	....	....	....	6	1	....	5	2
25	1	1	....	....	1	....	2	....	....	4	....	....	....	8	1	....	4	2
30	....	....	....	....	1	....	1	....	....	4	....	....	....	5	4	....	3	2
35	....	....	....	....	....	....	1	....	....	....	....	....	....	1	....	....	1	....
	....	....	....	....	....	....	....	....	....	....	1	....	....	1	....	....	....	....
45	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....
50	....	....	....	....	....	....	....	....	....	....	1	....	....	....	....	....	1	....
Totals	2	1	0	0	3	0	7	0	0	14	2	0	0	22	7	0	16	7

NO. 5
ECTED IN 1912) AND YIELDS OF PROGENY IN 1918 (PLANTED FROM SEED
NY ROWS OF 1917) ($r=0.07\pm0.59$)

12.5	12.7	12.9	13.1	13.3	13.5	13.7	13.9	14.1	14.3	14.5	14.7	14.9	15.1	15.3	15.5	15.7	Totals
....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	0
....	2	....	....	....	....	....	....	....	....	....	....	....	....	1	....	....	11
1	5	1	....	3	1	....	....	1	....	....	....	....	....	....	....	....	34
1	7	2	....	6	....	....	....	1	2	....	....	....	....	....	....	....	43
....	1	....	....	1	1	....	....	2	....	....	....	....	....	....	....	....	25
....	4	....	....	1	....	....	....	....	1	....	....	....	....	....	....	....	9
....	....	1	....	....	....	....	....	1	....	....	....	....	....	....	....	....	4
....	2	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	2
....	....	....	....	....	....	....	....	....	....	....	....	1	....	....	....	....	3
2	21	4	0	11	2	0	0	5	3	0	0	1	0	1	0	0	131

The foregoing Table 5, again indicates that there was practically no correlation in 1918 between the head-row yields of progeny for that year, and the length of original mother heads selected in 1912. Said result for the season of 1918 corresponds to that of every year after the first; namely that for 1915, 1916 and 1917.

CONCLUSION

The empirical conclusion that may be drawn from this series of correlation tables is that some slight positive correlation was found between the yield in grams of longer mother heads of wheat in the progeny of the first generation and the length of the original mother heads, but that this correlation failed to persist in the progeny of succeeding generations.

Stated otherwise this might mean that wheat seed actually threshed out of relatively long heads is capable of producing slightly higher yields than heads relatively shorter though otherwise similar; but that the increase produced from such selected heads will not retain their relatively higher yielding capacity. If general application of this were possible one might increase yields of wheat in any given year providing it were possible to secure all seed for putting out the given crop from relatively long heads. Obviously that is not practicable, there being no known method for making such selections on a commercial scale.

It is also borne out so far as these computations are concerned that the process of multiplying wheat from long-headed strains will not secure increased yields—if it did it would be a desirable method to use for securing such seed in quantity.

A practical wheat breeder would find it possible to go into his field of wheat each season and hand-select a good number of the relatively longest central spikes from the growing crop; or he might even produce a number of plants each year by nursery methods and select the longest spikes therefrom just as was done in securing the results of this bulletin. He could thus acquire seed enough from the longest spikes to put out at least a larger increase plot the following year, even at some labor—providing such labor should prove to give increased yields from said multiplying plot, or from fields seeded in later years out of the resulting crop.

The present research gives no indication that such results would accrue from such effort.

Why Did the Slight Increase Appearing in the Head Rows From the Longer Heads Fail to Reappear in the Following Generations?

The statement has long been accepted as a truism that "like begets like." It may at least be put down that nobody has proved the contrary, and it is worth something to know that one does not reap figs of thistles.

In a discussion of the very early work of Hallett, written by Mr. J. Arthur Harris (American Breeders Magazine. Jan.-Feb.-March 1913) attention is called to the theory, whereon the former based his time consuming work in wheat-and potato breeding. He apparently believed that "selection within a pure line can effect an improvement."

A paper by Hallett himself is quoted (On 'Pedigree' in Wheat as a Means of Increasing our Crop. Journal Agr. Soc. 22: 371-381): "Yet the minutest characteristics of a plant of wheat will be reproduced in its descendants; so much so that we can not only perpetuate the advantages presented to us in an individual ear, but by accumulation of selection, make further advances in any desired direction. To me it has always appeared that while offering an earnest of what a better system would effect, the mode in which the best varieties of our cereals have been raised (that is starting with accidentally fine ears and simply keeping the produce unmixed without any further selection) is a very imperfect one, and that its attainments are perhaps of less value than the earnest which it offers, of future success under a more complete system, for such beginning (and ending, so far as selection is concerned) with an accidentally fine ear, is a very different thing from starting annually with one of known lineage.

Mr. Harris further quotes Hallett, in regard the particulars of his selection method and it is worth while extending the quotation here: "A grain produces a 'stool' consisting of many ears. I plant the grains from these ears in such a manner that each ear occupies a row by itself. At harvest, after the most careful study and comparison of stools from all these grains, I select the finest one which I accept as proof that its parent grain was the best of all under the peculiar circumstances of that season. This process is repeated annually,

starting each year with the proved best grain, although the verification of this superiority is not obtained until the following harvest.

"During these investigations no circumstance has struck me as more forcibly illustrating the necessity of repeated selection than the fact that **of the grains in the same ear one is found to greatly excel all the others in vital power.**"

This work of Hallett was carried out in England by what is now known as the "head-row method" as early as the middle of the nineteenth century. Apparently Hallett's early conclusions were based on observations rather than on the use of statistical data. His observations would conform to the computations of the present bulletin or vice versa, in that he believed that merely selecting occasional fine ears (heads) for a single generation would not in itself constitute a perfect system of plant breeding. Hallett apparently believed that neither single heads nor a single head of wheat is an ultimate unit of selection, except for the fact that a head, is sure to be taken from a single plant which in turn grows from a single seed. Hallett apparently did conform to the principle of **pure line** selection which is accepted today as the basis for improvement of wheat.

Pure line selection "is selection from a single plant which plant with its progeny are kept free from outside pollination." Thus a pure line is the progeny of a single, self-fertilizing individual. It is not necessary at this point to attempt a discussion of further defining **pure line.** (The Small Grains—Carleton, p. 195) Johannsen believed in the necessity of working with pure lines and advanced the idea of the immutability of these pure lines. "The constituents of all his pure lines showed fluctuations, it is true, in different directions but when some of these constituents which deviated to the furtherest extremes were selected and propagated separately instead of producing a progeny similar to the mother plant they reverted to the original type of the line. Further experiments finally forced Johannsen to conclude that continuous selection with pure lines cannot produce permanent changes and that there is no hereditary variation within pure lines." (The Small Grains, p. 194) The details of our pres-

ent experiment correspond to the latter part of the conclusions of Johannsen, namely, that variation within pure lines is not hereditary; although long spikes of wheat of a pure line yielded higher than shorter spikes of the same line, this difference in yielding capacity failed to persist after the first generation.

If the capacity for relatively high yield as determined for longer heads in the first generation does not persist and is therefore not a hereditary quality, why does it appear at all? Obviously the present experiment cannot decide that question but the question need not be perplexing.

There may be several possible explanations outside of actual heredity. The increased yield resulting from longer spikes in the first generation may be one of the several "fluctuations" observed by Johannsen. For instance it is possible that the kernels of the longer heads were larger or heavier than those from the smaller heads, which in the present instance for want or more definite knowledge may be called the result of mere chance. It is generally accepted that large, heavy kernels yield a better crop, other things equal than correspondingly small light ones. Various researches might be cited along that line but they need not be discussed further until further statistical results are available.

ANNUAL RAINFALL BY MONTHS AT THE SEVERAL STATIONS

BROOKINGS

	1905	1906	1907	1908	1909	1910	1911
Jan.	0.22	0.17	1.06	0.26	1.20	1.07	0.61
Feb.	1.00	0.02	0.28	1.80	1.57	0.40	0.53
Mch.	0.68	0.58	0.55	1.16	0.37	0.35	0.53
Apr.	1.01	1.40	1.67	2.10	1.16	2.34	1.62
May	6.14	3.51	2.36	6.46	4.85	0.87	1.90
June	6.09	4.89	5.65	6.35	2.29	1.85	3.78
July	0.98	1.86	3.77	4.69	2.44	1.68	3.32
Aug.	4.54	4.28	1.41	2.37	3.39	2.46	3.81
Sept.	2.16	5.13	1.28	3.89	1.67	0.96	3.08
Oct.	1.50	3.01	0.96	1.43	1.71	0.38	5.12
Nov.	2.45	0.89	0.10	1.30	0.65	0.17	0.23
Dec.	T	0.52	1.12	0.42	1.14	0.10	0.42
Total	22.77	26.26	20.21	32.17	22.44	12.63	24.95

BROOKINGS

	1912	1913	1914	1915	1916	1917	1918
Jan.	0.28	0.02	0.22	0.18	1.47	1.54	0.19
Feb.	0.24	0.09	0.40	1.12	0.32	0.47	0.14
Mch.	0.26	0.45	0.42	0.18	0.50	1.09	0.44
Apr.	3.36	2.24	1.64	2.03	2.95	3.09	1.28
May	6.98	3.60	4.16	2.12	3.72	3.08	3.40
June	2.09	1.96	6.67	3.28	4.27	3.49	1.85
July	2.52	2.99	1.62	3.04	0.40	2.03	3.95
Aug.	4.68	1.33	3.16	3.52	2.03	1.20	4.19
Sept.	1.61	1.55	3.32	2.68	0.84	2.89	0.72
Oct.	0.96	1.18	2.21	1.37	0.45	0.12	1.56
Nov.	0.00	0.81	T	0.28	0.03	0.04	1.61
Dec.	0.20	0.09	0.33	0.62	0.36	0.31	1.09
Total	23.18	16.31	24.15	20.42	17.34	19.35	20.42

COTTONWOOD

	1910	1911	1912	1913	1914	1915	1916	1917	1918
Jan.	0.66	T	0.17	0.16	0.03	0.39	0.04	0.45	0.32
Feb.	0.97	0.15	0.05	0.10	1.18	1.57	0.02	1.50	1.50
Mch.	0.76	T	3.00	0.43	0.35	0.46	0.04	0.31	0.34
Apr.	1.06	0.85	3.32	1.15	2.26	2.80	0.81	0.80	2.27
May	2.54	1.10	1.18	2.95	2.35	6.61	3.87	3.30	2.78
June	1.30	0.64	0.95	0.59	1.64	4.79	1.83	0.62	1.37
July	1.11	0.59	2.42	0.81	1.04	4.58	1.80	0.90	2.29
Aug.	0.48	2.41	3.42	1.84	1.88	2.51	2.22	2.00	3.43
Sept.	0.82	3.59	1.30	1.15	1.19	2.42	0.18	1.17	1.43
Oct.	0.32	1.15	0.11	0.76	2.23	0.90	0.57	0.14	0.28
Nov.	0.53	0.20	T	0.14	0.02	T	0.15	0.39	0.11
Dec.	3.00	0.42	0.12	0.38	0.84	0.10	0.14	0.50	0.25
Total	12.65	11.10	16.04	10.46	15.28	27.31	11.67	12.08	16.37

EUREKA

	1909	1910	1911	1912	1913	1914	1915	1916	1917	1918
Jan.	0.10	0.60	0.50	0.25	0.10	0.22	0.90	0.79	0.40	0.14
Feb.	0.45	1.70	0.73	0.40	0.03	0.05	1.08	0.13	0.20	0.50
Mch.	0.14	1.23	0.62	1.05	0.09	0.13	0.23	1.78	1.46	0.58
Apr.	0.50	0.82	2.24	1.29	0.68	2.07	1.83	0.88	2.18	1.98
May	2.65	0.42	0.97	3.37	1.97	2.20	2.58	3.57	1.30	1.97
June	3.35	3.80	1.29	1.50	2.91	4.28	4.66	4.16	1.61	0.93
July	2.21	0.53	0.43	2.19	2.16	1.25	3.38	—	1.04	1.03
Aug.	1.39	2.60	3.27	3.27	1.53	2.11	2.47	4.62	0.93	1.77
Sept.	1.25	3.65	1.15	1.43	0.54	0.70	3.74	1.05	0.67	0.36
Oct.	0.17	0.18	0.61	0.07	1.52	0.87	3.10	0.29	0.06	0.55
Nov.	0.60	T	0.88	T	0.06	T	0.56	0.14	2.00	0.53
Dec.	2.40	0.25	0.80	0.11	0.52	0.53	0.36	0.06	0.75	0.20
Total	15.21	15.78	13.79	14.93	12.11	14.41	24.89	17.47	12.60	10.54

HIGHMORE

	1908	1909	1910	1911	1912	1913	1914	1915	1916	1917	1918
Jan.	T	0.26	0.82	0.11	0.13	0.05	0.13	0.43	1.40	1.12	0.60
Feb.	0.53	0.34	0.19	0.39	0.11	0.30	0.62	1.28	0.27	0.52	0.25
Mch.	0.00	0.13	0.58	2.54	0.27	0.87	0.45	0.37	0.74	1.27	0.45
Apr.	1.35	0.30	1.40	0.32	1.05	1.27	3.65	2.50	0.89	2.79	2.57
May	2.68	4.72	0.94	2.31	2.20	4.56	2.23	3.48	4.15	2.04	3.57
June	5.78	1.69	3.74	0.09	1.31	0.97	4.09	4.87	4.54	2.04	1.59
July	2.49	1.81	0.85	2.69	1.44	1.79	2.01	5.55	2.10	1.91	5.26
Aug.	3.53	3.74	0.66	2.52	3.39	1.20	1.16	0.78	4.10	0.68	1.88
Sept.	0.62	1.70	0.89	3.06	0.71	0.53	1.01	2.36	2.75	2.03	0.62
Oct.	2.19	1.04	0.24	1.05	0.20	0.61	1.92	1.15	0.58	0.06	0.49
Nov.	1.39	0.71	0.40	0.35	0.00	0.03	—	0.32	0.13	0.07	1.10
Dec.	0.31	1.41	0.44	0.44	0.35	0.28	0.25	0.20	0.47	0.27	0.86
Total	28.87	17.85	9.05	15.87	12.00	12.46	17.52	23.29	22.12	14.80	19.24

VIVIAN

	1915	1916	1917	1918
Jan.	0.50	1.00	1.35	1.10
Feb.	1.77	0.04	0.18	0.50
Mch.	1.19	0.29	1.00	0.50
Apr.	2.62	1.08	2.38	3.92
May	3.02	3.46	5.20	3.33
June	4.31	4.49	1.18	1.70
July	6.76	3.53	1.02	2.07
Aug.	1.12	3.52	2.01	3.32
Sept.	3.16	0.90	2.64	0.75
Oct.	1.12	0.57	0.00	0.82
Nov.	0.38	0.12	—	0.22
Dec.	0.03	0.04	0.32	0.90
Total	25.98	19.04	17.28	19.13

REFERENCES

The following may be classified as among the number that are of interest to students of wheat, with reference to improvement by selection; also with some bearing upon the present subject.

"The Small Grains"—Carleton, M. M. Co. Chapters on: Cereal Improvement-Selection, p. 179. Hybridization, p. 207.

"Principles of Breeding"—Dean E. Davenport, University of Illinois. Ginn & Co.—Correlation, p. 453.

"Breeding Cereals"—Prof. C. A. Zavitz, Ontario Agricultural College. Guelph—American Breeders Assoc. Vol. I, p. 118. With Oats: "The selection of each of the following years was from the product of the selected seed of the previous years .... In the crop of 1905 it was found that large plump seed produced 65.5 bushels, and the light seed 44.7 bushels."

"Some Correlated Characters in Wheat"—Dr. T. L. Lyon, University of Nebraska. American Breeders Assoc. Vol. I, p. 29. Discussion of Relation of Size of Head to Yield, and Tillering, p. 37: "It is quite evident from these tables that the number of heads on a plant is more important in determining its productiveness than is the size of the heads, and that although the kernels are larger on plants having large heads, they are not necessarily so on plants producing the greatest weight of grain." The statement apparently relates to given plants, rather than to relation between plants and their progeny.

"Methods for Testing the Seed Value of Light and Heavy Kernels in Cereals."—E. G. Montgomery, Proc. Am. Society of Agronomy, Vol. 2, p. 59-69.

"Variations in the Plants from the same head of wheat"—Ewart, Journal of Agriculture, Victoria, March 1916. "The germination is most rapid in the grains of the 16th row from the top and ...... the average rate of germination decreases toward the base and apex of the head."

"Does the Value of a Wheat Grain Depend on its Position in the Ear?"—Richardson and Green, Journal of Agriculture, Victoria, March 1916. "The weight of the individual grains may be described as following the shape of the ear the grains increasing in weight from either extremity to the middle of the ear." .... "4. These results justify the practice often recommended of rejecting the upper and lower portions of the ears and grading the remainder when applying mass selection to wheat for an improvement in yield."

"Relation to Size of Seed and Sprout Value to the Yield of Small Grain Crops." T. A. Kiesselbach and C. A. Helm, Nebraska Experiment Station Bulletin 11. "When space-planted to permit maximum development a higher individual plant yield is obtained from large than from small seeds. When planted in equal weights at a rate of optimism for the large seed, all three grades—large, small and unselected—yield equally. As an average for all investigations, large and small seed yielded alike, and the unselected seed yielded one per cent more than the large. This also seems to be a matter of rate planting. The shortage in yield of plants from small seeds is overcome by planting a greater number of seeds."

"Wheat Experiments"—C. G. Williams, Ohio Experiment Station Bulletin 298, "The Relation of Weight of Kernel to Yield" p. 463. "As a result of both of these tests it seems to be apparent that heavy kernels may be expected to give larger yields of wheat

than light kernels, if the differences in weight of kernels are large enough; certainly is this true in pure lines, and possibly in a mixed population. However, in the use of ordinary varieties screened and separated by wind blast, no important differences are likely to be secured."

South Dakota Bulletin 146—"Some Varieties and Strains of Wheat and their Yields in South Dakota"—History of Bluestem Wheat, p. 293.

LIST OF AVAILABLE BULLETINS
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Bulletins

106. Sugar Beets in South Dakota.
107. Sheep Scab.
129. Growing Pedigreed Sugar Beets in South Dakota.
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131. Scabes (Mange) in Cattle.
132. Effects of Alkali Water on Dairy Products.
140. Selection and preparation of seed potatoes.
143. Roughage for Fattening Lambs.
142. Sugar Beets in South Dakota.
144. Preliminary Report on the milking machine.
145. A report of Progress in Soil Fertility Investigations.
147. Effect of Alkali Water on Dairy Cows.
148. Corn Silage and Mill Products for Steers
149. Some Varieties and Strains of Oats and their yields in South Dakota.
151. Trials with Sweet Clover as a Field Crop in South Dakota.
152. Testing and Handling Dairy Products.
153. Selecting and Breeding Corn for Protein and Oil in So. Dak.
154. The Pit Silo.
155. Selection and Preparation of Seed Potatoes.
156. Kaoilang, A New Dry Land Crop.
157. Rape Pasture for Pigs in Corn Field.
158. Proso and Kaoliang for table use.
159. Progress in Plant Breeding.
160. Silage and Grains for Steers.
161. Winter Grain in So. Dak.
162. First Annual Report of Vivian Experiment and Demonstration Farm.
163. Comparative Yields of Hay, from Several Varieties and Strains of Alfalfa, at Brookings, Highmore, Cottonwood and Eureka.
164. Making Butter and Cheese on the Farm.
165. Corn Silage for Lambs.
166. Important Factors Affecting Milking Machines.
167. Transplanting Alfalfa.
168. Breakfast Foods and Their Relative Value.
169. Flax Culture.
170. Quack Grass Eradication.
171. Cream Pasteurization.
172. Grasshoppers and Their Control.
173. Sugar Beets in So. Dakota.
174. Sorghums for Forage in South Dakota.
175. The Role of Water in a Dairy Cow's Ration.
176. Potato Culture.
177. The Sheep.
178. Injurious Corn Insects.
179. Emmer in South Dakota.
180. Root Crop Culture.
181. Corn Culture.
182. Corn Silage for Steers.
183. Barley Culture in South Dakota.
184. Two Systems of Corn Breeding in South Dakota.
185. Making Ice on the Farm.
186. Corn Families of South Dakota.

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