5-1929

Correlated Inheritance in a Cross of F 22 X Dicklow Wheat

R. Kenneth Bischoff

Utah State University

Recommended Citation

Bischoff, R. Kenneth, "Correlated Inheritance in a Cross of F 22 X Dicklow Wheat" (1929). *All Graduate Theses and Dissertations*. 3939.
https://digitalcommons.usu.edu/etd/3939

8

CORRELATED INHERITANCE IN A CROSS OF F 22 X DICKLOW WHEAT

Submitted to the Department of Agronomy
at the Utah State Agricultural College,
Logan, Utah, in partial fulfillment
of the requirements for the degree
of Master of Science
May 1929

R. Kenneth Bischoff

CORRELATED INHERITANCE IN A CROSS OF F 22 X DICKLOW WHEAT

Geo. Stewart and R. K~~enneth~~ Bischoff

This paper reports a study of the inheritance and of the correlated inheritance in certain observed and measured plant characters in a cross between a hybrid from Dicklow x Sevier, (F22) and a pure line from Dicklow, (D#3), one of the original parents of F 22.

Literature

Hayes and Garber(3), Clark(1), and Stewart(6) have recently compiled bibliographies of literature relating to the inheritance of characters in wheat herein reported. On this account literature citations are limited to those that refer directly to the material studied.

Description of Parents

F22 is a segregate from the cross, Sevier x Dicklow, and was developed by Stewart at the Utah Experiment Station. The straw is much stronger than the Sevier parent but not as strong as the Dicklow parent. The glumes are light bronze in color. It is a fully awned wheat.

Measurements of the parent rows are summarized as follows:

Length of longest culm to base of spike --------- 108.43 ± 6.06 cm.
Spike density - length of one rachis internode -- 2.56 ± .249 cm.
Number of culms per plant ---------------------- 11.61 ± 3.44

Dicklow is a favorite spring wheat on the irrigated farms of Utah. This popularity is due to its ability to resist lodging under irrigation and to produce a high yield. It has a medium tall, stiff straw. The spikes are beaked with short awns. The glumes are white in color. The grain shatters from the spike rather easily.

Measurements of the parent rows follow:

Length of longest culm to base of spike ------- 103.84 ± 4.80 cm.
Spike density - length of one rachis internode 5.03 ± .502 mm.
Number of culms per plant --------------------- 9.43 ± 2.70

These measurements indicate that F 22 has a culm length averaging 4.59 ± 6.06 centimeters longer than Dicklow. The difference is less than the probable error. The range for the longest culm is 92.5 to 123.0 cm. for F 22 and from 93.5 to 117.4 for Dicklow. In spike density Dicklow, ranging from 43.47 cm. to 64.75 cm. is twice as lax as the F 22 parent whose range is from 23.83 to 28.05 cm. This measurement considers ten rachis internodes. The two parents differ but slightly in number of culms produced. F 22 produces an average of 11.61 ± 3.44 culms with a range from 9.3 to 15.7 per plant. The Dicklow parent has an average of 9.43 ± 2.70 ranging from 7.7 to 11.4 per plant.

Experimental Procedure

The cross between a pure line of F 22 and Dicklow, D#3, was made in 1925 at Logan, Utah. The F_1 plants were grown in 1926. The year following, the F_2 families were grown. One of the most vigorous of the F_2 families was chosen to continue the study. This family consisted of 248 plants. Each of these plants was classified according to awn class, glume color, and spike density. The spike density figure was obtained by measuring the length of ten rachis internodes. Grain from each plant seeded an F_3 progeny row in 1928. The kernels were spaced about three inches apart with 40 to 50 in a row except where an F_2 plant furnished fewer kernels. The rows were one foot apart.

After each tenth progeny row the parental varieties F 22 and Dicklow were sown side by side in the same manner and at the same time as the progeny rows. In all there were 25 parent rows. Two of the Dicklow parent rows were destroyed thru accident and are not included in the calculations reported. This planting arrangement made it possible to study the progeny characters in relation to the parental characters.

When the grain was ripe each F_3 and parent row was carefully harvested by pulling the plants individually in the row. The plants of each row were bundled, tied and labeled. The material was worked in the laboratory during the winter months.

Culms length was measured by placing the root end of the individual plant against a foot board and extending the culms along a table board marked in centimeters. The longest culm was measured to the base of the spike and recorded. The number of dwarfs were determined by counting. The number of culms were counted with the precaution of avoiding second growth culms, that sometimes appeared at the base of the plant. Each plant was examined for its awn behavior. Those that approached the F 22 parent were classified as awn class 4, or simply awns 4. Those that approached the Dicklow parent were called awn 2. Rows that produced both awn 2 and 4 were said to be segregating. Spike density was determined by measuring ten rachis internodes in the middle of a typical spike on each plant. This avoided the extremes of laxity and density found on opposite ends of the spike. Each plant was classified for glume color as white or bronze which was determined by inspection.

The data were so taken and recorded that all data from each plant could be readily traced to that plant and to the row from which it came. This permitted the study of correlations.

The usual number of plants in each progeny was 30 to 35. In some progenies there were fewer than this and in others there were more. The parental rows averaged approximately the same number of plants. Measurements and classifications were made on the basis of genetic material in evidence in the plants. No theory of inheritance was advanced until all data were taken, recorded, and calculated.

Experimental Results and Their Interpretation

After the data were assembled and recorded, classifications and calculations were made. The mean length of the longest culm was calculated for each progeny. The same calculation was made for number of culms. The progeny rows were classified into segregating and true-breeding groups for dwarfs, for awns, and for glume color. The mean spike density of each progeny was obtained as well as the coefficient of variability for each row. When correlation studies were made the mean values for the F_3 progenies were the figures used. This was regarded as more accurate than the individual figures for the F_2 plants.

Inheritance of Individual Characters

Inheritance studies were made for the following individual plant characters: Culm length, dwarfs, number of culms, awn classes, spike density, and color of glume.

Culm Length.- Table 1 compares the distribution of F_3 progenies for culm length and coefficient of variability with that of the parental rows. The range for F 22 parents is from 92.5 to 123 ± 6.06 centimeters; that of the Dicklow parent from 93.5 to 117.4 ± 4.80 centimeters. The range of the two parents is almost identical but the F 22 parent averages somewhat taller than the Dicklow. The range in culm length for the F_3 progenies is from 88.0 to 128.0 ± 5.77 cm. There were more individuals considered in the progenies than there were in the parental rows. The distribution shown fails to indicate segregating groups.

Dwarfs.- The F_3 progenies segregated for tall and dwarf plants as follows: 99 were segregating for either 3 tall to 1 dwarf or 13 tall to 3 dwarf plants; 30 progenies were segregating 1 tall to 3 dwarf plants; 11 were homozygous for the dwarf character and 108 were homozygous for the tall characters. These data seem to indicate a 13 tall to 3 dwarf segregation.

Two factors are involved in this explanation of dwarfness. (1). Ii an inhibitor factor which prevents the expression of dwarfness when the dominant I is present either in the heterozygous or in the homozygous condition; and (2) Dd, a dwarf factor which, in the dominant condition, produces dwarfs when in the homozygous or heterozygous condition.

The recombination of these factors would produce all tall plants in F_1 but calls for two phenotypes in F_2 , tall, and dwarf, which would behave in F_3 as follows:

F22 IIDD x Dicklow iidd
F_1 IiDd All tall

13 Tall Plants

1 IIDD (tall in F_2, tall in F_3)
2 IIDd (tall in F_2, tall in F_3)
2 IiDD (tall in F_2, segregate 3 tall : 1 dwarf in F_3)
4 IiDd (tall in F_2, segregate 13 tall : 3 dwarf in F_3)
1 IIdd (tall in F_2, tall in F_3)
2 Iidd (tall in F_2, tall in F_3)
1 iidd (tall in F_2, tall in F_3)

3 Dwarf Plants

1 iiDD (dwarf in F_2, dwarf in F_3)
2 iiDd (dwarf in F_2, segregate 3 dwarf to 1 tall in F_3)

It was impossible from inspection to separate the 13 : 3 and the 3 : 1 segregating groups, therefore the segregation was made by the Dev./P.E. method and is summarized in Table 2. The Dev./P.E. calculation was made for each progeny considered on the basis of a 13 :3 segregation and also on the basis of a 3 : 1 segregation. The final segregation was made on the basis of the smallest Dev./P.E. calculation. By this calculation 46 progenies were found to be segregating for the 3 : 1 ratio; 53 for the 13 : 3 group; 30 for the 1 : 3 group; 11 were homozygous for the dwarf character and 108 were homozygous tall. In this instance X^2 = 9.903 and P = .042 which is not a good fit.

Table 1. Parental rows and F_3 progenies arranged according to means of culm length and according to the coefficients of variability (C.V.) classes. (Cross 35 c; grown in 1928 at Logan, Utah)

(Length of longest culm)

	Class											C.V.	Total
	85	90	95	100	105	110	115	120	125	130	Total	Class	Individuals
Dicklow				1	2	4	2				9	4	
			4	4	3	1					12	8	
			1								1	12	23
			1								1	16	
											Mean	6.94	
						1	1				2	4	
			1	1	8	1	4	2	1		18	8	25
			2	1							3	12	
			1				1				2	16	
											Mean	8.46	
			3	6	8	7	12	7	2		45	4	
	1	2	9	39	29	30	20	12	2	2	146	8	
	1	4	8	11	4	6	2	4			40	12	237
			1	1	1						3	16	
				2	1						3	18	
											Mean	7.95	

No of Progenies in Per Cent

Figure 1. Frequency curve showing percentage distribution of F 22, Dicklow and F 3 progenies for culm length.

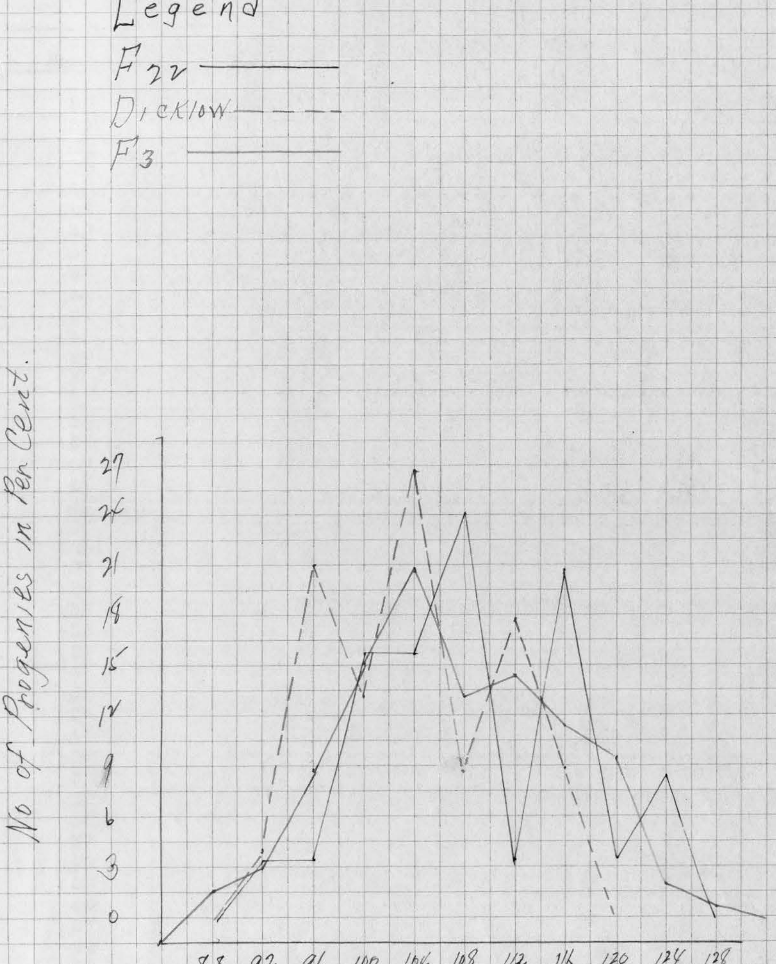


Table 2. Segregation for normal and dwarf plants in F_3 progenies from normal F_2 plants, grouped into two classes determined by the nature of the segregation of normal to dwarf plants (a) 13:3, (b) 3:1

Family 35 c; grown in 1928 at Logan, Utah

Normal	Dwarf	Calculated	Dev.Cal. 3:1	P.E.	Dev./P.E.
27	5	6	1	1.49	.67
38	4	7.9	3.9	1.71	2.27
31	4	6.6	2.6	1.56	1.66
31	5	6.8	1.8	1.58	1.13
40	1	7.7	6.7	1.69	2.91
25	1	4.9	3.9	1.34	2.91
32	3	6.7	3.7	1.56	2.36
34	7	7.7	.7	1.69	.41
23	3	4.9	1.9	1.34	1.41
44	6	8.6	2.6	1.79	1.55
34	5	7.3	2.3	1.64	1.4
37	6	8.06	2.06	1.73	1.19
27	1	5.3	4.3	1.39	3.09
36	6	7.9	1.9	1.71	1.11
31	5	6.8	1.8	1.58	1.13
32	2	6.4	4.4	1.54	2.85
24	3	5.01	2.01	1.37	1.46
40	6	8.6	2.6	1.79	1.45
40	3	8.06	5.06	1.73	2.92
36	5	7.7	2.7	1.69	1.59
25	3	5.3	2.3	1.39	1.65
29	2	5.8	3.8	1.47	2.58
37	7	8.3	1.3	1.75	.74
27	6	6.2	.2	1.51	.13
32	5	6.9	1.9	1.60	1.18
38	5	8.1	3.1	1.73	1.79
33	8	7.7	.3	1.69	.17
40	3	8.1	5.1	1.73	2.94
33	4	6.9	2.9	1.60	1.81
34	7	7.7	.7	1.69	.41
40	3	8.1	5.1	1.73	2.94
27	3	5.6	2.6	1.44	1.80
35	5	7.5	2.5	1.66	1.50
25	5	5.6	.6	1.44	.41
37	9	8.6	.4	1.79	.22
37	9	8.6	.4	1.79	.22
40	14	10.1	3.9	1.93	2.02
28	6	6.4	.4	1.54	.25
40	10	9.4	.6	1.86	.32
27	7	6.4	.6	1.54	.38
22	6	5.3	.7	1.55	.50
35	8	8.1	.1	1.73	.57
40	10	9.4	.6	1.86	.32
29	9	7.1	1.9	1.62	1.17
34	8	7.9	.1	1.71	.58
40	11	9.6	1.4	1.88	.74

(Cont.)

Table 2. (Cont.)

Normal	Dwarf	Calculated	Dev.Cal. 3:1	P.E.	Dev./P.E.
40	8	9.0	1.0	1.82	.54
36	8	8.3	.3	1.75	.17
25	6	5.8	.2	1.47	.14
40	10	9.5	.6	1.86	.32
32	8	7.5	.5	1.66	.30
40	9	9.2	.2	1.64	.12
44	14	13.5	.5	2.15	.23
33	10	10.8	.8	1.92	.41
34	13	11.8	1.2	2.00	.60
34	14	12.0	2.0	2.02	.99
33	15	12.0	3.0	2.02	1.48
27	16	10.8	5.2	1.92	2.70
24	10	8.5	1.5	1.70	.88
32	10	10.5	.5	1.89	.26
38	11	12.3	1.3	2.04	.63
28	17	11.3	5.7	1.96	2.90
38	13	12.8	.2	2.09	.95
28	16	11.0	5.0	1.94	2.57
34	14	12.0	2.0	2.02	.99
37	11	12.0	1.0	2.02	.49
29	11	10.0	1.0	1.85	.54
40	15	13.8	1.2	2.17	.55
31	13	11.0	2.0	1.94	1.03
28	13	10.3	2.7	1.87	1.44
31	9	10.0	1.0	1.85	.54
27	12	9.8	2.2	1.82	1.20
27	10	9.3	.7	1.78	.39
20	8	7.0	1.0	1.55	.64
31	16	11.8	4.2	2.00	2.10
37	11	12.0	1.0	2.02	.49
27	14	10.3	3.7	1.87	1.97
19	9	7.0	2.0	1.55	1.29
29	10	9.8	.2	1.82	.10
24	13	9.3	3.7	1.78	2.07
35	10	11.3	1.3	1.96	.66
29	13	10.5	2.5	1.89	1.32
24	7	7.8	.8	1.63	.49
23	7	7.5	.5	1.60	.31
36	12	12.0	.0	2.02	.00
26	10	9.0	1.0	1.75	.57
38	14	13.0	1.0	2.11	.47
40	14	13.5	.5	2.15	.23
22	8	7.5	.5	1.60	.31
29	12	10.3	1.7	1.87	.90
25	11	9.0	2.0	1.75	1.15
24	10	8.5	1.5	1.70	.88
37	12	12.3	.3	2.04	.15
39	14	13.25	.8	2.13	.37
27	13	10.0	3.0	1.85	1.62
19	7	6.5	.5	1.49	.33
29	11	10.0	1.0	1.85	.54
27	15	10.5	4.5	1.89	2.38

Since some difficulty was experienced in segregating the 3 : 1 and 13 : 3 groups and a very poor fit was obtained, these two groups were considered as one and compared with a 13 : 3 ratio for goodness of fit. By this grouping 99 progenies were segregating 3 : 1 and 13 : 3; 30 were segregating 1 tall to 3 dwarf plants; 11 were homozygous for the dwarf character and 108 were homozygous for tallness. By this calculation $X^2 = 1.7256$ and $P = .7395$, which is a very good fit. These comparisons are summarized in Tables 3 and 4.

Table 3. Closeness of fit of five groups on a 13 : 3 segregation
Family 35 c; grown in 1928 at Logan, Utah

Group	C	O	O - C	$(O - C)^2$	$\frac{(O - C)^2}{C}$
Segregating 3 : 1	31	46	15	225	7.2580
" 13 : 3	62	53	9	81	1.3064
" 1 : 3	31	30	1	1	.0322
Homozygous Dwarf	15.5	11	4.5	20.25	1.3064
Homozygous Tall	108	108	0	0	0

$X^2 = 9.9030$
$P = .0402$

Table 4. Closeness of fit of four groups on a 13 : 3 segregation.
Combining 3 : 1 and 13 : 3 segregating groups

Group	C	O	O - C	$(O - C)^2$	$\frac{(O - C)^2}{C}$
Segregating 3:1 13:1	93	99	6	36	.3870
" 1:3	31	30	1	1	.0322
Homozygous Dwarf	15.5	11	4.5	20.25	1.3064
Homozygous Tall	108	108	0	0	0

$X^2 = 1.7256$
$P = .7395$

The theory fits the observations so well that in about 73 cases out of 100 a wider deviation might be expected due to chance alone. The evidence seems to bear out the theory of one dominant factor and an inhibitor factor operating in the inheritance of dwarfs but also indicates the difficulty of separating similar groups.

Number of Culms.- Both the F 22 and Dicklow parents are essentially alike in number of culms produced. No segregation of the F_3 progenies was observed. Table 5 and Figure 2 summarize the data. The parental types were both recovered. The mean coefficient of variability is almost identical for both parents~~(3)~~ and for F_3 progeny.

Awn Classes.- Hayes and Garber(3) in summarizing various inheritance studies found awn inheritance to be very simple in some crosses and in others very complex. They concluded that there may be two or more genetic factors involved in awnedness. Howard and Howard(5) obtained single-factor results in some crosses, but in others between fully awned and awnless parents they were able to separate the F_2 progeny into five or six classes, which results required two factors to explain.

In this family the F 22 parent is homozygous for awns 4 and the Dicklow parent for awn 2. There were 56 progenies homozygous for awn 2, 131 were heterozygous for awn inheritance and 51 were breeding true for awn 4. When compared for closeness of fit on the basis of a 1 : 2 : 1 segregation X^2 = 2.6689 and P = .2709 (Table 6). This fit indicates that the segregation considered is probably correct since a worse fit in 27 cases out of every 100 would be expected due to chance alone.

Spike Density.- The mean spike densities and the coefficients of variability were calculated for each progeny. The F_3 progenies were classified into three groups: (1) Those homozygous for dense spikes, (2) those heterozygous for spike density, and (3) those homozygous for lax spikes.

Table 7 compares the spike density classes with the coefficient of variability (C.V.) classes of both parents and F_3 progenies.

Heterozygosity or homozygosity was indicated by the size of the coefficient of variability. The mean coefficient of variability for the homozygous F 22 parent was 13.68 ± 1.428 with a range of 10.24 to 16.25 per cent. The same calculation for Dicklow was 10.54 ± 1.018 and ranged from 7.7 to 16.19 per cent. The mean coefficient of variability for the homozygous dense group was 12.00 ± .739 and ranged from 6.45 to 22.30; the lax group exhibited a mean of 9.04 ± .636 and a range from 4.1 to 16.22 and the heterozygous group had a mean of 38.15 ± 1.8182 per cent with a range from 23.33 to 47.42 per cent for the same character. These figures indicate that the entire range of the parents was recovered in the progenies and that the true-breeding F_3 rows are no more variable than the parental rows.

Table 8 proves rather definitely that there were progenies which were homozygous for dense spikes, others which were homozygous for lax spikes and that the spikes of intermediate length were heterozygous. The rows of homozygous dense progenies tended to be very similar in appearance and density to the F 22 parent. The heterozygous group was intermediate between the parents and contained individuals representative of both parental groups indicating segregation. The homozygous lax group exhibited a tendency toward greater laxity than the Dicklow parent. In only three progenies was the mean density of the Dicklow spike recovered. The mean length of each rachis internode in the F_3 progenies was 5.6 ± .393 mm. as compared with 4.8 ± .502 mm. for Dicklow. These figures indicate a tendency toward transgressive segregation in the direction of a more lax spike than that which characterizes the Dicklow parent. Figure 3 illustrates this new mean graphically.

Figure 2. Frequency curve showing percentage distribution of number of culms for F22, Dicklow and F3 Progeny-

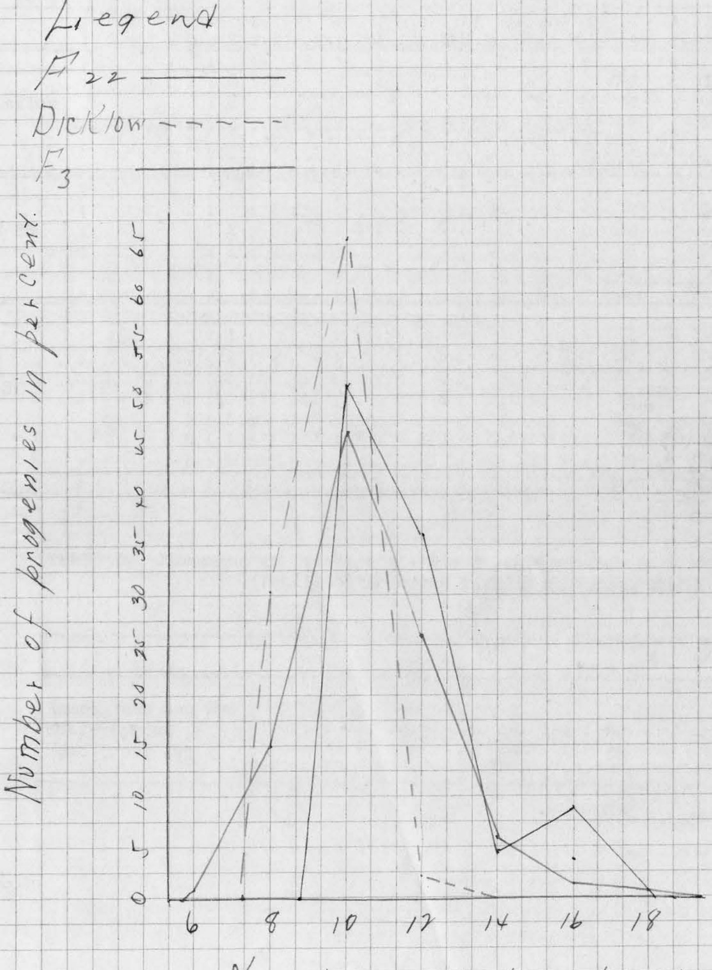


Table 5. Parental rows and F_3progenies arranged according to number of culm classes and according to Coefficient of Variability(C.V.) classes.
(Cross 35 c; grown in 1928 at Logan, Utah)

(Number of Culm Classes)

	6	7	8	9	10	11	12	13	14	15	16	17	Total	C.V. Classes	Total Number
Dicklow		1	1	2	1								5	30	23
			2	3	3	1							9	40	
		1	2	2	2								7	50	
			1		1								2	60	
													Mean	42.48	
F 22					2					1			3	30	25
				2	5	3	3		1				14	40	
				1	2	1				1			5	50	
					1		2						3	60	
													Mean	44.45	
F_3				1			1						2	20	237
			3	11	4	6	4	1	3	2		1	35	30	
	2	3	15	25	24	20	8	5	2		1	1	106	40	
		3	4	15	21	12	5	5	2	1			68	50	
			1	5	3	7	2	1					19	60	
			3	1	1								5	70	
			1	1									2	80	
													Mean	43.96	

Table 6. Closeness of fit on a 1 : 2 : 1 segregation
(Family 35 c; grown in 1928 at Logan, Utah)

Group	C	O	C - O	$(C - O)^2$	$\frac{(C - O)^2}{C}$
Homozygous Awn Two	59	56	3	9	.152
Heterozygous	118	131	13	169	1.4322
Homozygous Awn 4	59	51	8	64	1.0847

$X^2 = 2.6689$

$P = .2709$

Table 7. Frequency distribution of the rows of Dicklow and F 22 parents and of F_3 progenies, arranged into classes according to the mean spike density and according to the Coefficients of Variability(C.V.) classes of the individual rows of parents and of the F_3 hybrid progenies.

(Family 35 c; grown in 1928 at Logan, Utah)

(Spike Density Classes)

	20	24	28	32	36	40	44	48	52	56	60	64	Total	C.V. Classes	Total No. Individuals
F 22		3											3	10	25
		15	6										21	14	
			1										1	18	
														22	
													Mean	13.68	
D #3								4	8				12	8	22
								5	2				7	12	
							1	1					2	16	
												1	1	20	
													Mean	10.54	
Homozygous Dense	1	1											2	6	60
	12	17											29	10	
	6	16	3	2									27	14	
			1										1	18	
	1												1	22	
													Mean	12.00	
Heterozygous							1						1	24	129
			1	2	4	1		1					9	28	
		2	1	4	6	3	1						17	32	
		1	3	15	13	6	2						40	36	
			3	14	14	6							37	40	
			1	8	7	2		1					19	44	
			2	2	1	1							6	48	
													Mean	38.15	
Homozygous Lax											2		2	4	46
								1	3	15	6	1	26	8	
									4	8	5		17	12	
										1			1	16	
													Mean	9.04	

Table 8. Frequency distribution of the F_3 progenies from a cross of Dicklow x F 22, arranged into classes according to the mean spike density and according to Coefficient of Variability (C.V.) classes. Three classes, (1) those homozygous for dense spikes, (2) those heterozygous, and (3) those homozygous for lax spikes are plotted in one table to show the well defined margins of the three classes.

(Family 35 c; grown in 1928 at Logan, Utah)

(Spike Density)

20	24	28	32	36	40	44	48	52	56	60	64	Total	C.V. Classes	Total Number Individuals
1	1									2		4	6	
12	17		1				1	3	15	6	1	56	10	
6	16	3	1				4	8	5			43	14	
		1							1			2	18	
1												1	22	
						1						1	26	
		1	2	4	1		1					9	30	237
	2	1	4	6	3	1						17	34	
	1	3	15	14	6	2						41	38	
	1	3	14	14	6							38	42	
		1	8	7	2		1					19	46	
		2	2	1	1							6	50	
												Mean	27.08	

Table 9. The range of mean spike densities and the mean of mean spike densities of F 22 and Dicklow parent rows and of three groups of F_3 progenies, together with the range of the coefficients of variability and the mean of the mean coefficients of variability for the same three groups.

(Family 35 c; grown in 1928 at Logan, Utah)

Strain	Spike Density Range	Mean of Spike Density	C.V. Range	Mean of C.V.
F 22 parent	2.4-2.8	2.51	10-18	13.68
Dicklow parent	4.0-5.2	4.29	8-16	10.54
Homozygous dense	2.0-3.2	2.52	6-22	12.00
Heterozygous	2.4-4.8	3.47	24-48	38.15
Homozygous lax	4.8-6.4	5.65	4-16	9.04

Table 9 indicates that the range of spike density and the range of coefficients of variability (C.V.) not far different in homozygous groups of progenies than in either parent. It also proves that the density of the F 22 parent was recovered almost identically. The mean density of the F 22 parent was 2.51 ± 2.49 as compared with a mean of 2.52 ± .155 for the dense progenies. The heterozygous group could be identified at a glance by the difference in the mean coefficient of variability. This figure also lends additional evidence to the observation previously made that the Dicklow spike was not recovered except in 3 progenies and that transgressive segregation occurred toward a more lax spike of 4.29 ± .502 with a range of 4. -5.2 with a mean coefficient of variability of 10.54 ± 1.018 per cent and a range of 7.7 to 16.19. The comparison is between this and the homozygous lax group with a higher range, 4.8 -6.4 and a mean 1.36 ±.393 mm. longer than the lax parent. The range of the coefficient of variability is also greater, 4 -16 with a mean of 9.04 ± .635 slightly less than the Dicklow parent, indicating a stability of behavior toward greater laxness.

Stewart(6) found transgressive segregation in both directions in a cross of Kanred by Sevier wheat. Parent rows were placed at every ten-row interval in the nursery and the measurements indicate the definite tendency toward greater laxness. The F 22 parent type was recovered completely and almost identically.

It is evident from the material presented so far that there are three definite groups of progenies when classified according to spike density. When compared with a 1:2:1 ratio indications are that other factors not accounted for must be present and operating in producing the results indicated. Table 10 compares the closeness of fit on a 1:2:1 segregation basis. $X^2 = 5.269$ and P = .0733. In 7 cases out of every 100 a worse fit would be expected from pure chance alone. It is concluded, therefore, that there is a major dominant factor operative in the inheritance of spike density in this family.

Table 10. Closeness of fit of three groups of F_3 progenies on a 1:2:1 segregation for spike density

(Family 35 c; grown in 1928 at Logan, Utah)

Group	C	O	C - O	$(C - O)^2$	$\frac{(C - O)^2}{C}$
Homozygous dense	59.5 59	5 60	1	1	.0169
Heterozygous	119 108	129	8 21	441	4.0833 ✓
Homozygous lax	59	49	10	100	1.1690

$X^2 = 5.2692$
P = .0733

Glume Color.- The F 22 parent has a bronze glume of intermediate intensity. The Dicklow parent has a white glume. It has been noted by other workers that bronze exhibits a dominant influence to white. In this family 58 of the progenies were homozygous for bronze, 110 were heterozygous and 69 were homozygous for white. Table 11 indicates the number calculated and observed and records X^2 as 1.7295 and P = .4324. No color variations outside the range of the parental variations were observed and both parental types were recovered. The fit indicates that in 43 cases out of 100 cases, a worse fit could be expected due to chance alone. This fit is rather significant in indicating that the inheritance is due to a single major factor difference.

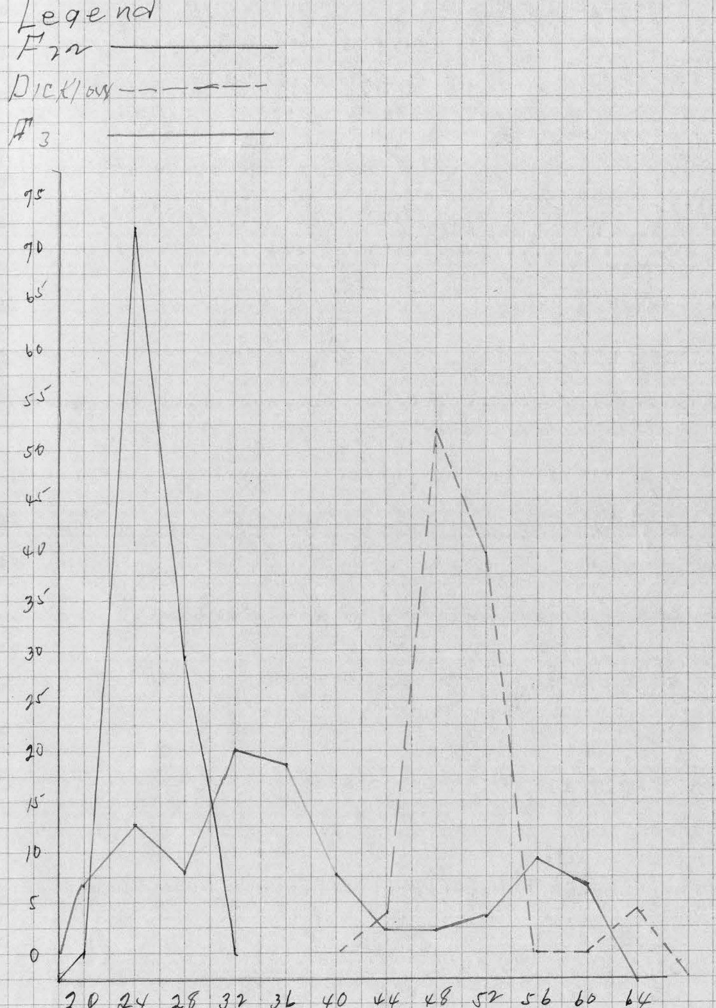
Table 11. Closeness of fit on a 1:2:1 segregation

(Family 35 c; grown in 1928 at Logan, Utah)

	C	O	C - O	$(C - O)^2$	$\frac{(C - O)^2}{C}$
Homozygous Bronze	59	58	1	1	.0169
Heterozygous	118	110	8	64	.5424
Homozygous White	59	69	10	100	1.1692

$X^2 = 1.7295$
P = .4324

Figure 3. Frequency curve showing percentage distribution of F 22, Dicklow and F 3 progenies for spike density.



Correlation Studies

Correlation studies were made of the mean values of each character studied on the F_3 progenies. Measurements or counts were made for each of the plant characters for every F_3 plant and for the mean of the row calculated for each progeny.

All possible correlations were made between the four characters for which counts or measurements were taken. The combinations were as follows: (1) Number of culms x culm length, (2) number of culms x awn length, (3) number of culms x ten rachis internodes, (4) awn length x ten internodes, (5) awn length x culm length, (6) awn length x ten internodes, (7) culm length F_2 x F_3, (8) ten rachis internodes F_2 x F_3. Table 12 gives a summary of the correlation results.

The correlation coefficient (r) and the probable error (P.E.) were calculated for each of the contrasted characters. The correlation ratio (n) and Blakeman's Test for linearity were calculated for the same characters to determine if the regressions were sensibly linear.

When number of culms x culm length are correlated no significant results are obtained. r is only .1795 ± .029 and is six times its probable error indicating that there probably is no correlation existing here. (n) is .235 ± .013 and Blakeman's Test is only 1.76, indicating that the very slight correlation, if any, is linear.

In the correlation between the number of culms x awn length r is ± .172 ± .069 and n is .352 ±.049, which is 7 times its probable error. Blakeman's test is 1.88. It should be observed at this point that measurements for awn length were taken only on the 47 progenies that were homozygous for awn 4. This limited the number of individuals considered in the correlation to 47 and Blakeman's Test indicates no correlation not measured by r.

The correlation coefficient r .167 ± .032 obtained when number of culms x spike density are correlated is not significant. n approaches significance with a figure of .425 ± .028. This figure and Blakeman's Test of 5.5 indicates that the correlation is not linear and that r does not measure all correlation present.

The groups were separated in an effort to determine the cause of the difference found between r and n. Three groups were made of the spike density classes and each group correlated with the number of culms as follows: (1) Homozygous dense spikes x number of culms; (2) heterozygous spikes x number of culms; and (3) homozygous lax spikes x number of culms. The first of these, homozygous dense spikes x number of culms, gave a slight negative correlation of -.0796 ± .033, which is barely more than twice its probable error indicating that it is almost insignificant. The only other correlation in this separation that gave any result approaching significance was the last mentioned, where homozygous lax was correlated with number of culms. The result here was an r of .269 ± .028 which is 9 times its probable error and begins to approach a dependable figure. It might be observed that the slight negative correlation considered with this positive correlation might account for the non-linear correlation suggested by Blakeman's Test and n.

In comparing the correlation of awn length x spike density neither r nor n were significant. The same is true of the correlation awn length x culm length. It is concluded therefore that for these two pairs of factors that no measurable correlation existed.

The only correlation that gave a positive indication of value was that which measured awn length x spike density. In this case r equals .406 ± .094 and is 4½ times its probable error. n also is large, .6379 ± .078. Blakeman's Test for linearity is only 3.088 and indicates that the regression is sensibly linear. It is concluded, therefore, that there is a definite correlation between the length of the awn and as the spike becomes less dense the awn becomes longer.

Culm length in 1927 was correlated with culm length in 1928. It was found that no correlation existed as neither r nor n were large enough to be even slightly important. The correlation study indicates that no segregation occurred that could be detected by either r or n.

Table 12. Correlation coefficients (r), correlation ratios (n), their respective probable errors (P.E.), and Blakeman's test of linearity for various pairs of plant characters.

(Family 35 c; grown in 1928 at Logan, Utah)

Characters Correlated	r ± P.E.		n ± P.E.		Blakeman's Test
Number of culms x culm length	.1795 ±	.029	.235 ±	.015	1.76
Number of culms x awn length	.172	.069	.352	.049	1.886
Number of culms x ten internodes	.167	.0316	.425	.028	5.5
Awn length x ten internodes	.142	.035	.271	.028	1.93
Awn length x culm length	-.055	.095	.347	.019	6.05
Awn length x ten internodes	.406	.094	.6379	.078	3.088
Culm length 1927 x same 1928	.118	.043	.164	.0098	1.306
Ten rachis internodes F_2 x F_3	.3785	.0376	.809	.048	10.74
Ten internode(homozygous dense and lax) F_2 x F_3	.383	.085			
Ten internode(homozygous dense) x number of culms	-.0796	.033			
Ten internode(heterozygous) x number of culms	.023	.178			
Teh internode(homozygous lax) x number of culms	.269	.028			

Soil Heterogeneity.- The Harris' method, (4), of measuring soil heterogeneity uses the coefficient of correlation, r, as an index to soil heterogeneity. The correlation between contiguous plats systematically grouped, is measured by this statistical constant. When the variation in yield is due to random sampling, no correlation is noted. On the other hand when the field is "spotted" certain of the contiguous units will tend to yield high while others will yield low. This condition results in a high correlation. When random sampling is the only influence entering the variability of certain groups is counterbalanced by the corresponding variability of other groups of contiguous rows, and when a large enough group is used, the law of average operates in equalizing the effect. It is obvious that for this factor to be significant plots must have the same cultural treatment.

One row of each parent variety was grown side by side at intervals of every ten of the F_3 progeny rows, thus insuring systematic distribution. All the contiguous parental and progeny rows received identical treatment within the range of reasonable error.

Correlation studies were made between culm length measurements of the F 22 x Dicklow parents and the spike density of the two parents. The results of these correlations follow in Table 13.

Table 13. Correlation studies of parent plant characters in cross 35 c to determine the presence of soil heterogeneity

(Family 35 c; grown in 1928 at Logan, Utah)

Character Studied	Correlation Coefficient and Probable Error
Culm length Dicklow x F 22	± .461 ± .111
Spike Density. Dicklow x F 22	± .626 ± .085

In the light of the theory advanced by Harris' that variability producing a positive, significant correlation, is due to soil heterogeneity Table 13 proves that heterogeneity of the soil was measurably noticeable in this field. The culms length correlation gave a positive ±r of .461 ±.111 and that of spike density a positive r of .626 ±.085. Both of these figures are significant in indicating the existance of considerable soil heterogeneity.

Competition.- The ability of one strain to thrive at the expense of the near-by strain is known as competition. When a tall strain depresses the growth of a short strain or a vigorous strain inhibits the development of contiguous neighbor, the experimental data are seriously affected. When competition is operative, as one strain becomes more vigorous the near-by strain would be expected to be retarded. This opposing effect would produce a negative correlation provided competition was the factor operating. One of the obvious plant characters that would be influenced by competition is number of culms, therefore, a correlation was made between the number of culms produced by each parent when grown side by side between each ten rows of F_3 progenies. These data gave a negative correlation (r) of -.557 ± .097. This is a significant correlation and is 5.5 times its probable error, indicating that the more vigorous F 22 parent was growing at the expense of the Dicklow parent. It will also be remembered that the F 22 parent averaged slightly longer in culm length than the Dicklow. These factors indicate that the experimental results were influenced by competition.

Summary

The cross between a pure line of F 22 and Dicklow, D #3, was made in 1925 at Logan, Utah.

The data were so taken and recorded that the parent and progeny characters could be compared and in such a manner that correlation studies could be made.

The range of the two parents for culm length was recovered in the progeny and no segregating groups were revealed.

The F_3 progenies segregated on a 13 tall to 3 dwarf basis for tall and dwarf plants. This was plainly indicated when compared with a 13 : 3 ratio for goodness of fit.

The Dev./P.E. method was used to separate the 3 tall to 1 dwarf and 13 : 3 classes. This calculation was not successful as indicated by the unsatisfactory fit compared with the good fit when the two groups were considered as one. The evidence bears out the theory that one dominant dwarf factor and an inhibitor factor were operating in the inheritance of dwarfs.

The F 22 and Dicklow parents were essentially alike in number of culms per plant and no segregation was observed.

There was a single factor difference in awn class inheritance. The awn types of both parents were recovered. There was also a segregating awn class.

The mean spike density and coefficient of variability were calculated for each progeny. One major factor difference was found operating in spike density inheritance. Three groups were recovered, (1) a homozygous dense group, like the F 22 parent; (2) a heterozygous group segregating for spike density and (3) a homozygous lax group which tended to be more lax than the Dicklow parent. The mean difference was 5.6 ± .393 mm. for the F_3 plants and 4.8 ± .502 mm. for the Dicklow parent.

A major and one or more minor factor differences are probably operating in the recovery of the F 22 parent spike and the greater laxity of the Dicklow type. The coefficient of variability determined for the lax class indicates stability of behavior.

Correlation studies were made of the mean values of each character studied on the F_3 progenies.

The correlation between awn length and spike density gave a positive correlation of .406 ± .094 indicating a correlation between these two characters. Another significant correlation was that which compared spike density of the F_2 progenies with F_3 indicating stability of behavior of the F_2 plants for this character.

Soil heterogeneity was studied by using the coefficient of correlation on parent row characters. These parental rows were spaced systematically throughout the plot. The correlations were significantly positive and indicated the presence of soil heterogeneity as being measurably noticeable in this field.

Competition between varieties was studied by correlating the number of culms produced on the two parental rows growing side by side. This gave a negative correlation, indicating that competition existed between the contiguous rows.

Literature Cited

1. Clark, J.A.
Segregation and correlated inheritance in crosses between Kota and Hard Federation wheats for rust and drouth resistance.
Journal of Ag. Research, Vol.29, pp. 1-47

2. Clark, J.A.
Inheritance of awnedness, yield and quality in crosses between Bobs, Hard Federation and Propo wheats at Davis, California.
U.S.D.A. Technical Bul. 39. pp. 1-38

3. Hayes, H.K. and Garber, R.J.
Breeding Crop Plants. pp. 1-438, illus.
McGraw Hill Book Co.

4. Harris, J.A.
Practical universality of soil heterogeneity as a factor influencing plot yields
Journal Ag. Research, Vol.19, pp.279-314

5. Howard, A. and Howard, G.L.C.
On the inheritance of some characters in wheat
Mem. Dept. Agr. India, Bot. Ser. 5: 1-47

6. Stewart, G.
Correlated inheritance in Kanred and Sevier wheat
Journal of Ag. Research, Vol.36, No.10, pp.873-896

7. Stewart, G. and Tingey, D.C.
Transgressive and normal segregation in a cross of Marquis and Hard Federation wheat
Journal of American Society of Agronomy, Vol.20, No.6, pp.620-634