Correlation Studies in Wheat

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CORRELATION STUDIES IN WHEAT.

A

Thesis

Submitted to the Department of Agronomy

Utah Agricultural College

In Partial Fulfillment
of the
Requirements for the Degree of
Master of Arts

by

Joseph Reed

May 1926.

ACKNOWLEDGMENT.

The writer wishes to express his appreciation to Professor George Stewart under whose direction this investigation was made and to Associate Professor D. W. Pittman and Assistant Professor D. C. Tingey for helpful suggestions and criticisms.

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CORRELATION STUDIES IN WHEAT.

I. INTRODUCTION

Considerable work has been done by plant breeders and investigators in the study of individual plant characters, but only a few have attempted to work out correlations between characters in crop plants. One reason for this seems to be, that many investigators have felt that correlation studies were of very little practical value. This attitude was due perhaps to the interpretation given correlation data, especially the nature of the causal agency or agencies to which the correlation was attributed. Most of our plant breeders however, have been too busy working on experiments with single characters and have given little or no attention to correlation work. The few who have done work in correlations have usually found little or no correlation between the characters studied. The chief reason for lack of investigations in the field of correlations possibly lies in the fact that investigations in this field require very intricate and complex study. A number of characters must be studied and tabulated separately for each plant, the coefficient of correlation determined by means of a long mathematical process, and finally before the work is of any value, causal agencies must be considered and classified, and the data interpreted correctly. This makes the work slow and tedious.

It is quite natural then, in their rush to give to the world something new in plant breeding, that most of our investigators worked on individual characters. It is only recently that we have had men who have gone exhaustively into the field of correlations.

Before proceeding further, an explanation of correlations and what they indicate may be of value. Correlation as it relates to plant breeding is the association or relation that exists between plant characters due to a common causal agency or influence.

Davenport (11) states that correlation refers to that inter-relation between separate characters by which they tend in some degree at least to move together.

Webber (38) divides correlations into four classes which he thinks should be taken into consideration in the interpretation of correlation data; viz, environmental, morphological, physiological, and coherital. He terms environmental correlations those which are due to soil conditions, such as fertility, moisture supply, weather conditions and other environmental influences. He describes morphological correlations as those wherein a change in one character is the cause of a variation in another character. The physiological correlations, according to this investigator, are those cases where, for example, an increase in the number of leaves on a plant causes a decrease in seed production. It seems somewhat difficult to make a proper distinction between morphological and physiological correlations in using Webber's classification. His fourth type of correlations include those characters that are correlated to each other not in a causal sense but which are single unit characters due to inheritance.

Collins (9) classifies correlations as physical, physiological, and genetic. An example of a physical correlation is increased weight with increased height. His physiological correlations are those which result from the same physiological tendency. He describes his genetic correlations as those in which inheritance is associated as a causal agency.

East (14) states that correlations can be divided into two classes; viz, somatic and gametic. This classification seems to be a natural one and one which simplifies the interpretation of correlation data. East does not agree with Webber (38) who states that environmental correlations are merely the expression of equality of conformity to conditions of luxuriance. He thinks that there may be a temporary inheritance of effects of environment, and cites the fact that we find adaptations among plants to permanent environmental changes.

In order to determine the coefficient of correlation between two characters being studied the population data obtained as explained above are placed in a correlation table which indicates the frequency of distribution of the characters. By means of an equation the investigator solves for "r". This is the coefficient of correlation, and may be either positive or negative; positive when as one character increases the other increases, and negative when as one character increases the other decreases.

II. REVIEW OF LITERATURE

A review of correlation literature indicates but very little work done in the correlation of the characters in wheat which have been the subject of this investigation.

Leibenberg (22) in 1892-93 was probably the first to attempt to correlate length of culm in wheat with strength of culm with the length of head. He infers that a positive correlation exists between length of culm and length of head, and length of culm and strength of culm. Webber (38) classes these as environmental correlations, or merely an expression of a condition of luxuriance.

Lyon (27) an early twentieth century investigator found that plants with heads of slightly more than medium size were taller than plants with either smaller or larger heads.

Liebscher, Edler, and Von Seelhorst (25) in experiments with Noe summer wheat and Göttingen oats in 1897 found that five-noded plants produced longer heads than four-noded. Length of head was considered by them to be dependent upon vegetative conditions.

The work of these investigators indicates that there is a difference of opinion regarding the correlation of the characters which are herein being considered.

Comparatively recent and as yet unpublished data have been obtained by investigators at the Utah, Minnesota, and Cornell Experiment Stations and the U. S. Department of Agriculture, which indicate that many correlations heretofore considered merely environmental are in reality genetic correlations. For instance size characters have been found to be inherited and also that a positive relationship exists between these characters.

Professor George Stewart of the Utah Station is one of our more recent investigators in the field of correlations and his work, with that of others, when published will no doubt shed new light on this phase of plant breeding.

III. DESCRIPTION AND HISTORY OF CROSSES.

For the purpose of developing, if possible, a variety of wheat which would prove superior to any strain now grown in the intermountain region, several wheat crosses were made at the Utah Experiment Station by Professor George Stewart in the summer of 1919. The data presented in this thesis are the results of the study of these crosses. For a history of the parents of the Sevier X Dicklow cross reference is made to Frischknecht (15). A description of the parents of this cross follows, together with a history and description of the parents of the other crosses used in this investigation.

A. -- SEVIER PARENT.

I. - Description.

The Sevier plant has a spring habit. It is fairly early, and short to midtall; the culm is slender, weak and lodges excessively; the spike is awned, somewhat laterally compressed, oblong, dense, erect to inclined; the glumes are brownish in color, glabrous and midlong; the kernels are light amber in color, midlong to long and semihard to hard. The hardness of the kernels is increased when grown under dry farm conditions. It is also quite rust-resistant. This wheat has many desirable qualities and for the purpose of retaining these qualities and overcoming the weakness of culm so characteristic of this variety it was crossed with Dicklow.

B. -- DICKLOW PARENT.

I. Description.

The following description is given from Tingey (35). "Dicklow wheat possesses the spring habit of growth and is medium late in maturing. The stem and leaves display a rather grayish blue color just before maturing due to a distinct glacousness. The stems are rather strong and coarse and the leaves broad. The heads are what are considered awnless tho short beards or beaks appear at the apex. The glumes are glabrous and white. The kernels are soft, white and short to midlong. In respect to position the spikes vary from erect to nodding. The shape of the spike most common to the variety is middense and clavate (clubbed at apex)."

It will be noted from the descriptions of these two varieties that both have several qualities in sharp contrast with each other. Note especially the strong coarse culm of the Dicklow. The F_4 generations of this cross possess several of the desirable qualities of the parents and further experiments may possibly result in the segregation of a superior variety of wheat.

C. -- FEDERATION PARENT.

I. Description.

This variety possesses a spring habit; is early maturing and short; the culm is whitish in color and strong; the spikes are awnless, oblong, dense, and erect; the glumes are glabrous, brown, short and wide, and the kernels are white, short and soft.

II. - History.

According to Clark, Martin and Ball (8) quoting from Richardson (32), "It was produced by the late Mr. Farrer, wheat experimentalist of New South Wales, (Australia), from a cross between Purplestraw and Yandilla. Yandilla is a cross between Improved Fife and Etewah, an Indian variety. The production of this wheat was probably the greatest of Mr. Farrer's many triumphs in wheat breeding, for none of his many sucessful crossbred wheats have enjoyed such a wide measure of popularity as Federation."

Federation wheat was first introduced into the United States by the Department of Agriculture in 1914 from seed obtained from E. A. Cook of Perth, West Australia. In nursery experiments conducted at the Sherman County branch station, Moro, Oregon in 1916, it showed considerable promise. After further experiments and tests had been made it was distributed to farmers for commercial growing in the spring of 1920.

This variety was crossed with Sevier and the progeny of the F_4 generation were used in this study.

D. -- HARD FEDERATION PARENT.

I. - Description.

The plant possesses the spring habit; is early maturing and short; the culm is white in color and strong; the spike is awnless, oblong, dense and shorter than Federation; the glumes are glabrous, brown, short and wide; the kernels are white, short, hard, and ovate.

From the description it is seen that this variety differs from Federation in length of spike and hardness of kernel. Hard Federation was crossed with Dicklow and New Zealand. The progeny of this cross is known as a composite.

II. - History.

Clark, Martin and Ball (8) give the following, ~~quoted from~~ (17), "In consequence of the variations of the ordinary type exhibited by the strain of Federation wheat now being grown at Cowra Experiment Farm, it has been deemed advisable to apply a distinct name to it, and "Hard Federation" has been selected as the most appropriate. The departure from type was first noticed by J. T. Pridham, plant breeder, in 1907 or 1908, one of the plants selected from the stud plats being observed to thrash grain of remarkably hard and flinty appearance. The plant has the distinctive brown head and general appearance of Federation in the field, but the grain was of a class that has never been seen in the variety before. The seed was propagated, and in 1910 the occurrence of white heads was noticed, and from then until 1912 distinctly white heads were common among the brown, but in 1913 there were no white-eared plants, and it is hoped that the seed will now be true to type."

Hard Federation was introduced into the United States in August 1915 by the Department of Agriculture. The seed was presented to the United States Department of Agriculture by George Valder, undersecretary and director of the Department of Agriculture, Sidney, New South Wales. It made its first appearance at the Sherman County Branch Station, Moro, Oregon in 1916. Subsequent experiments by the Department have shown it to be a high yielding dry land wheat.

E. - NEW ZEALAND PARENT.

I. - Description.

This variety has a spring habit; is medium early in maturing; midtall to tall; the culm is white in color and strong; the spikes are awnless, linear-oblong, middense and inclined; the glumes are glabrous, white, midlong, and narrow; the kernels are midlong to long, soft and ovate.

II. - History.

The origin of New Zealand wheat is as yet undetermined. Apparently it was introduced into Utah about 1890 and is now being grown in small quantities.

All of the above crosses are segregating for head type.

IV. EXPERIMENTAL.

The data used in these correlation studies were obtained from the F_4 generations of the crosses described above. The first measurements were taken at the hybrid nursery just previous to harvesting, in the fall of 1924. The length of head and length of culm were measured in centimeters, and the strength of culm was estimated in percent. In estimating culm strength a perfectly erect culm was given 100%. This was used as a standard and each culm given a strength percentage according to its nearness to the standard.

For further study in the laboratory all rows of the crosses that were segregating for head type were pulled, tied separately, tagged and stored in the college seed house. During the winter of 1924-25 the bundles were taken to the laboratory, and the plants of each bundle studied carefully for head shape and segregated into the following head types; Club Compact, Medium Club, Long Compact and Long Loose, for the purpose of measurement and further investigation.

In order that the results might be significant and indicate with greater certainty the relationship of the characters to each other, several correlation tables for the same characters were obtained on a number of different populations, taken from families genetically different.

Data for Table 1 were obtained from measurements of the average length of culm and average length of head on two thousand seventy five plants of the Dicklow X Sevier cross.

Measurements were then taken of the longest culm and its head on one thousand four hundred twenty seven plants of the same cross as used in Table 1. The results are shown in Table 2.

It is seen from Tables 1 and 2 that a positive correlation exists between length of culm and length of head, and though the correlation coefficient is not large it is sufficient to indicate that a definite correlation does exist between these two characters. It will be noted that a slightly larger correlation was obtained from the data from the measurements of the longest culm and its head, than from the average length of head and average length of culm; the correlation coefficients being .297 and .283 respectively. The slight difference between the two coefficients is not large enough to be of any importance. The larger figure may probably be due to the more strictly individual culm used in Table 2.

The next group of material chosen for study was taken from the Federation X Sevier cross. Two thousand two plants of this cross were studied and the same measurements taken in the same manner as in the study of the preceding cross. The data and results are shown in Tables 3 and 4.

The correlation coefficients happen to be the same in Tables 2 and 4, being

TABLE 1.

Correlation table of Average length of head and average length of culm on plants of Dicklow X Sevier cross.

Length of Culm in Cm.

Length of Head in Cm.	60-65	65-70	70-75	75-80	80-85	85-90	90-95	95-100	100-105	105-110	110-115	115-120	
3-5	1	3	11	30	67	93	133	53	28				419
5-7			24	81	149	221	261	217	138	21	1		1113
7-9			2	15	27	53	81	54	44	5	3	1	285
9-11				2	9	27	54	49	82	15	8	1	247
11-13					1		3	2	4	1			11
	1	3	37	128	253	394	532	375	296	42	12	2	2075

$r = .283 \pm .013$

TABLE 2.

Correlation table of length of longest culm and length of its head on plants of Dicklow X Sevier cross.

Length of culm in Cm.

Length of head in Cm.	60-65	65-70	70-75	75-80	80-85	85-90	90-95	95-100	100-105	105-110	110-115	115-120	120-125	
3-5			1	9	20	47	81	64	53	13	1			289
5-7	1		2	7	26	68	131	179	207	83	26	1		731
7-9					5	16	33	43	49	15	7			168
9-11			1		1	3	24	44	65	46	16	8	3	211
11-13						1	4	7	9	6	1			28
	1		4	16	52	135	273	337	383	163	51	9	3	1427

$r = .297 \pm .016$

TABLE 3.

Correlation table of average length of head and average length of culm on plants of Federation X Sevier cross.

Length of culm in Cm.

Length of head in Cm.	35-40	40-45	45-50	50-55	55-60	60-65	65-70	70-75	75-80	80-85	85-90	
3-5	2	24	41	71	101	108	58	16	6			427
5-7	4	21	48	124	168	275	200	153	34	6	1	1034
7-9	1	3	7	27	37	72	44	39	13	2		245
9-11			2	15	23	70	66	64	33	3	1	277
11-13				1	2	2	3	9		1		18
13-15						1						1
	7	48	98	238	331	528	371	281	86	12	2	2002

$r = .313 \pm .013$

TABLE 4.

Correlation table of length of longest culm and length of its head on plants of Federation X Sevier cross.

Length of culm in Cm.

Length of head in Cm.	35-40	40-45	45-50	50-55	55-60	60-65	65-70	70-75	75-80	80-85	85-90	90-95	
3-5		9	19	40	63	97	61	42	13	3	1		348
5-7	3	13	21	71	124	199	254	208	118	31	6		1048
7-9		2	3	10	35	55	52	39	33	6	4		239
9-11			2	6	20	44	58	96	52	32	3	1	314
11-13				1	3	6	10	14	12	5	1		52
13-15						1							1
	3	24	45	128	245	402	435	399	228	77	15	1	2002

$r = .297 \pm .013$

.297 in each case though obtained from data of two different crosses, while in Tables 1 and 3 there is a slight difference, the Federation X Sevier cross showing a slightly larger coefficient. The coefficients are .283 and .313 respectively and the difference in this case as in the case of Tables 1 and 2 is so small that it also is not considered significant.

In order that the data obtained might be still more conclusive all the culms and their respective heads were measured on one thousand plants of the Dicklow X Sevier cross. In this study four thousand two hundred fourteen measurements were made. The data thus obtained gave a somewhat larger coefficient of correlation than was found in the preceding Tables. The results are shown in Table 5. The correlation coefficient is .343. The difference in this case is large enough to be significant and is probably due to the fact that individuals of greater extremes were studied as many of the plants possessed one or two short culms with correspondingly short heads that varied considerably from the normal length of culm and head.

The correlation data in the above mentioned Tables are significant; first, there is very little difference between the correlation coefficients; second, they all show a positive correlation; third, the material used for study viz, from the Dicklow X Sevier and Federation X Sevier crosses was raised on plats approximately two miles distant from each other and under different environmental conditions.

The soil on which the Dicklow X Sevier cross was grown is a silt loam, while that on which the Federation X Sevier cross was raised contains an appreciable amount of sand. The former plat received a normal amount of water during the growing season, while the latter suffered considerably from water

TABLE 5.

Correlation table of length of head and length of culm in population material from 1000 plants of Dicklow X Sevier cross.

Length of culm in Cm.

Length of head in Cm.	45-50	50-55	55-60	60-65	65-70	70-75	75-80	80-85	85-90	90-95	95-100	100-105	105-110	110-115	115-120	120-125	
3-5	1	6	16	32	66	115	186	225	200	164	111	51	10	2			1185
5-7	1	1	10	14	33	60	150	232	343	426	366	255	81	28	5		2005
7-9			3	3	8	21	37	59	89	85	61	46	16	6			434
9-11					3	4	16	41	55	96	100	99	50	29	4	1	498
11-13							2	3	9	10	26	24	15	3			92
	2	7	29	49	110	200	391	560	696	781	664	475	172	68	9	1	4214

$r = .343 \pm .009$

shortage and the plants, as a consequence, did not make completely normal growth.

As a matter of further investigation measurement data were obtained from three other crosses. Only a small number of plants were available from these crosses and consequently the results are not as significant as those in the preceding Tables. The results are shown in Tables 6, 7 and 8.

Table 8 you will notice indicates a negative correlation of .303. As only fifty-two plants were studied in this case the results cannot be considered at all conclusive. The writer is unable to explain however, why the results in this one case are in direct contrast to the results obtained in Tables 6 and 7 where the correlation coefficients are positive, being .360 and .501 respectively.

The coefficients of correlation in Tables 6 and 7 are considered rather high and not indicative of the true inter-relation of the characters studied. However, the study of a larger number of plants might reveal a larger correlation coefficient than that found in the Dicklow X Sevier cross.

The results obtained in the last three Tables also indicate that it is not safe to base any conclusions on correlation data obtained from the study of small numbers of individuals. It may often be possible to obtain by the study of a small number of individuals a correlation coefficient that is a correct indication of the correlation of the characters studied, but the chances of error are much greater than when a large number of individuals are used.

Again considering the results obtained in Tables 1 to 5 inclusive we find a consistent positive correlation existing between the two characters under investigation. Using East's (14) classification of correlation, because it seems the most workable, some investigators would interpret the results as being somatic or non-genetic in character. The correlations seem to indicate that head

TABLE 6.

Correlation table of average length of head and average length of culm on plants of New Zealand X Sevier cross.

Length of culm in Cm.

Length of head in Cm.	80-85	85-90	90-95	95-100	100-105	
3-5	7	27	23	5	2	64
5-7		4	4	2	10	20
7-9	1			1		2
9-11		7	3	13	4	27
	8	38	30	21	16	113

$r = .360 \pm .055$

TABLE 7.

Correlation table of average length of head and average length of culm on plants of Dicklow X Federation cross.

Length of culm in Cm.

Length of head in Cm.	65-70	70-75	75-80	80-85	85-90	90-95	95-100	100-105	
3-5			4	4	2		1		11
5-7		4	7	2					13
7-9	3	7	6	12	11	7	2	2	50
9-11				1	1	2	1	1	6
	3	11	17	19	14	9	4	3	80

$r = .501 \pm .056$

TABLE 8.

Correlation table of average length of head and average length of culm on plants of Dicklow X New Zealand X Hard Federation cross.

Length of culm in Cm.

Length of head in Cm.	75-78	78-81	81-84	84-87	87-90	90-93	
5	1	1		1		1	4
6	1			6	1	3	11
7	1	3	1	13	2		20
8	1	4		3			8
9	1	1	1	6			9
	5	9	2	29	3	4	52

$r = .303 \pm .084$

length and culm length in wheat conform equally to environmental conditions; in other words, when environmental conditions are favorable, i. e., when the soil is properly fertilized and in good tilth, and weather conditions have been favorable, a vigorous culm with a correspondingly vigorous head is produced, both conforming in length to the normal habit of the variety to which they belong; when environmental conditions are unfavorable we have produced a shorter than normal culm with a correspondingly short head.

The plants of the Dicklow X Sevier cross were grown under favorable environmental conditions while those of the Federation X Sevier cross suffered from lack of moisture. Nevertheless the correlation coefficients were very similar; in one case being exactly the same.

There is usually a fairly uniform reaction of plant parts to environmental conditions, but the amount or ratio of their reaction may be partially altered by changing a single environmental factor instead of all factors that effect the entire plant.

Since East (14) and others made their study and classification of correlations experiments by present day investigators have brought out many new ideas and solved many questions that the early plant breeders could not explain. East (14) possibly came nearest to the present day idea when he advanced the theory that there might be a temporary inheritance of the effects of environment, citing the adaptations of plants to permanent environmental changes, and as a concrete example, the Viola Stoneana which at the type-station in the woodland had leaves with much deeper and narrower lobes than it normally had elsewhere.

Our more recent investigators would probably class the correlations in Tables 1 to 5 as genetic because they have found that size characters are inherited

The results of this study seem to indicate that even though environmental conditions are in marked contrast to each other, plants produced under such conditions produce heads and culms that still maintain the same inter-relation. It seems therefore that there are characters within the plant which are inherited and which always preserve the size relationship of head and culm under whatever environment the plants are raised. This theory is no doubt a new one, but unpublished experiments together with future investigations will in all probability substantiate it.

Additional correlation studies were made to determine the relationship between length of head and strength of culm, and length of culm and strength of culm. Only a small number of individuals were available for study and consequently the correlation coefficients obtained as explained above, cannot be taken as conclusive. It is felt however, that the study of a larger number of individuals might change the correlation coefficients in degree rather than in kind, and that the results found in Tables 9 to 16 inclusive are a fairly dependable indication of the inter-relation of the characters considered.

Tables 9, 10, 11, and 12 show a fairly consistent negative correlation of -.862, -.509, -.735, and -.384 respectively, indicating that as length of head increases, strength of culm decreases. Here as in the comparison of Tables 1 to 5 with Tables 6 and 7, the tables obtained from the study of the smaller number of plants give a larger correlation coefficient, and as the number of plants studied is increased the coefficient becomes smaller. The coefficient in Table 12 probably indicates the normal relationship of length of head to strength of culm. The fact that material from a composite was used in Table 11 did not seem to change the consistency of the results. This is no doubt due to the fact that the parents do not differ widely in genetic constitution.

TABLE 9.

Correlation table of length of head and strength of culm in plants of Dicklow X Federation cross.

Strength of culm in percent

Length of head in Cm.	75	76	77	78	79	80	81	82	83	84	85	
3-5											12	12
5-7						2			8		2	12
7-9	2			6		27	1	5	1		8	50
9-11				1		4		1				6
	2			7		33	1	6	9		22	80

$r = .862 \pm .028$

TABLE 10.

Correlation table of length of head and strength of culm in plants of New Zealand X Sevier cross.

Strength of culm in percent

Length of head in Cm.	75	76	77	78	79	80	81	82	83	84	85	
3-5						15		11	7	1	30	64
5-7						3		3	1		13	20
7-9	2											2
9-11	15		5	5		2						27
	17		5	5		20		14	8	1	43	113

$r = .509 \pm .07$

TABLE 11.

Correlation table of length of head and strength of culm in plants of Dicklow X New Zealand X Hard Federation cross.

Strength of culm.

Length of head.	74-76	76-78	78-80	80-82	82-84	84-86	
5-7		1		7	6	1	15
7-9	3	4	8	12			27
9-11	5	4		1			10
	8	9	8	20	6	1	52

$r = .735 \pm .043$

TABLE 12.

Correlation table of length of head and strength of culm in plants of

Dicklow X Sevier cross.

Strength of culm in percent.

Length of head in Cm.	60-65	65-70	70-75	75-80	80-85	85-90	90-95	
3-5				4	13	40	1	58
5-7				4	10	38		52
7-9	2	1		12	34	13		62
9-11				20	7	2		29
11-13				2				2
	2	1		42	64	93	1	203

$r = .384 \pm .059$

TABLE 13.

Correlation table of length of culm and strength of culm in plants of

Dicklow X Sevier cross.

Strength of culm in percent.

Length of culm in Cm.	59-61	61-63	63-65	65-67	67-69	69-71	71-73	73-75	75-77	77-79	79-81	81-83	83-85	85-87	87-89	89-91	
70-75											2						2
75-80									1		4			5			10
80-85									1		4			12			17
85-90									3	1	11			19			34
90-95									15		17	1		32			65
95-100									6	2	13			20			41
100-105	2		1						14		10		1	4	1	1	34
	2		1						40	3	61	1	1	92	1	1	203

$r = .197 \pm .045$

TABLE 14.

Correlation table of length of culm and strength of culm in plants of Dicklow X Federation cross.

Strength of culm in percent.

Length of culm in Cm.	75	76	77	78	79	80	81	82	83	84	85	
65-70						4						4
70-75						5		3				8
75-80				1		5		1	7		6	20
80-85						6	1	1			8	16
85-90						8			1		5	14
90-95				5		5						10
95-100	1							1			2	4
100-105				1		3						4
	1			7		36	1	6	8		21	80

$r = .05 \pm .075$

TABLE 15.

Correlation table of length of culm and strength of culm in plants of Dicklow X New Zealand X Hard Federation cross.

Height of culm in Cm.	Strength of culm in percent. 74-76	76-78	78-80	80-82	82-84	84-86	
75-78				4	1		5
78-81	2	3	1	2	1		9
81-84	1			1			2
84-87	5	4	6	11	3		29
87-90			1	1	1		3
90-93		1		1	1	1	4
	8	8	8	20	7	1	52

$$r = .086 \pm .092$$

TABLE 16.

Correlation table of length of culm and strength of culm in plants of New Zealand X Sevier cross.

Strength of culm in percent

Length of culm in Cm.	75	76	77	78	79	80	81	82	83	84	85	
80-85	1					2		2			3	8
85-90	3		5			10		6	6	1	8	39
90-95	1			2		6		6	2		12	29
95-100	11			3							7	21
100-105	2					2					12	16
	18		5	5		20		14	8	1	42	113

$r = .064 \pm .063$

TABLE 17.

Table showing probability of occurrence of correlations as designated, in 100 trials.

Table	r	P.E.	r/PE	odds in favor of
1	.283	.013	21.76	∞
2	.297	.016	18.56	∞
3	.313	.013	24.07	∞
4	.297	.013	22.84	∞
5	.343	.009	38.11	∞
6	.360	.055	6.54	19,230.00 : 1
7	.501	.056	8.94	1,470,588,234.00 : 1
8	.303	.084	3.60	64.79 : 1
9	.862	.028	30.78	∞ : 1
10	.509	.070	7.27	434,782.00 : 1
11	.735	.043	17.09	∞ : 1
12	.384	.059	6.50	19,230.00 : 1
13	.197	.045	4.37	332,33 : 1
14	.050	.075	.66	less than 1
15	.086	.092	.93	less than 1
16	.064	.063	1.01	1 : 1

Tables 13, 14, 15, and 16 show correlation coefficients of negative .197, .05, and positive .086, and .064 respectively. These figures are not large enough to be significant; neither are they consistent and though only small numbers of individuals were used in obtaining the data considered, it is believed we are safe in concluding that no correlation exists between length of culm and strength of culm.

Table 17 shows the probable occurrence of correlations as designated in 100 trials. It indicates in all cases, with the exception of those shown in Tables 14, 15, and 16 that the odds are greatly in favor of the occurrence of the correlation as obtained in each case. Where the coefficient of correlation is not at least four times as great as its probable error it is of little significance.

V. - SUMMARY.

As very little experimental work has been done in the investigation of correlations in crop plants, and as the published data are conflicting in nature, this study was undertaken for the purpose of determining if possible, the relationship, and the nature of that relationship, if it exists, between certain characters in wheat.

The placement of the material in the correlation tables is shown and a brief explanation is given of the manner in which the coefficient of correlation is obtained.

The data presented in this study indicate the following:

1. That a consistent positive correlation exists between length of head and length of culm.

2. That the consistency of the correlation coefficients, even though different crosses were used, grown under different environmental conditions, seems to indicate that these correlations are genetic in character.

3. That a negative correlation exists between length of head and strength of culm which implies that as length of head increases, strength of culm decreases

4. That no correlation exists between length of culm and strength of culm.

5. That correlation data are more dependable and there is less danger of error when large numbers of individuals are studied.

6. That crosses that do not differ widely in genetic constitution may be used together in a correlation table without effecting materially the coefficient of correlation.

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