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The Inheritance of Rachilla Length and its Relation to Other Characters in a Cross Between Avena Sativa and Avena Sativa Orientalis

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(Technical)

By

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Fig. 1.—Grain types of the parental varieties. Garton 784 on left and Early Gothland on right.

The Inheritance of Rachilla Length and Its Relation to Other Characters in a Cross Between Avena Sativa and Avena Sativa Orientalis

The inheritance of quantitative characters such as yield, size of nt, and others of like nature has been much less extensively studied n the inheritance of qualitative characters. The reason is found gely in the fact that they are usually much less easily analyzed and en present rather complex problems. Quantitative characters are en so influenced by environmental conditions that genetic differ- es are obscured. A number of workers have, however, demon- ted that the inheritance of size characters may be explained on a torial basis similar to that of the inheritance of qualitative char- ers. Sax *(16)*, Lindstrom *(9)* and others have pointed out the irability of attempting to correlate size characters with easily rec- nized qualitative characters and thus facilitate the analysis of the mer in any inheritance study.

A quantitative character that is relatively stable under varying vironmental conditions is obviously very desirable for making a dy of the nature of size inheritance. In the present study the size racter chosen, length of rachilla in oats, seemed to offer an excep- nally stable character and one that could be studied in relation to a nber of definite qualitative characters.

REVIEW OF LITERATURE

East *(2)* made a study of the inheritance of corolla length in a acco cross. This study is taken as typical of many size inheritance dies made by East. In this tobacco cross the corolla length in the generation was intermediate between the two parents and was only htly more variable than the more variable parent. The F_2 genera- n ranged between the two parents and had a much greater varia- ty than either the parents or the F_1 generation. In the F_3 and ceeding generations families were recovered with various lengths corolla. Some of these families showed a variability no greater n that of the parents, while others were more like the F_2 in this pect. The data indicate that the inheritance of this character can

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Acknowledgement is due to Dr. H. H. Love, of Cornell University, for his helpful ction and guidance during the course of this investigation, and to Dr. R. J. Garber, of t Virginia University, who contributed many valuable suggestions with respect to out- g the problem and handling the data.

be explained on a multiple factor basis. In this paper East outli certain requirements which, if met in a size inheritance study, tend indicate that the results may be explained on a factorial basis.

Quisenberry *(15)* in a study of the inheritance of length of gr in an oat cross found the F_1 to have grains intermediate in length wh the F_2 ranged from one parent to the other. In 150 F_3 families, t were recovered with a mean length as short as the short parent a four with a length as great as the long parent. Between the extren were lines that apparently bred true for intermediate lengths. T results were explained on the basis that the parents differed by least three main factors or groups of factors for grain length.

Garber and Quisenberry *(6)* studied the inheritance of date heading, leaf width, number of culms, and color of seed in anot oat cross. Earliness was found to be inherited as a dominant charac with evidence of a two factor difference. Leaf width was found to a variable character. One F_3 family was recovered with a leaf wi less than the narrow-leaved parent. The data indicated that this ch acter was controlled by multiple factors. The number of culms v also found to be greatly influenced by environment, but the data dicated that it was an inherited character. Seed color was found be due to a single factor difference. No evidence of linkage v found between any of the characters studied.

Noll *(14)*, in a study of the inheritance of earliness in crosses tween early and late varieties of oats, found the F_1 generation to as early or earlier than the early parent. The F_2 ranged beyond extremes of both parents. Homozygous races were obtained in F_3 a F_4 which covered the same range as the F_2. Earliness was apparen due to a series of dominant factors, which together had a cumulat effect. The data, the author states, indicate but do not prove c clusively that the factors had the same effect.

Caporn *(1)* crossed an early with a late variety of oats. T lines out of 106 F_3 families were found to be as early as the ea parent but no lines were recovered that were as late as the late pare The author explains the results obtained on a three factor basis. L ripening was found to be closely associated with the amount tillering.

Nilsson-Ehle *(12)* made a study of various size characters. Th studies have been reviewed by Hayes and Garber *(8)*. Transgress segregation was found in oat crosses involving differences in heig leaf width, kernel size, and number of florets per spikelet. The sults were explained on a multiple factor hypothesis. Nilsson-Ehle a obtained transgressive segregation for date of maturity in certain oat crosses. Homozygous forms were obtained in the F_3 progenies which were earlier than the early parent and also some that were later than the late parent.

The linkage of size factors with certain qualitative characters have been noted by several workers. Tedin and Tedin *(18)* crossed a two-rowed hulled with a six-rowed hull-less barley. The two-rowed barley was about ten centimeters higher than the other variety. The inheritance of type of spike and of the hull condition was explained on single factor differences which were independent of each other. Evidence for linkage between the factor for two-rowedness and a factor for plant height was found. The authors state that evidence was also found that heterozygosity in the factor for two-rowedness had a marked "stimulating" effect upon height of plant.

Sax *(16)* studied the relation between size of seed and pigmentation of seed in beans. A linkage was found between factors, or groups of factors, for seed weight and factors for pigmentation and pattern of the seed coat.

Lindstrom *(9)* in a study of inheritance of size of tomatoes found that a factor for size of fruit was linked with a factor for skin color.

Griffe *(7)* using barley, studied the relation of resistance to *Helminthosporium sativum* and certain morphological characters. He concluded that resistance to this disease was controlled by at least three factors or groups of factors apparently linked with the factors determining the character pairs: six-rowed versus two-rowed; black versus white glumes, and rough versus smooth awn. The linkage was not complete as resistance or susceptibility could be combined with any desired morphological character.

MATERIALS AND METHODS

The object of the study reported in this bulletin was to attempt to determine the mode of inheritance of a definite size character, length of rachilla in oats, and its relation to certain other qualitative characters. The material for this study was obtained by making a cross between Early Gothland *(Avena sativa)* and Garton 784 *(Avena sativa orientalis)*.

The Early Gothland parent has a pubescent rachilla approximately 2.7 millimeters long on its lower grain (Fig. 1), while in the Garton 784 parent the rachilla is extremely short, being only approximately 1.6 millimeters long. It is free from pubescence except for an occasional hair.

Early Gothland is a white grained variety, has an open type panicle (Fig. 2), and has a leaf with a very prominent ligule. Garton 784 parent has black colored grains, has a side type of pani and has no ligule at the juncture of the leaf blade and the leaf she The parental material used all descended from a single panicle of e variety selected from pure line material grown in the Plant Breed Nursery at Morgantown, West Virginia, in 1921. The recipro crosses were made in 1922.

Figure 2.—Panicle types of the parental varieties. Early Gothland on left and G 784 on right.

An F_1 generation was grown in the greenhouse during the winter 22-23. The plants were late in maturing so that only enough ds were secured to grow an F_2 population of 290 plants in 1923. few additional F_1 plants and also parental material were grown h the F_2 generation in the field. Larger F_2 populations were grown 1924 and 1925. A few F_1 plants and also parental material were wn with these each year. In 1925 F_3 families were grown from a nber of the F_2 plants.

All material in this study was grown in rows five feet long and ced one foot apart. Twenty seeds were planted per row. At the of each row and set off by a small stake, three seeds of Victory s were planted in order to eliminate border effect as far as possible. se plants were pulled and discarded before any of the plants under ly were harvested. When it was necessary to plant only a part of ow of the material under study on account of lack of seed, the ainder of the row was planted to Victory and the plants discarded he same manner as the border plants.

The F_3 families from which it was planned to get rachilla measnents were all planted in five-row plots except in a few instances re there was not enough seed. Rachilla measurements were made 60 such F_3 families. In addition to these, 75 families consisting of y one row each were grown in order to get additional data on the tion of the ligule and panicle type. The five-row F_3 families were from F_2 plants grown in 1924 while the single row families were n both the 1923 and 1924 F_2 plants. The parental material in 5 was grown in 18 three-row plots distributed among the F_2 and F_3 families. Both parents appeared at distances of from 23 to 36 s apart. The average distance apart of the parental material was rows.

A plot of each variety was also grown on rich and poor soil in 3 for the purpose of studying the influence of the productivity of soil on the length of the rachilla.

The rachilla measurements were made by means of a pair of portional dividers (Fig. 3) using a ratio of 10 to 1 and reading measurements on a millimeter scale. The units in which the measnents are reported are in terms of .1 millimeters. A mounted readglass was used to facilitate making the readings obtained with the ders.

The classification of the panicle type and the ligule note were e in the field before the plants were harvsted. The classifications color of grain and for rachilla pubescence were made at the time the rachilla was measured.

DETERMINATION OF SIZE OF SAMPLE

Before proceeding with the measuring of the F_2 material it w necessary to make measurements of the rachillas of the parental r terial in order to determine how many grains would be necessary a dependable sample from each plant. Preliminary measureme made in 1922 had shown that the length of rachilla did not v significantly on grains taken from the base to tip on the same pani nor on grains from different panicles of the same plant. The lead panicle was therefore chosen to represent each plant measured. T grains selected from this panicle were taken in a systematic order fr the tip to the base of the panicle..

The preliminary measurements also indicated that the sh rachilla parent was probably the more variable as measured by coefficient of variability. This parent was therefore chosen for mak a determination on the size of sample required to represent a pla For this study 15 grains were taken in systematic order from tip base of the leading panicle from 100 Garton 784 plants grown in 19 Samples consisting of three, five, and eight grains from each pan were then made up from the original 15-grain samples. Freque distributions were then made of the means as secured by these differ samples. The statistical constants obtained are shown in Table 1.

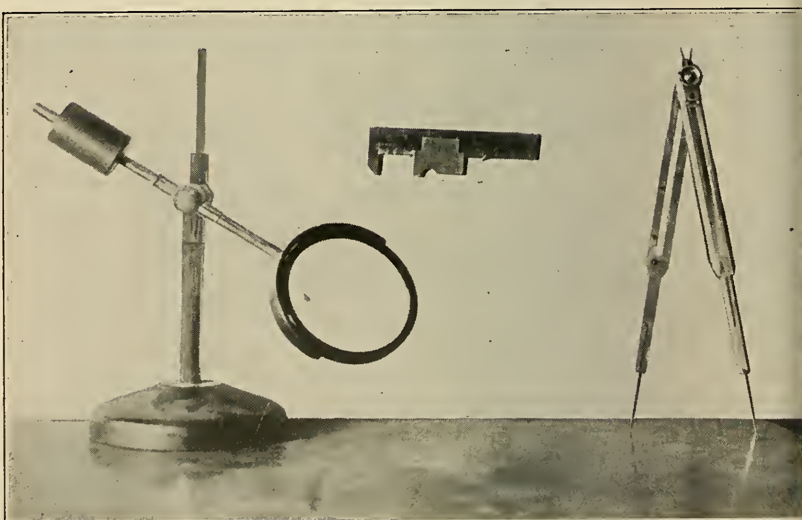

Fig. 3.—Equipment used in making rachilla measurements.

BLE 1.—Statistical constants for length of rachilla for samples of 3, 5, 8, and 15 grains obtained from 100 plants of the Garton 784 parent grown in 1923.

Grains in Sample	Number of Samples	Means in .1 mm. Units	Standard Deviation	Coefficient of Variability	E_S
3	100	16.570±0.070	1.042±0.050	6.29±0.30	0.703
5	100	16.630±0.065	0.966±0.046	5.81±0.28	0.652
8	100	16.570±0.057	0.852±0.040	5.14±0.24	0.575
15	100	16.510±0.054	0.806±0.038	4.88±0.23	0.544

The data of Table 1 show that there is no significant difference he means for length of rachilla, whether three, five, eight, or fif- grains were selected as a representative sample. The standard iation and the coefficient of variability are reduced as the size of ple is increased. It was decided to use a sample of five grains n each plant as a representative sample for determining the length achilla.

DETERMINING THE SIZE OF F_3 FAMILIES

The question also arose as to how many plants it would be nec- ry to grow in order to obtain a dependable estimate of the breed- behavior for the length of rachilla in any particular family in the nd later generations. This question was of considerable import- e in this study on account of the amount of time it required to e the measurements.

For this study the F_2 population grown in 1923 was used. The F_2 plants were first divided into 10 samples of 29 plants each by cting plants 1, 29, 58, and so on, for sample number one, plants 0, 59, and so on, for sample number two, and proceeding in the e way for the other eight samples. In a similar way six samples 8 plants each, five samples of 58 plants, and three samples of 96 ts were made up. Statistical constants were then calculated for of these samples. These constants are given in Table 19 of the endix. In Table 2 a summary is given of the results obtained.

Since the coefficient of variability is the constant which is fre- ntly used to determine if any F_3 family is homozygous for any n set of size factors, a comparison of this constant in the various ples will give an indication of the number of individuals which

TABLE 2.—Range in means and in coefficients of variability for lengt rachilla when samples of 29, 48, 58, and 96 plants were taken fron F_2 generation grown in 1923.

Number of F_2 Plants in Sample	Number of Samples	Range in Means		Range in Coefficients of Varia	
		High	Low	High	Low
29	10	22.172±0.289	21.207±0.295	12.29±1.10	8.00±
48	6	21.917±0.214	20.937±0.215	11.27±0.79	8.91±
58	5	21.690±0.211	21.362±0.174	11.24±0.71	9.19±
96	3	21.875±0.161	21.000±0.142	10.66±0.53	9.48±
290	1	21.652±0.083		9.65±0.27	

will be required to give a trustworthy sample of the F_2 generat Since no F_3 families with a variability greater than that of the F_2 ordinarily expected in any cross of this kind involving size fact any sample that is found satisfactory as a representative of the population should be large enough to be taken as a trustworthy san of any of the F_3 and later progenies grown.

Table 2 shows the coefficient of variability ranges from 8.0 0.71 to 12.29±1.10 when samples of only 29 individuals were ta The wide range in this constant indicates that this would not b sample large enough to fairly represent the entire F_2 populat When 48 plants were used the coefficient ranges from 8.91±0.6 11.27±0.79. The coefficient of variability for the entire popula is 9.65±0.27. As the number of individuals in the samples is creased to 58 and 96 respectively the range between the high and coefficients becomes less. From these data it would seem that a 50 individuals in the F_3 families could be accepted as being a tr worthy sample. On account of the other characters studied in nection with the size character it was decided to plant 100 seeds each F_3 family where enough seed was available but to measure a random sample of 50 plants taken from each family.

EFFECT OF SOIL PRODUCTIVITY ON LENGTH OF RACHIL

In order to study the effect of the productivity of the soil on length of rachilla a plot of each parent was planted on both rich poor soil. The rich soil plots were located on land that had at time been used for gardening purposes and which had received he applications of fertilizers and manure. The plots located on the p l were located on a ridge where the soil was in a very low state of oductivity. The plots consisted of 15 five-foot rows each.

The heights of all plants were taken before harvest. Each plant s harvested and threshed separately. The grains for measuring re removed from the leading panicle before threshing. One hund plants taken in order from each plot were used for rachilla gth determinations. In tabulating the data obtained, only the lds and heights from the plants on which rachilla measurements re made have been used. A summary of the results obtained is en in Table 3.

BLE 3.—Means for length of rachilla, yield, and height of individual plants of Early Gothland and Garton 784 parents grown on rich and poor soil in 1923.

Parent	Number of Plants	Kind of Soil	Average Length of Rachilla in .1 mm. Units	Average Yield in Grams	Height in Centimeters
E·ly Gothland	100	Rich	27.720±0.067	6.95±0.25	114.70±0.55
E·ly Gothland	100	Poor	25.850±0.076	2.69±0.10	76.05±0.52
Crton 784	100	Rich	16.710±0.055	6.32±0.21	105.15±0.62
Crton 784	100	Poor	16.120±0.053	3.87±0.14	80.35±0.49

It is clearly evident from the results shown in Table 3 that there was a considerable difference in the productivity of the soil between t two plots both as measured by yield and by the height of the pnts. The difference between the two plots of Garton 784 was ratively less in both instances than between the plots of Early Gothled.

It is also evident that the productivity of the soil has influenced t length of rachilla in both parents. In the Early Gothland parent t difference between the length of rachilla in the rich and poor soil p ts amounts to 1.870±0.101 units and in Garton 784 it is 0.590± 0·76 units. Even with soil differences as extreme as these were, the d erences in rachilla length were not large. Evidently this character is very stable and only relatively little influenced by soil differences.

INHERITANCE OF LENGTH OF RACHILLA

The mode or inheritance of length of rachilla was studied by making measurements of the hybrid material as described previously, computing statistical constants, and analyzing the data from a biometrical standpoint. In this cross no significant difference was fo between the reciprocal crosses in the inheritance of length of rach or in any of the other characters studied. In the tabulations and ot data presented the two crosses are, therefore, combined.

A summary of the results obtained in the three years for m urements of the parental material, the F_1 plants, and the F_2 populati is given in Table 4. The data show that the length of rachilla va only slightly in the different years both in the parents and in the populations. The means for the Early Gothland parent were 27.51 0.060, 26.608±0.054, and 26.885±0.019 units for the three y 1923, 1924, and 1925, respectively. Between the years 1923 1924 there was a difference of 0.904±0.081. This is a relativ small difference but significant in the light of its probable error. difference between the means of this parent for 1924 and 1925 0.277±0.057. The difference is about five times its probable e and indicates that there was less difference in seasonal influences tween 1924 and 1925 than between 1923 and 1924. When means for the years 1923 and 1925 are compared there is found to a difference of 0.629±0.063. This difference may also be conside as significant.

The coefficients of variability for this parent were 5.52±0. 5.69±0.14, and 3.18±0.05 for the three years, respectively. I obvious that there was no difference in variability in this parent measured by the coefficient of variability between the years 1923 1924. The difference in this constant, however, between the t years 1923 and 1925, 2.34±0.16, shows that this parent was variable in 1925 than in the other two years. As will be shown la this was also true of the Garton 784 parent.

The means for the Garton 784 parent were 16.731±0.0 16.119±0.034, and 16.210±0.016 for the three years, respectiv The difference in means for the years 1923 and 1924 was 0.61 0.052 units. This is not a large difference, but is significant in light of its probable error. The difference in means for this par between the years 1924 and 1925 was 0.091±0.037, a differe less than three times its probable error and, therefore, not conside significant. The difference in means for the years 1923 and 19 was 0.521±0.043, which may be considered as a significant differen

The coefficients of variability for this parent for the three ye were 5.89±0.17, 5.38±0.15, and 4.37±0.07, respectively. Betw the years 1923 and 1924 there was a difference of 0.51±0.23. T difference is not significant in the light of its probable error a

TABLE 4.—Statistical constants for length or rachilla of the parents, F_1 and F_2 of the cross Early Gothland by Garton 784 and re-
:iprocal.

Material or Generation	Year	Classes for Length of Rachilla in Units of .1 mm.																				Total No.	Means	Standard Deviation	Coefficient of Variability
		14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33				
E. G.	1923											4	15	61	72	74	42	16	8	2	1	295	27.512±0.060	1.518±0.042	5.52±0.15
E. G.	1924										6	19	58	88	82	61	32	3	2	1		352	26.608±0.054	1.513±0.038	5.69±0.14
E. G.	1925												45	223	422	173	18	1				882	26.885±0.019	0.855±0.014	3.18±0.05
G. 784	1923		14	114	88	36	14	2														268	16.731±0.040	0.986±0.029	5.89±0.17
G. 784	1924	1	67	152	63	16	2	1														302	16.119±0.034	0.868±0.024	5.38±0.15
G. 784	1925	1	117	497	253	24	2															894	16.210±0.016	0.708±0.011	4.37±0.07
F_1	1923						1	4	2													7	20.143		
F_1	1924							2	5	1	1											9	21.111		
F_1	1925						1	3	2	1												7	20.429		
F_2	1923			2	3	16	25	49	62	42	35	27	18	6	4	0	0	1				290	21.548±0.087	2.191±0.061	10.17±0.29
F_2	1924			4	12	32	71	86	99	92	54	43	24	8	3	1						529	21.185±0.062	2.116±0.044	9.99±0.21
F_2	1925			2	7	19	57	97	93	87	47	16	8	0	3							436	20.938±0.056	1.734±0.040	8.28±0.19

therefore, this parent is like the Early Gothland in that there was difference in variability in the first two years of the experiment. tween the years 1924 and 1925 there was a difference of $1.01 \pm 0.$ which is significant. The difference for this constant between years 1923 and 1925 was 1.52 ± 0.18, which may also be conside as an actual difference. Like the Early Gothland parent the Gar 784 parent showed less variability in 1925 than in the other years.

By means of the coefficient of variability the variability of two parents may be compared directly. These constants did differ significantly between the two parents in 1923 and 1924 bu 1925 there was a difference of 1.19 ± 0.09. This shows that in latter year the Early Gothland parent was less variable than the o parent.

The means for the F_2 populations were 21.548 ± 0.087, 21.18 0.062, and 20.938 ± 0.056 units for the three years 1923, 1924, 1925, respectively. The difference in means between the years 1 and 1924 was 0.363 ± 0.107 and between the years 1923 and 1 it was 0.610 ± 0.103. The difference is approximately three time probable error in the former case and six times its probable erro the latter case and, therefore, both are considered significant. difference in means between the years 1924 and 1925 was 0.24 0.084, a difference which is a little less than three times its prob error. The F_2 population, therefore, is like the parents in that mean length of rachilla in the years 1924 and 1925 was slightly than in 1923.

An examination of Table 4 shows that in variability, as measu by the coefficient of variability, there was no difference in the generation for the character under study between the years 1923 1924. Between the years 1924 and 1925 there was a differenc 1.71 ± 0.28, which is significant. In respect to variability, theref the F_2 showed less range in 1925 than in the previous years and similar to the parents in this respect.

In all three years the F_1 plants showed a rachilla length w was approximately intermediate between the parents. The F_2 po lation ranged between the two parents although in no year were pl obtained with rachillas reaching the extremes of the parents.

The variation in length of rachilla from parent to parent in F_2, with the mean of the population approximately midway betw them and also a gradual falling off in numbers in the classes from mid point to the two extremes, suggests that the inheritance of length of rachilla can probably be best explained on a multiple fa basis.

If the factors concerned in the inheritance of this character were equal value and had a cumulative effect, a normal frequency curve ould be expected in plotting any F_2 distribution. As may be seen om Table 4, the type of curve obtained in plotting the F_2 distributions otained in any year shows a considerable variation from a normal equency curve. Skew curves such as the ones obtained suggest that e factors involved are either of unequal value in determining the ngth of rachilla or are modified by factors of unequal value.

REEDING BEHAVIOR OF F_3 PROGENIES FOR LENGTH OF RACHILLA

Sixty-one F_2 plants from the 1924 F_2 generation were grown i F_3 families in order to test their breeding behavior for the inherit-ce of the length of rachilla. One of these families, 18-2-48 row 290, oduced only seven plants. No measurements were made on these ants due to the lack of sufficient numbers. In subsequent tables this mily is left out of consideration thus leaving 60 families on which easurements for length of rachilla were obtained. The F_2 plant om which this family was grown was continued in F_3, even if there ere only a few seeds available because it seemed to be a False Wild t plant. This proved to be the case as shown by its behavior in te F_3.

In four other F_3 families, 18-4-77, 18-5-31, 19-1-65, and 19-4-27 te number of plants matured were 45, 43, 38, and 15, respectively. ie small number of plants in these families was due to lack of seed. I all other cases 50 plants were used for making length of rachilla eterminations. The data obtained in measuring the length of rachilla c the F_3 families and of the parental material grown with these are sown in tables 20, 21, and 22 of the appendix.

In choosing the F_2 plants for continuing in the F_3, a number from ech class for length of rachilla were chosen. The number from each c.ss was approximately in proportion to the total number in that c.ss in the entire F_2 population, except that nearly all the plants in t: extreme classes were included. The plants were also chosen so tat they would afford a test for the breeding hehavior of the other caracters studied.

A comparison of the distribution of the entire F_2 population and c the F_2 plants selected for continuing in the F_3 is shown in Table 5.

A distribution was obtained which represented the F_2 population frly well, except for the extreme classes where proportionally more pnts were included than in the intermediate classes. If the inherit-ace of length of rachilla is explained on a multiple factor basis, it

TABLE 5.—Comparison of the total number of F_2 plants, grown in 1924, various classes for length of rachilla and the number from each class co tinued in F_3 progenies.

Plant Designations	Classes for Length of Rachilla in Units of .1 mm.						
	15-16	17-18	19-20	21-22	23-24	25-26	27-28
Total No. F_2 plants . .	4	44	157	191	97	32	4
F_2 plants tested in F_3	4	6	12	19	9	7	3

would be expected that there would be a greater probability of th extremes breeding true for a certain length of rachilla than any of th intermediate classes. For this reason more of the extreme classes wer included.

CORRELATION BETWEEN F_2 PLANTS AND THEIR F_3 PROGENIES

In order to determine to what degree the length of rachilla inherited, a correlation coefficient was calculated for the means of th F_2 plants continued in the F_3 and the means of these F_3 families. Th distributions are shown in Figure 4.

Length of Rachilla in F_2	Mean Length of Rachilla in F_3										Tot
	17	18	19	20	21	22	23	24	25	26	
16	2	2									4
17		1	2								3
18		2	1								3
19		2	1	1	2						6
20				1	4	1					6
21				5	3	1	1				10
22				1	4	4					9
23						2	1	1			4
24						4	1				5
25						1		2			3
26							1	1	1	1	4
27						1		1			2
28										1	1
Total	2	7	4	8	13	14	4	5	1	2	60

$$r = 0.886 \pm 0.019$$

Fig. 4.—Correlation between average length of rachilla in F_2 plants and the mea length of rachilla in their F_3 progenies.

The coefficient obtained, $r = 0.886 \pm 0.019$, indicates that length f rachilla is an exceptionally stable size character, and that the F_2 ives a good indication of what may be expected in the F_3 progeny rom any plant.

VARIABILITY IN F_3 PROGENIES

The coefficient of variability was used as a criterion for deter-iining which F_3 families were breeding true for certain rachilla lengths nd which appeared to be heterozygous for the factors determining ıis character.

The coefficients of variability ranged from 2.55 ± 0.18 to $3.61 \pm$ .24 for the various plots of the Early Gothland parent grown in 1925 Table 20). In the Garton 784 parent this constant varied from 26±0.22 to 5.01±0.34 (Table 21). For the F_2 grown this year ıe coefficient is 8.28±0.19 (Table 4). Omitting family 19-5-13, hich segregated for false wild oats and is therefore not considered this comparison, the F_3 progenies varied from 4.06 ± 0.27 to $9.09 \pm$ 61 (Table 22). In Table 6 a frequency distribution has been made the coefficients of variability and of mean length of rachilla for the fferent F_3 families.

ᐠBLE 6.—Variability in length of rachilla in the F_3 progenies grouped by classes for length of rachilla.

ɩan Length Rachilla units of .1 mm.	Classes for Coefficient of Variability of the F_3 Progenies											Total No.
	4.0	4.5	5.0	5.5	6.0	6.5	7.0	7.5	8.0	8.5	9.0	
17	1			1								2
18								2	1	1	3	7
19				1				1	1		1	4
20				1	2		1	1	2	1		8
21			3	1		1	1	3	2	1	1	13
22	1			3	5	1	1		2			13
23				1	2	1						4
24			1	1	1	1		1				5
25		1										1
26		1		1								2
otals	2	2	4	10	10	4	3	8	8	3	5	59

If the highest coefficient for the parental material (5.01 ± 0.34 is taken as marking the upper limit of variability expected in line homozygous for a certain length of rachilla, we find there is one famil breeding true for a rachilla length of 17, three for 21, one for 22, on for 24, one for 25, and one for 26. Apparently one family has bee recovered breeding true for approximately the same length of rachill as the Garton 784 parent and also one with a rachilla approximatel as long as the Early Gothland parent. Between these extremes ther are on this basis six other families breeding true for intermediat lengths. If a three factor difference with all factors of equal value b assumed, it would be expected to recover one family breeding true fo each extreme and six intermediate homozygous families in a rando sample of 64 individuals. The distribution of the homozygous fan ilies among the various intermediate classes for length of rachilla not in very close agreement with what would be expected on such three factor basis. The F_3 breeding behavior supports the theory th the inheritance of length of rachilla may be put on a multiple fact basis, and also that the factors concerned are either not of equal val or are modified by factors of unequal value.

INHERITANCE OF OTHER CHARACTERS

The inheritance of ligule, panicle type, color, and rachilla pub scence was studied both independently and in their interrelation each other and to the length of rachilla.

Inheritance of Ligule

The Early Gothland parent in this cross had a leaf with a promi ent ligule at the juncture of the leaf blade with the leaf sheath, whi the Garton 784 parent was without a ligule. The ligule is ordinari a very easy character to classify in inheritance. Occasionally, ho ever, a plant is found where the ligule is so poorly developed that resembles a liguleless plant. In the 60 F_2 plants continued in F_3 o plant should have been classed as liguled that was classed as ligulele and one plant where the opposite was the case (Table 23). The plants were all liguled indicating that the liguleless character is r cessive.

Table 7 presents the results obtained with this character in t F_2 population.

The results obtained are practically identical with the calculat ratio when it is assumed that the inheritance of this character is due two independently inherited duplicate factors. Love and Craig (1 found that inheritance of ligule was due to a one factor difference

[T]ABLE 7.—Inheritance of ligule in the F_2 generation.

Year	No. of F_2 Plants		Deviation	Probable Error	Dev./P. E.
	Liguled	Liguleless			
1923	270	20			
1924	495	34			
1925	411	25			
[O]bserved total	1176	79			
[C]alculated 15:1 ratio	1176.6	78.4	0.6	5.81	0.10

[s]ome varieties of oats and two in others. Garber *(5)* found a two [fa]ctor difference for the inheritance of this character. Nilsson-Ehle *[(]13)* found that this character segregated in a monohybrid ratio in [o]ne cross while in others its inheritance could be explained on the [b]asis of a two or three factor difference.

In all the different F_2 populations grown it was found that the [li]guleless condition was very closely associated with the side type of [p]anicle. On account of this relationship between these two characters [it] is necessary to take both into consideration in analyzing the data [fo]r either one in the F_3.

If the liguled condition is dependent upon a two factor difference [a]s the F_2 generation indicates, it would be expected that all liguleless [F]$_2$ plants would breed true in the F_3 generation while some of the [li]guled forms would breed true for this condition and others segregate. [In] one-half of the segregating lines a 15 to 1 ratio would be expected [an]d in the others a monohybrid ratio.

With the one exception previously mentioned all liguleless F_2 [pl]ants continued in the F_3 bred true for this condition. Evidently this [pl]ant should have been classed as liguled. The breeding behavior of [th]e F_2 plants in the F_3 progenies for the various characters studied is [gi]ven in Table 23 of the appendix.

Inheritance of Panicle Type

The Early Gothland parent has an open, spreading panicle while [M]arton 784 is characterized by a side or "horsemane" type of panicle. [Th]e F_1 plants were all intermediate. There seemed to be considerable [va]riation in the expression of this character, some of the F_1 plants [re]sembling the open type more than the side type while in others the [re]verse was true. The expression of this character appears to be in[flu]enced considerably by the environmental conditions and by the [st]age of maturity of the plants.

The inheritance of panicle type was apparently closely associate with or influenced by the factors producing the liguleless conditio No open liguleless forms were found among any of the F_2 populatio grown. This relation suggests that there either is a very close linkag between one of the factors for ligule and the factor or factors f panicle type or that the absence of both of the factors for the ligule condition prevents the factor or factors for open panicle from fun tioning. Since no open liguleless plants were found among the 125 F_2 plants grown, it was assumed that the latter was the case. On th assumed basis that the liguled condition is dependent on independen ly inherited duplicate factors and the open panicle type depends on single factor difference independent of the two factors for ligule, bu inhibited from functioning by the absence of both of the factors f ligule, it would be expected to obtain in F_2 a proportion of 45:15:4 open panicled liguled plants, side panicled liguled, and side panicle liguleless plants, respectively, or a proportion of 45 open to 19 sid panicled plants. The results obtained and the calculated numbe are presented in Table 8.

TABLE 8.—Inheritance of panicle type in the F_2 generation.

Year	No. of F_2 Plants		Deviation	Probable Error	Dev. / P. E.
	Open Panicle	Side Panicle			
1923	191	99			
1924	380	149			
1925	280	156			
Observed total	851	404			
Calculated 45:19 ratio	882.4	372.6	31.4	10.92	2.88

The agreement of the observed with the calculated is fairly goo the difference being 2.88 times its probable error. In one out of 1 chances a deviation as large as this might be expected from rando sampling and, therefore, the hypothesis appears plausible. The population grown in 1924 agrees much better with the theoretic than do those grown in either of the other two years, the deviation b ing only a little more than its probable error. The F_3 breeding b havior of the F_2 plants grown in 1924 shows that the classification f panicle type was relatively free from errors. One plant was evident classed as side which should have been classed as open while in a other case the reverse was true.

The breeding behavior of the F_2 plants grown in 1923 when sted in F_3 progenies shows that two plants classified as side in that ear should have been classed with the open panicled class. These ants segregated for panicle type and, therefore, were heterozygous r this character. The high percentage of side panicle plants in the)25 F_2 population suggests that in this year, also, probably a numer of the plants classed as side panicled were actually heterozygous r this character and should have been classed with the open panicle rms. When the fact is taken into consideration that this character ems to be considerably influenced by environment and thus overpping of classes is likely to occur, the data undoubtedly support the eory that in this cross the inheritance of panicle type is due to a ngle factor difference.

When the two characters, ligule and panicle type, are considered gether the results shown in Table 9 were obtained.

TABLE 9.—Inheritance of ligule and panicle type in the F_2 generation.

Year	Ligule Present		Ligule Absent	
	Open	Side	Open	Side
1923	191	79	0	20
1924	380	115	0	34
1925	280	131	0	25
Observed total	851	325	0	79
Calculated 45:15:4 ratio	882.4	294.1	0	78.4

$X^2 = 4.368$ $P = 0.116$

Without correcting for the apparent errors in classification in 23 and 1925, the observed shows only a fair agreement with the lculated, P = 0.116 or 12 times in 100 trials would deviations great as these be expected from chance selection. If the 1924 pulation alone is considered, the fit is very close; the calculated ing 372, 124, and 33, while the observed were 380, 115, and 34 the three classes, respectively. X^2 is less than one showing a very se fit. The data give further evidence in support of the assumed torial analysis for the inheritance of ligule and panicle type.

A summary of the breeding behavior for ligule and panicle type the F_3 progenies grown from the 1924 F_2 plants in the five-row ots is given in Table 10.

TABLE 10.—Breeding behavior for ligule and panicle type of the F_3 progen grown in 5-row plots in 1925.

F_2 Plants	Number of F_2 Plants	F_3 Progenies								
		Liguled			Seg. for Ligule			Liguleless		
		Open	Seg.	Side	Open	Seg.	Side	Open	Seg.	Side
Open liguled	21	8	6	1		6				
Corrected	20	8	6	0		6				
Side liguled	22			1			20			
Corrected	23			2			21			
Side liguleless	17						1			1
Corrected	17						0			1
Total (Corrected)	60	8	6	2		6	21			1
Calculated	60	3.1	6.2	10.7		10.6	12.3			1

The 21 F_2 plants classed as open-liguled bred as follows in t F_3 progenies: Eight bred true to the open-liguled condition, six br true for ligule but segregated for panicle, one bred true for sid liguled, and six segregated for both ligule and panicle. The F_2 pla producing the side-liguled progeny should evidently have been clas fied as side-liguled in the F_2 and has, therefore, been added to th class in the corrected tabulation.

The number of families in each class obtained from the ope liguled plants agrees fairly well with the calculated.

With the exception of one plant which segregated for ligule the F_2 plants classed as liguleless bred true for this condition. In t corrected totals the plant segregating for ligule is classed with the sid liguled plants.

All of the F_2 plants classified as side-liguled and continued in t F_3 bred true for side panicle. One plant bred true for the liguleleı condition. It should evidently have been classified as liguleless aı has been put with this class in the corrected totals.

Of the 23 side-liguled F_2 plants on the corrected basis two br true for ligule and 21 segregated. The calculated proportion is 10 liguled to 12.3 segregating. In this case the observed does not agr very well with the theoretical. Although the numbers are small, would seem that for some undetermined reason more of the heterozygous side-liguled plants were selected than of the homozygous ones for continuance in F_3. Some factor may also be present which causes a modification of the expected ratios in this class.

In addition to the foregoing test of the 1924 F_2 plants, 15 additional progenies were grown in single rows. It is realized that the number of plants grown is too small to obtain any definite ratios. The chief aim was to find out if the side and liguleless condition bred true. The results obtained are given in Table 24 of the appendix. Only side panicled plants were used in this supplementary test. All liguleless plants bred true for this condition. One of the side-liguled plants segregated for panicle type and evidently should have been classed as open in the F_2. Two of the other nine side-liguled plants bred true for this condition while seven segregated. Here again the proportion of side-liguled plants breeding true is too small as compared with the calculated.

In addition to the foregoing tests of the F_2 plants grown in 1924, 55 single row families were grown from the 1923 F_2 plants. The results obtained are shown in Table 25 of the appendix. A summary is presented in Table 11.

TABLE 11.—Breeding behavior of F_3 progenies from 1923 F_2 plants grown in single rows in 1925.

F_2 Plants	Number of F_2 Plants	F_3 Progenies								
		Liguled			Seg. for Ligule			Liguleless		
		Open	Seg.	Side	Open	Seg.	Side	Open	Seg.	Side
Open liguled	11	3	6			2				
Corrected	13	3	7			3				
Side liguled	34		1	3		1	29			
Corrected	33		0	3		0	30			
Side liguleless	15						1			14
Corrected	14						0			14
Total (Corrected)	60	3	7	3		3	30			14
Calculated	60	2.0	4.0	15.4		7.0	17.6			14

Two plants classified as side panicled in 1923 segregated fo panicle in the F_3 test in 1925. They evidently were heterozygous an should have been classed with the open panicle group. Likewise on of the plants classed as liguleless was heterozygous. Again in thi test there were too many of the side-liguled F_2 plants segregating fo ligule in the F_3 progenies as compared with the class breeding tru for ligule and side panicle.

In the three tests made of the breeding behavior of ligule an panicle type in the F_3 progenies, the results obtained agree fairly satis factorily with the calculated except in the case of the proportion o progenies breeding true for the side-liguled condition and those segre gating for ligule and breeding true for side panicle. The results in dicate therefore that panicle type is conditioned by a single facto difference. It also seems safe to conclude that the presence of bot factors for the liguleless condition in the homozygous state prevent the development of an open panicle.

Nilsson-Ehle *(13)* explained the inheritance of panicle type o the basis of one, two, and three factor differences in various oa crosses. A very close association was found between panicle typ and ligule in certain crosses. No open liguleless forms were obtaine in any of the crosses made. In one cross between an open-ligule variety and a liguleless side-panicle variety, the results obtained wer explained on the basis that two independent duplicate factors fo ligule were present in the liguled parent and that both of these factor had an influence on the panicle type. The presence of one of thes factors alone would produce an intermediate panicle. The other facto alone would produce an intermediate panicle also, but more dens than the former while the absence of both would result in a sid panicle. In other crosses there were apparently factors for panicl type present which did not influence the ligule and also factors whic would produce a ligule but did not affect the panicle type.

Quisenberry *(15)* found a two factor difference for panicle typ in the oat cross which he studied. Gaines *(3)* and also Wakabaysh *(19)* found irregular segregation for panicle type in the F_2 generatio and obtained forms breeding true for the intermediate condition a well as for open and side panicles in the F_3 progenies. Garber *(4)* obtained results indicating a one factor difference for the inheritanc of panicle type.

Inheritance of Color

In this cross the Early Gothland has a white grain while the color ıf the Garton 784 grain is black. The plants in the cross were either lassed as black or white, no attempt being made to make further livisions on the basis of intensity of the color. The F_1 plants all had ılack seed indicating that black is dominant. The segregation in the lifferent F_2 populations is shown in Table 12.

'ABLE 12.—Inheritance of color of grain in the F_2 generation.

Year	Number of F_2 Plants		Deviation	Probable Error	Dev. / P. E.
	Black	White			
1923	223	67			
1924	403	126			
1925	309	127			
'bserved total	935	320			
alculated 3:1 ratio	941.25	313.75	6.25	10.32	0.61

The observed numbers agree very closely with a 3:1 ratio and ıdicate that color in this cross is due to a single factor difference.

In classifying the F_3 lines for color of grain the first fifteen plants 'ere used as a basis for the determination, except in ten of the segreating lines where a count was made for a verification of the F_2 ratios. summary of the breeding behavior for color of the F_3 lines is given Table 13.

ABLE 13.—Summary of breeding behavior for color of the F_3 progenies.

Color of F_2 Plant	F_3 Breeding Behavior			
	Black	Segregating	White	Total Families
ack	13	27		40
hite			20	20
ɔserved	13	27	20	60
ılculated	13.3	26.7	20	60

All F_2 plants classed as white bred true for this color while those 'assified as black segregated in the ratio of 13 to 27 for lines breeding ue for black and lines segregating for color. The calculated is 13.3 26.7. The F_3 breeding behavior, therefore, verifies the assumption that a one factor difference is concerned in the inheritance of this character. These results are in agreement with results obtained by Love and Craig *(10)*, Gaines *(3)*, Garber and Quisenberry *(6)*, and other workers. Nilsson-Ehle *(13)* found three separately inherited color factors each allelomorphic to its absence in a certain oat cross. Through the interaction of these factors four classes for color were obtained, black, gray, yellow, and white. Other workers have also reported similar results when certain crosses were made.

Inheritance of Rachilla Pubescence

The study of the inheritance of pubescence on the rachilla was based on the rachilla of the lower grain. The Early Gothland parent has a rachilla usually with a number of rather fine hairs. The Garton 784 parent has a smooth rachilla with only an occasional hair on some grains. In classifying plants for this character the five seeds from each plant used for making rachilla measurements were also used for making the pubescence determination. A plant was classed as hairy if any hairs were found on any of the grains examined. Since an occasional hair is sometimes found in the smooth parent this classification results in some overlapping of classes. The F_1 plants all had smooth rachillas. The results obtained in the F_2 populations are given in Table 14.

TABLE 14.—Inheritance of rachilla pubescence in the F_2 generation.

Year	Number of F_2 Plants		Deviation	Probable Error	Dev. / P. E.
	Smooth	Hairy			
1923	225	65			
1924	355	174			
1925	331	105			
Observed total	911	344			
Calculated 3:1 ratio	941.25	313.75	30.25	10.32	2.94

The total observed numbers agree fairly well with the calculated the deviation being slightly less than three times its probable error. The proportions in the years 1923 and 1925 agree very closely with the calculated 3:1 ratio while in 1924 there were too many in the hairy class. It would seem that for some reason there was more overlapping of classes for this character in this year than in the other two. A check on this is afforded by the breeding behavior of the 60 F progenies grown from 1924 F_2 plants and which were classified for this character.

In classifying the F_3 families for rachilla pubescence the first fif-en individuals were used as a basis for classifying the families. In a umber of the segregating families counts were made of the propor-on of smooth and hairy individuals in order to check the ratios ob-ined in the F_2 generation.

A summary of the breeding behavior for rachilla pubescence in e F_3 progenies is shown in Table 15.

ABLE 15.—Summary of breeding behavior for rachilla pubescence in the F_3 progenies.

ssification of F_2 Plant	F_3 Breeding Behavior			Total Families
	Smooth	Segregating	Hairy	
ooth	14	27	1	42
iry		4	14	18
served (Corrected)	14	31	15	60
lculated	15	30	15	60

From the 42 F_2 plants classified as smooth, 14 lines bred true for is condition, 27 segregated for smooth and hairy, and one bred true r the hairy condition. Evidently this latter plant should have been assified as hairy in the F_2. Fourteen of the F_2 plants, classified as iry, bred true, while four segregated. On the assumed basis of a e factor difference with smooth condition dominant, these four ants should have been classified as smooth in the F_2. When these plants are reclassified on the basis of their breeding behavior the mber of lines breeding true and the number segregating agree very osely with the calculated. The observed are 14 to 31, and the cal-lated 15 to 30, respectively. The F_3 breeding behavior, therefore, rifies the assumption that rachilla pubescence in this cross is due to single factor difference with smooth rachilla dominant.

On the basis of the breeding behavior in the F_3 and assuming at the same proportion of overlapping of classes occurred in the nainder of the F_2 classification in 1924, 30 plants should be changed om the hairy class to the smooth class in the 1924 F_2 population. If s were done, the observed and calculated totals for the three years ould be:

	Smooth	Hairy
Observed	941	314
Calculated	941.25	313.75

A number of individuals were, no doubt, classed in the wrong oup in the other years, also, so that the close fit is probably coinci-ntal.

Surface *(17)* found that pubescence of the rachilla together wi six other characters were completely linked with wild base in a cro between wild and cultivated oats. These were all inherited in a mon hybrid ratio. Absence of rachilla hairs was found dominant to th hairy condition.

INTERRELATION OF CHARACTERS

In order to determine if any of the characters studied tended t be associated in their inheritance, the F_2 plants were classified i various combinations. The breeding behavior of the F_3 progenie shows that some of the F_2 plants were wrongly classified for rachil pubescence. Since only the 1924 F_2 can be checked from the breedin behavior of the F_3 progenies, the F_2 grown in this year is used in th various groupings where rachilla pubescence is one of the characte studied. With the exception of the relation found between the ligul character and panicle type, which has already been discussed, n association in inheritance was found between any of the qualitativ characters studied. Table 16 is presented as typical of the metho used. All the different qualitative characters studied are included i this table.

In Table 16 the correction for pubescence has been applied as i the other tests with this character. The deviation from the calculate is such as might be expected by chance two times in five trials, P = 0.410. From these tests it seems safe to conclude that the four char acters are all conditioned by factors that are independently inherite and that the relation between the factor differences which cause panicl type and the liguled condition is of the nature assumed.

CORRELATION OF RACHILLA LENGTH WITH OTHER CHARACTERS

In order to determine if there is any correlation between th inheritance of length of rachilla and any of the other character studied, the means were calculated for the F_2 plants in each contrast ing class for the various characters. If there was no significant differ ence found in the means between any two contrasted classes it wa concluded that no correlation existed between that particular characte and the length of rachilla. In addition to this test the means for lengtl of rachilla of the F_3 progenies breeding true for the contrasted char acters and those segregating were thrown into frequency distribution from which a mean of means was calculated for each class. The rela tionship between any character and the length of rachilla could thu be studied in these progenies and the results could then be used as a check on the results obtained in the F_2 generation.

TABLE 16.—Inheritance of ligule, panicle type, color, and rachilla pubescence in the F_2 generation grown in 1924.

Observed and Calculated	Number of F_2 Plants															
	Liguled								Liguleless							
	Open Panicle				Side Panicle				Open Panicle				Side Panicle			
	Black		White		Black		White		Black		White		Black		White	
	Smooth	Hairy	Smooth	Hairy	Smooth	Hairy	Smooth	Hairy	Smooth	Hairy	Smooth	Hairy	Smooth	Hairy	Smooth	Hairy
Observed	192	102	68	18	49	35	20	11	0	0	0	0	19	6	7	2
Observed (Corrected)	209.8	84.2	71.1	14.9	55.1	28.9	21.9	9.1	0	0	0	0	20.0	5.0	7.3	1.7
Calculated	209.2	69.7	69.7	23.2	69.7	23.2	23.2	7.7	0	0	0	0	18.6	6.2	6.2	2.1

$X^2 = 11.411$ $P = 0.410$

Pubescence and Length of Rachilla

In Table 17 the means for the pubescent and the smooth segr gates in the F_2 populations and the means for the F_3 progenies bree ing true for the hairy condition, segregating, and breeding true f smooth rachilla are compared.

The data show that in all three F_2 populations the means for t length of rachilla were greater for the hairy segregates than for t smooth and in no case was the difference less than ten times its pro able error. This is taken as evidence that the characters pubescen of rachilla and length of rachilla are definitely associated in inheritanc

As a further test of this relationship, coefficients of contingen were calculated for pubescence and length of rachilla in the F_2 gener tions. The following coefficients were obtained in the various I populations: 1923, C = 0.346 ± 0.046; 1924, C = 0.416 ± 0.033; 1924, C = 0.321 ± 0.039. In all three years there was positive correlation between these two characters. This method analysis, therefore, also shows the linkage relation which exists b tween pubescence and length of rachilla in their inheritance.

When the F_3 generation is considered it is also seen that th families breeding true for the hairy condition had a greater mea length of rachilla than either the segregating families or those breedin true for smooth rachilla. The families segregating for this charact also had a greater mean length of rachilla than those breeding tru for the smooth condition. In no case was the difference less tha three times its probable error. This is further confirmation that thes two characters are definitely associated in inheritance.

Since it has been shown that the inheritance of pubescence of th rachilla is dependent upon a single factor difference and that th length of rachilla may be explained on a multiple factor basis, it seem logical to conclude that the factor determining the inheritance of pu bescence of the rachilla is in the same linkage group as one or mor of the factors determining the length of rachilla.

TABLE 17.—Length of rachilla in the pubescent and smooth rachilla segregates in the F_2 generations and the mean length of rachilla in the F_3 progenies breeding true for pubescent rachilla, segregating, and breeding true for smooth rachilla.

Character of Pubescence	Generation	Year	Classes for Length of Rachilla in Units of .1 mm.															Total No.	Means	Difference	Diff. / P. E.
			16	17	18	19	20	21	22	23	24	25	26	27	28	29	30				
Smooth	2	1923	2	3	16	25	48	48	26	25	18	12	2					225	21.089±0.091		
Hairy	2	1923					1	14	16	10	9	6	4	4			1	65	23.138±0.168	2.049±0.191	10.7
Smooth	2	1924	4	11	29	66	73	74	54	25	10	6	3					355	20.485±0.066		
Hairy	2	1924		1	3	5	13	25	38	29	33	18	5	3	1			174	22.615±0.098	2.130±0.118	18.0
Smooth	2	1925	2	6	18	53	85	73	56	29	6	3						331	20.592±0.058		
Hairy	2	1925		1	1	4	12	20	31	18	10	5		3				105	22.029±0.115	1.437±0.129	11.1
Smooth	3	1925		2	3	2	3		3	1								14	19.643±0.345	2.957±0.447*	6.6
Segregating	3	1925			4	2	4	9	8		3		1					31	21.065±0.226	1.422±0.412**	3.4
Hairy	3	1925					1	4	3	3	2	1	1					15	22.600±0.284	1.535±0.363†	4.2

*Between hairy and smooth rachilla progenies.
**Between smooth and segregating progenies.
†Between hairy and segregating progenies.

Ligule, Panicle Type, Color of Grain, and Length of Rachilla

The means for length of rachilla of the various classes for ligule, panicle type, and color were calculated in the same manner as these were calculated for the classes for pubescence of the rachilla. A summary of the results obtained is given in Table 18.

TABLE 18.—Mean length of rachilla in different contrasted classes in the F_2 and F_2 generations.

Description	Generation	Number of Plants and Mean Length of Rachilla in Units of .1 mm					
		1923		1924		1925	
		No.	Means	No.	Means	No.	Means
Liguled	F_2	270	21.548±0.090	495	21.178±0.065	411	20.934±0.05
Liguleless	F_2	20	21.550±0.311	34	21.294±0.222	25	21.000±0.27
Liguled	F_3					16	20.875±0.33
Seg. for ligule	F_3					27	21.370±0.29
Liguleless	F_3					17	20.882±0.29
Open panicle	F_2	191	21.534±0.110	381	21.097±0.074	280	20.811±0.06
Side panicle	F_2	99	21.576±0.140	148	21.412±0.114	156	21.167±0.09
Open panicle	F_3					8	20.125±0.52
Seg. for panicle	F_3					12	21.250±0.45
Side panicle	F_3					40	21.250±0.20
Black grain	F_2	223	21.453±0.102	403	20.980±0.070	309	20.861±0.06
White grain	F_2	67	21.866±0.158	126	21.841±0.125	127	21.126±0.09
Black grain	F_3					15	20.800±0.33
Seg. for color	F_3					25	20.400±0.26
White grain	F_3					20	22.150±0.27

It is evident from a consideration of the data given in Table 18 that there was no correlation between the inheritance of the length of rachilla and the inheritance of either ligule or panicle type. The differences between the means for the various classes are not significant in the light of their probable errors.

The differences in length of rachilla between the black and white :ained classed in the F_2 generation for the three years were 0.413 ± .188, 0.861 ± 0.143, and 0.265 ± 0.118. In two out of the ıree years the differences were not large enough to be considered sig- ficant. In the other year, 1924, the difference was approximately x times its probable error and shows that the white seeded plants ıd the longer rachillas that year. The fact that there is only a dif- rence in one year out of the three indicates that if this difference was ıe to inheritance, the association between color and length of rachilla very loose.

In the F_3 generation there was no significant difference in length rachilla between the families breeding true for black and those gregating for color. The actual length for the segregating families as less than for the families breeding true for black color. The dif- rences in mean length of rachilla between the segregating and white milies was 1.750 ± 0.386 units. This difference is significant in e light of its probable error. The difference between the black eded families and the white was 1.350 ± 0.438 which may also be ›nsidered as significant. These results seem to point to a slight asso- ation between the inheritance of color and length of rachilla.

SUMMARY

A cross was made between Early Gothland and Garton 7{ two varieties of oats differing in certain characters. A study was ma(of the inheritance of the length of the rachilla, ligule, panicle typ color, and pubescence of the rachilla. From the results obtained ce tain conclusions and deductions can be drawn.

1.—The length of rachilla was found to be a very stable si character and was not greatly influenced by environmental conditior

2.—The length of rachilla in the F_1 plants was intermediate b tween the two parents. The F_2 individuals ranged from one parent the other for length of rachilla. From 60 F_3 progenies grown, o apparently homozygous line was recovered with a rachilla length short as the short parent, and one F_3 family with a rachilla length a proximately as long as the longer parent. Families apparently homoz gous for rachilla lengths intermediate between these extremes we also recovered. The inheritance of rachilla length can be explain on the basis of multiple factors for length of rachilla. The results i dicated that the factors involved were not of equal value in determi ing the length of rachilla.

3.—The ligule of the leaf was found to be determined by dup cate factors giving a ratio of 15 liguled to 1 liguleless plant in the generation.

4.—The panicle type was found to be controlled by a single fa tor difference. The presence of the two factors for the liguleless co dition in the homozygous state prevented the factor for open panicl if present, from functioning and resulted in producing a side panicl No open panicled liguleless forms were found.

5.—Black color of grain was dominant to white. Inheritan of color was controlled by a single factor difference.

6.—Pubescence of the rachilla was found to be recessive to tl smooth condition and was controlled by a single factor difference.

7.—No evidence of linkage was found between the factors f ligule, panicle type, color, or pubescence. All seemed to be inherit independently of each other except for the duplicate relationship b tween the two factors for ligule and their common relationship to tl factor for panicle type.

8.—No evidence was found of linkage between any of the fa tors for length of rachilla and ligule or panicle type. Some of the da indicated a possible loose linkage between color and length of rachill

9.—A close linkage was found between at least one of the fa tors or group of factors for length of rachilla and the factor for pube cence of the rachilla.

SUPPLEMENT

Since this paper was originally submitted for publication, addinal data have been obtained by growing F_4 families from a number selected F_3 plants. These F_4 families were grown during the sumer of 1926 and handled in a way similar to that in which the F_3 and ner material was handled in the previous years of the study. In all ere were twelve F_4 families grown including progenies from single nts from each of the eight F_3 families which were apparently breed- true for certain rachilla lengths. The data obtained are given in ble 26 of the appendix.

The highest coefficient of variability obtained in the parental terial grown in 1926 was 5.84 ± 0.38. If this is taken as the per limit for the coefficients of variability for homozygous lines it is nd that all but two of the F_4 lines are apparently homozygous. nong these are included all F_4 progenies from the F_3 families which re classed as homozygous and also two lines from F_3 families which re classified as heterozygous. If an F_3 family were homozygous a certain length of rachilla it would be expected that it would conue to show this condition in the F_4 also. Either heterozygous or mozygous F_4 lines might be expected from a heterozygous F_3 family. l data show a very close correlation between the length of the rachilin the F_3 and F_4 generations.

The F_4 data substantiate the conclusion previously reached that a mber of F_3 families had been obtained that were breeding true for tain rachilla lengths.

Data on the other characters studied were also obtained for the families. These data are not presented here but in all cases they ostantiate the conclusions drawn from the study of the previous genations.

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APPENDIX

TABLE 19.—Statistical constants for length of rachilla, for samples of 29, 48, 58, and 96 plants taken from the F_2 generation. grown in 1923.

Sample Number	Classes for Length of Rachilla in Units of .1 mm.															Number of Plants	Means	Standard Deviation	Coefficient of Variability
	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30				
1			2	1	3	6	6	4	2	2	1	2				29	22.172±0.289	2.306±0.204	10.40±0.93
2			3	4	4	5	3	2	6	2						29	21.414±0.262	2.190±0.194	10.23±0.92
3	1	0	0	2	8	5	5	3	2	2	1					29	21.448±0.262	2.094±0.185	9.76±0.86
4			4	2	3	8	3	2	4	1	1	0	0	0	1	29	21.621±0.333	2.657±0.235	12.29±1.10
5		1	3	3	2	5	6	7	0	2						29	21.241±0.256	2.045±0.181	9.63±0.85
6	1	2	0	2	5	9	0	5	4	0	0	1				29	21.207±0.295	2.354±0.208	11.10±0.99
7			1	1	9	7	4	5	0	1	1					29	21.310±0.213	1.704±0.151	8.00±0.71
8			1	4	5	4	7	4	1	2	0	1				29	21.552±0.256	2.044±0.181	9.48±0.84
9			1	5	3	8	4	1	2	4	1					29	21.586±0.272	2.174±0.193	10.07±0.90
10			1	1	7	5	4	2	6	2	1					29	21.931±0.253	2.016±0.179	9.19±0.81
1		1	3	4	4	10	10	7	2	6	1					48	21.708±0.206	2.121±0.146	9.77±0.67
2			3	4	9	10	5	4	6	5	0	1	0	0	1	48	21.833±0.240	2.461±0.169	11.27±0.79
3	1	0	2	6	9	13	8	3	3	3						48	21.063±0.183	1.887±0.130	8.91±0.61
4		1	1	4	4	12	7	7	8	2	2					48	21.917±0.195	2.008±0.138	9.16±0.63
5			2	2	11	8	7	10	1	2	3	2				48	21.917±0.214	2.197±0.151	10.02±0.70
6	1	1	5	5	9	10	5	4	7	0	0	1				48	20.937±0.215	2.204±0.152	10.53±0.73

TABLE 19.—Concluded.

Sample Number	Classes for Length of Rachilla in Units of .1 mm.															Number of Plants	Means	Standard Deviation	Coefficient of Variability
	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30				
1	1	2	2	3	8	15	6	9	6	2	1	3				58	21.690±0.211	2.380±0.149	10.97±0.69
2			4	5	13	12	7	7	6	3	1					58	21.362±0.174	1.963±0.123	9.19±0.57
3	1	0	1	6	13	9	12	7	3	4	1	1				58	21.500±0.183	2.070±0.130	9.63±0.60
4			5	7	6	16	7	3	6	5	2	0	0	0	1	58	21.603±0.215	2.428±0.152	11.24±0.71
5		1	4	4	9	10	10	9	6	4	1					58	21.586±0.182	2.060±0.129	9.54±0.60
1		2	4	8	8	22	17	14	10	8	3					96	21.813±0.142	2.068±0.101	9.48±0.46
2			5	6	20	18	12	14	7	7	3	3	0	0	1	96	21.875±0.161	2.333±0.114	10.66±0.53
3	2	1	7	11	18	23	13	7	10	3	0	1				96	21.000±0.142	2.056±0.100	9.79±0.48
1	2	3	16	25	49	62	42	35	27	18	6	4	0	0	1	290	21.652±0.083	2.089±0.059	9.65±0.27

TABLE 20.—Statistical constants for length of rachilla of the Early Gothla parent grown in various plots in 1925.

1925 Row Number	Classes for Length of Rachilla in Units of .1 mm.						Total No.	Means	Standard Deviation	Coefficien of Variabilit
	25	26	27	28	29	30				
604–606		15	27	7	1		50	26.880±0.068	0.711±0.048	2.64±0.
625–627	2	10	24	13		1	50	27.040±0.085	0.894±0.060	3.31±0.
648–650	3	16	16	10			45	26.733±0.088	0.879±0.062	3.29±0.
679–681	6	17	20	7			50	26.560±0.083	0.875±0.059	3.29±0.
711–713	3	12	24	10	1		50	26.880±0.082	0.863±0.058	3.21±0.
745–747	4	22	17	7			50	26.540±0.079	0.830±0.056	3.13±0.
779–781		17	23	7			47	26.787±0.067	0.682±0.047	2.55±0.
808–810	1	8	25	16			50	27.120±0.070	0.739±0.050	2.72±0.
839–841	4	15	21	7	1		48	26.708±0.087	0.889±0.061	3.33±0.
873–875	3	13	23	11			50	26.840±0.079	0.833±0.056	3.10±0.
905–907	1	12	24	9	4		50	27.060±0.086	0.904±0.061	3.34±0.
936–938	1	10	25	11	1		48	27.021±0.076	0.777±0.053	2.88±0.
967–969	2	8	27	12	1		50	27.040±0.076	0.799±0.054	2.95±0.
1003–1005	4	14	22	6	1		47	26.702±0.086	0.673±0.061	3.27±0.
1035–1037	4	9	30	4			47	26.723±0.072	0.735±0.051	2.75±0.
1061–1063	2	7	26	14	1		50	27.100±0.077	0.806±0.054	2.97±0.
1081–1083	3	7	29	8	3		50	27.020±0.084	0.883±0.060	3.27±0.
1114–1116	2	11	19	14	4		50	27.140±0.093	0.980±0.066	3.61±0.

ABLE 21.—Statistical constants for length of rachilla of the Garton 784 parent grown in various plots in 1925.

1925 Row Number	Classes for Length of Rachilla in Units of .1 mm.						Total No.	Means	Standard Deviation	Coefficient of Variability
	14	15	16	17	18	19				
607–609		3	24	20	3		50	16.460±0.067	0.699±0.047	4.25±0.29
628–630		2	26	21	1		50	16.420±0.058	0.603±0.041	3.67±0.25
651–653		3	34	13			50	16.200±0.050	0.529±0.036	3.26±0.22
682–684		3	32	15			50	16.240±0.052	0.550±0.037	3.39±0.23
714–716		4	27	19			50	16.300±0.058	0.608±0.041	3.73±0.25
784–750		15	29	5	0	1	50	15.860±0.071	0.749±0.051	4.72±0.32
782–784		5	27	15	3		50	16.320±0.070	0.733±0.049	4.49±0.30
811–813		9	31	10			50	16.020±0.059	0.616±0.042	3.84±0.26
842–844		7	25	16	2		50	16.260±0.071	0.743±0.050	4.57±0.31
876–878	1	5	24	18	1		49	16.265±0.072	0.750±0.051	4.61±0.31
908–910		3	24	18	5		50	16.500±0.072	0.755±0.051	4.58±0.31
939–941		5	31	12	2		50	16.220±0.064	0.672±0.045	4.14±0.28
970–972		14	26	9	0	1	50	15.960±0.076	0.799±0.054	5.01±0.34
)06–1008		9	23	13	2		47	16.170±0.077	0.780±0.054	4.82±0.34
)38–1040		8	30	8	2		48	16.083±0.068	0.702±0.048	4.36±0.30
)64–1066		11	30	8	1		50	15.980±0.065	0.678±0.046	4.24±0.29
)84–1086		4	33	13			50	16.180±0.053	0.555±0.037	3.43±0.23
117–1119		7	21	20	2		50	16.340±0.073	0.764±0.052	4.68±0.31

TABLE 22.—Breeding behavior for length of rachilla of the F_3 progenies grown in 1925.

1925 Row Number	N. H. N.	Rachilla Length of F_2 Plant	Classes for Length of Rachilla in Units of .1 mm.																Total No.	Means	Coefficient of Variability
			14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29			
654–658	18–1–25	21.2				1	2	5	11	13	8	1	7	1	1				50	21.180±0.181	8.94±0.60
659–663	18–1–29	20.6					1	10	20	9	6	4							50	20.420±0.116	5.96±0.40
664–668	18–1–32	21.6						2	9	14	9	12	3	1					50	21.660±0.132	6.37±0.43
669–673	18–1–66	20.0					3	5	11	13	8	9		1					50	21.000±0.147	7.31±0.49
674–678	18–1–70	17.2		5	6	13	16	5	2	1	2								50	17.600±0.153	9.09±0.61
685–689	18–2–29	19.4			1	2	2	10	11	9	7	7	1						50	20.480±0.169	8.64±0.58
691–695	18–4–22	17.8	1	1	7	7	12	13	5	4									50	18.140±0.153	8.82±0.59
696–700	18–4–42	23.0								2	7	10	14	7	6	4			50	24.020±0.150	6.53±0.44
701–705	18–4–47	22.2							9	15	8	17	1						50	21.720±0.111	5.37±0.36
706–710	18–4–54	19.8				3	2	5	12	10	13	2	2	1					50	20.740±0.165	8.34±0.56
717–721	18–4–56	16.0		1	11	20	15	3											50	17.140±0.086	5.29±0.36
722–726	18–4–58	18.2		1		8	5	12	10	8	5	1							50	19.400±0.164	8.87±0.60
727–731	18–4–68	22.4					2	5	10	16	5	8	2	2					50	21.180±0.156	7.71±0.52
732–736	18–4–76	18.8				1	2	8	11	10	8	8	1	1					50	20.880±0.160	8.05±0.54
737–739	18–4–77	27.8											10	13	13	2	6	1	45	25.867±0.140	5.38±0.38
740–744	18–4–104	19.2		1	1	5	8	17	10	4	3	1							50	19.120±0.149	8.14±0.55
751–753	18–5–31	17.0			1	2	13	16	10	1									43	18.814±0.102	5.28±0.38

1925 Row Number	N. H. N.	Rachilla Length of F_2 Plant	Classes for Length of Rachilla in Units of .1 mm.																Total No.	Means	Coefficient of Variability
			14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29			
754–758	18–5–32	21.0				1	4	11	17	10	3	2	2						50	20.400±0.135	6.93±0.47
759–763	18–5–33	16.4			4	11	12	10	10	2	1								50	18.420±0.136	7.76±0.52
764–768	8–5–34	21.8					1	3	6	10	12	11	2	4	1				50	21.920±0.164	7.84±0.53
769–773	18–5–42	20.0				4	7	15	12	6	3	2	1						50	19.620±0.150	8.02±0.54
774–778	18–5–43	22.2					4	5	22	11	7	1							50	20.300±0.108	5.60±0.38
785–789	18–6–117	19.0		2	4	14	12	12	4	2									50	17.960±0.131	7.63±0.51
790–792	18–6–124	26.8						2	2	9	21	6	7	3					50	22.200±0.131	6.18±0.42
793–797	18–6–131	18.0		3	1	8	16	11	6	2	3								50	18.440±0.154	8.75±0.59
798–802	18–6–135	24.8							1		3	10	16	11	6	2	1		50	24.260±0.137	5.94±0.40
803–807	18–6–136	19.2					2	3	10	12	9	9	4		1				50	21.440±0.157	7.70±0.52
814–818	18–6–155	22.0						3	12	17	10	4	2	1	1				50	21.300±0.138	6.79±0.46
819–823	18–6–169	16.0		3	20	25	2												50	16.520±0.064	4.06±0.27
824–828	19–1–26	17.4				9	14	9	10	6	2								50	18.920±0.136	7.54±0.51
829–833	19–1–34	20.8					2	15	15	9	7	2							50	20.200±0.118	6.10±0.41
834–838	19–1–36	20.8				2	9	15	8	10	4	2							50	19.700±0.141	7.48±0.50
845–849	19–1–41	23.8							2	5	13	13	12	4	1				50	22.880±0.126	5.77±0.39
850–852	19–1–65	16.0		3	6	5	12	8	2	2									38	17.789±0.167	8.57±0.66

(Continued)

TABLE 22.—Continued.

1925 Row Number	N. H. N.	Rachilla Length of F_2 Plant	Classes for Length of Rachilla in Units of .1 mm.																Total No.	Means	Variability Coefficient of
			14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29			
853–857	19–3–22	22.6						1	2	5	14	13	13	1	1				50	22.680±0.127	5.88±0.40
858–862	19–3–28	24.4						2	5	14	13	13	3						50	21.780±0.116	5.61±0.38
863–867	19–3–49	25.6									2	17	14	7	8	2			50	24.160±0.121	5.26±0.35
868–872	19–3–55	21.2						4	6	12	5	12	7	4					50	22.040±0.164	7.80±0.53
879–883	19–3–61	19.0			3	8	19	8	8	3	1								50	18.460±0.130	7.37±0.50
884	19–4–27	25.8								4	3	3	3	1	1				15	22.800±0.264	6.64±0.82
885–889	19–4–40	23.2							3	15	15	10	4	3					50	22.120±0.120	5.69±0.38
890–894	19–4–52	22.4						1	9	18	9	8	5						50	21.580±0.122	5.94±0.40
895–899	19–4–88	24.8										15	19	11	1	3		1	50	24.240±0.120	5.19±0.35
900–904	19–4–89	21.4							2	8	14	11	13	1	1				50	22.640±0.123	5.71±0.38
911–915	19–4–94	23.8							2	13	19	14	2						50	22.020±0.088	4.21±0.28
916–920	19–5–13	19.8				1	1	4	11	14	4	3			1	7	3	1	50	22.200±0.297	14.01±0.96
921–925	19–5–15	25.6										4	15	15	11	5			50	24.960±0.106	4.46±0.30
926–930	19–5–16	21.4						5	18	14	11	2							50	20.740±0.099	4.99±0.34
931–935	19–5–17	20.4					1	13	8	9	12	4	2		1				50	20.880±0.159	7.99±0.54
942–946	19–5–32	25.4						1	3	10	15	9	9	3					50	22.340±0.133	6.24±0.42
947–951	19–5–33	23.8						1	5	14	13	6	7	4					50	22.100±0.143	6.79±0.46

TABLE 22.—Concluded.

1925 Row Number	N. H. N.	Rachilla Length of F_2 Plant	Classes for Length of Rachilla in Units of .1 mm.																Total No.	Means	Coefficient of Variability
			14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29			
952–956	19–5–35	26.8								1	3	14	10	9	7	2	2	2	50	24.480±0.171	7.32±0.49
957–961	19–5–36	23.4							4	12	8	13	11	2					50	22.420±0.131	6.12±0.41
962–966	19–5–38	20.4					1	10	6	14	12	6	1						50	20.960±0.135	6.75±0.45
973–977	19–6–21	22.4						3	17	20	6	3	1						50	20.840±0.100	5.02±0.34
978–982	19–6–27	20.8				2	3	10	13	12	5	3	1	1					50	20.360±0.156	8.03±0.54
983–987	19–6–32	20.6					1	4	12	16	13	4							50	20.960±0.110	5.48±0.37
988–992	19–6–33	21.6						2	7	14	20	7							50	21.460±0.098	4.77±0.32
993–997	19–6–40	25.6										1	7	18	13	9	2		50	25.560±0.106	4.37±0.29
998–1002	19–6–51	23.6						1	3	12	13	12	7	2					50	22.220±0.127	5.99±0.40

TABLE 23.—Breeding behavior of F_3 progenies for ligule, panicle type, grain c and rachilla pubescence.

1925 Row Number	N. H. N	Ligule			Panicle Type			Grain Color				Rachilla Pubescenc			
		F_2 Plant	No. F_3 Plants		F_2 Plant	No. F_3 Plants		F_2 Plant	F_3 Families			F_2 Plant	F_3 Families		
			P	A		O	S		B	Seg.	W		Sm.	Seg.	H
654–658	18–1–25	P	85		O	85		B		x		Sm.		x	
659–663	18–1–29	P	83	7	O	63	27	B		x		Sm.	x		
664–668	18–1–32	P	64	18	S		82	B		x		Sm.		x	
669–673	18–1–66	A		86	S		86	B		x		Sm.		x	
674–678	18–1–70	P	58	16	O	41	33	B		x		Sm.		x	
685–689	18–2–29	P	86		O	69	17	W			x	Sm.		x	
691–695	18–4–22	P	59	25	S		84	W			x	Sm.	x		
696–700	18–4–42	P		85	O	66	19	B	x			H			x
701–705	18–4–47	P	63	26	S		89	W			x	Sm.		x	
706–710	18–4–54	A		79	S		79	B	x			Sm.		x	
717–721	18–4–56	P	73	7	O	49	31	B	x			Sm.	x		
722–726	18–4–58	P	65	21	S		86	B	x			Sm.		x	
727–731	18–4–68	A		82	S		82	W			x	Sm.		x	
732–736	18–4–76	P	63	19	S		82	W			x	Sm.		x	
737–739	18–4–77	P	35	11	S		46	W			x	H			x
740–744	18–4–104	P	60	19	S		79	B		x		Sm.	x		
751–753	18–5–31	P	34	11	S		45	B		x		H		x	
754–758	18–5–32	A		90	S		90	W			x	Sm.		x	
759–763	18–5–33	P	79		O	79		B		x		Sm.		x	
764–768	18–5–34	P	71	18	S		89	W			x	Sm.		x	
769–733	18–5–42	P	71		S		71	B		x		Sm.		x	

(Continued)

A = Ligule absent O = Open Panicle B = Black H = Hairy
P = Ligule Present S = Side Panicle W = White Sm. = Smooth
Seg. = Segregating

LE 23.—Continued.

25 w ber	N. H. N.	Ligule			Panicle Type			Grain Color				Rachilla Pubescence				Total Number
		F_2 Plant	No. F_3 Plants		F_2 Plant	No. F_3 Plants		F_2 Plant	F_3 Families			F_2 Plant	F_3 Families			
			P	A		O	S		B	Seg.	W		Sm.	Seg.	H	
7-778	18–5–43	A		80	S		80	B		x		Sm.	x			80
8-789	18–6–117	A		91	S		91	B		x		Sm.	x			91
9-792	18–6–124	P		50	O	28	22	W			x	H			x	50
9-797	18–6–131	A		77	S		77	B		x		Sm.	x			77
9-802	18–6–135	A		83	S		83	W			x	Sm.		x		83
0-807	18–6–136	A		88	S		88	B	x			Sm.		x		88
1-818	18–6–155	P	73	18	S		91	B	x			H			x	91
1-823	18–6–169	P	80		O	80		B	x			Sm.	x			80
2-828	19–1–26	P	70	15	S		85	B		x		Sm.	x			85
2-833	19–1–34	P	60	18	S		78	B		x		Sm.		x		78
3-838	19–1–36	P	84		O	84		B		x		H			x	84
4-849	19–1–41	A		89	S	89		W			x	Sm.	x			89
5-852	19–1–65	P	41		O	41		B		x		Sm.		x		41
5-857	19–3–22	P	59	25	S		84	B		x		H			x	84
6-862	19–3–28	P	89		O	89		W			x	Sm.	x			89
6-867	19–3–49	P	62	23	S		85	B	x			Sm.		x		85
6-872	19–3–55	A		87	S		87	B	x			Sm.		x		87
7-883	19–3–61	A		76	S		76	B		x		Sm.	x			76
	19–4–27	P	15		O		15	B		x		H			x	15
8-889	19–4–40	P	80	3	O	32	51	W			x	Sm.	x			83
9-894	19–4–52	A		81	S		81	W			x	H		x		81
9-899	19–4–88	A		73	S		73	B		x		Sm.		x		73
0-904	19–4–89	P	66	22	S		88	W			x	H			x	88

(Continued)

A = Ligule absent O = Open Panicle B = Black H = Hairy
P = Ligule Present S = Side Panicle W = White Sm. = Smooth
Seg. = Segregating

TABLE 23.—Concluded.

1925 Row Number	N. H. N.	Ligule			Panicle Type			Grain Color				Rachilla Pubescei		
		F_2 Plant	No. F_3 Plants		F_2 Plant	No. F_3 Plants		F_2 Plant	F_3 Families			F_2 Plant	F_3 Famili	
			P	A		O	S		B	Seg.	W		Sm.	Seg.
911–915	19–4–94	P	79		O	58	21	B		x		H		
916–920	19–5–13	A	61	24	S		85	W			x	Sm.		x
921–925	19–5–15	P	63	22	S		85	B		x		Sm.		
926–930	19–5–16	P	78		O	59	19	W			x	H		
931–935	19–5–17	P	87		O	70	17	B	x			H		
943–946	19–5–32	P	58	21	S		79	B		x		Sm.		x
947–951	19–5–33	P	66	17	S		83	B		x		H		
952–956	19–5–35	P	90		O	90		W			x	H		
957–961	19–5–36	P	64	21	S		85	W			x	Sm.	x	
962–966	19–5–38	A		75	S		75	B	x			Sm.		x
973–977	19–6–21	A		86	S		86	B	x			H		
978–982	19–6–27	P		87	S		87	B	x			Sm.	x	
983–987	19–6–32	P	54	22	S		76	B		x		H		x
988–992	19–6–33	P	79		O	79		B		x		H		x
993–997	19–6–40	P	75	8	O	50	33	W			x	Sm.		x
998–1002	19–6–51	P	69	5	O	45	29	B		x		Sm.		x

A = Ligule absent   O = Open Panicle   B = Black   H = Hairy
P = Ligule Present   S = Side Panicle   W = White   Sm. = Smooth
Seg. = Segregating

LE 24.—Breeding behavior for ligule and panicle type of single row F_3 progenies grown from 1924 F_2 plants.

25 ow nber	N. H. N.	Ligule			Panicle Type			Total No.
		F_2 Plant	No. F_3 Plants		F_2 Plant	No. F_3 Plants		
			P	A		O	S	
87	18–1–22	P	18		S		18	18
88	18–1–33	P	14	3	S	9	8	17
89	18–1–41	P	15	5	S		20	20
90	18–4–18	P	15	5	S		20	20
91	18–4–21	P	11	3	S		14	14
92	18–4–65	P	14	5	S		19	19
93	18–6–163	A		14	S		14	14
94	19–3–17	A		16	S		16	16
95	19–4–47	A		17	S		17	17
96	19–4–92	A		19	S		19	19
97	19–5–25	A		17	S		17	17
98	19–6–22	P	9	7	S		16	16
99	19–6–41	P	13	3	S		16	16
00	19–6–43	P	17		S		17	17
01	19–6–53	P	17	1	S		18	18

TABLE 25.—Breeding behavior for ligule and panicle type of single row progenies grown from 1923 F_2 plants.

1925 Row Number	N. H. N.	Ligule			Panicle Type			Total
		F_2 Plant	No. F_3 Plants		F_2 Plant	No F_3 Plants		
			P	A		O	S	
1009	18–1–1	P	16		O	16		1
1010	18–1–3	P	12	3	S		15	1
1011	18–1–8	P	9	4	S		13	1
1012	18–1–17	A	7	4	S		11	1
1013	18–1–19	P	8	5	S		13	1
1014	18–2–8	P	13		O	13		1
1015	18–2–11	P	5	5	S		10	10
1016	18–2–12	A		6	S		6	6
1017	18–3–1	P	13	3	S		16	16
1018	18–3–4	P	13	1	O	10	4	14
1019	18–3–10	P	10	5	S		15	15
1020	18–3–18	A		13	S		13	13
1021	18–3–21	P	7	2	S		9	9
1022	18–3–25	P	8	1	S		9	9
1023	18–4–9	A		13	S		13	13
1024	18–5–2	A		11	S		11	11
1025	18–5–3	P	13		S		13	13
1026	18–5–8	P	18		O	18		18
1027	18–5–24	P	12	1	S		13	13
1028	18–6–8	A		14	S		14	14
1029	18–6–11	P	5	2	S		7	7
1030	18–6–13	P	9	5	S		14	14
1031	18–6–16	P	12	3	S		15	15
1032	18–6–4	P	5	7	S		12	12
1033	18–6–23	A		16	S		16	16

(Continued)

BLE 25.—Continued.

1925 Row Number	N. H. N.	Ligule			Panicle Type			Total Number
		F_2 Plant	No. F_3 Plants		F_2 Plant	No. F_3 Plants		
			P	A		O	S	
1034	18–6–29	P	9	4	S		13	13
1041	18–6–33	P	8	6	S		14	14
1042	18–6–38	P	11	3	S		14	14
1043	18–6–42	P	9	4	S		13	13
1044	18–6–48	P	15		S	8	7	15
1045	18–6–51	P	9	5	S		14	14
1046	18–6–58	P	11		O	7	4	11
1047	18–6–60	P	12		O	5	7	12
1048	18–6–78	A		13	S		13	13
1049	18–6–85	P	11		O	5	6	11
1050	18–6–86	P	13		S		13	13
1051	18–6–89	P	15	1	O	9	7	16
1052	18–6–92	A		13	S		13	13
1053	18–6–94	P	12	3	S		15	15
1054	18–6–102	P	12	4	S		16	16
1055	18–6–103	A		13	S		13	13
1056	18–6–106	P	13		O	7	6	13
1057	18–6–108	P	13		S		13	13
1058	18–6–109	P	10	7	S		17	17
1059	18–6–111	P	12		O	5	7	12
1060	18–6–113	P	16		O	11	5	16
1067	19–1–1	P	14	6	S		20	20
1068	19–1–2	A		16	S		16	16
1069	19–1–20	A		14	S		14	14
1070	19–2–5	A		16	S		16	16
1071	19–3–4	A		17	S		17	17

(Continued)

TABLE 25.— Concluded.

1925 Row Number	N. H. N.	Ligule			Panicle Type			Total
		F_2 Plant	No. F_3 Plants		F_2 Plant	No. F_3 Plants		
			P	A		O	S	
1072	19–3–5	P	8	3	S		11	1
1073	19–4–1	P	13	5	S		18	1
1074	19–4–5	P	9	4	S		13	1
1075	19–5–2	A		10	S		10	1
1076	19–5–4	P	15	2	S		17	1
1077	19–6–2	P	13	6	S		19	1
1078	19–6–12	P	15	2	S		17	1
1079	19–6–13	P	13	2	S		15	1
1080	19–6–14	P	11	4	S	7	8	1

1926 Row Number	Material	Length (class)	C. V. (class)	Classes for Length of Rachilla in Units of .1 mm. 14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30		Means	Coefficient of Variability
501–503	E. G.													5	18	11	10	5	1		50	25.900±0.118	4.78±0.32
504–506	G. 784				16	28	2	1													47	15.745±0.062	4.03±0.28
507–509	18–1–70–32	18	9.0		4	12	14	5	3												38	16.763±0.116	6.34±0.49
510–512	18–4–56–29	17	5.5		4	11	16	8	1												40	16.775±0.102	5.73±0.43
513–515	18–4–77–1	26	5.5										3	9	8	5	10	10	3	2	50	26.240±0.180	7.17±0.48
516–518	18–6–169–1	17	4.0			3	25	14	3												45	17.378±0.071	4.07±0.29
519–521	E. G.												3	6	10	21	10	1			51	25.627±0.109	4.50±0.30
522–524	G. 784			7	21	20	1														49	15.306±0.071	4.80±0.33
525–527	19–4–88–1	24	5.0								14	24	5	2	3						48	22.083±0.103	4.79±0.33
528–530	19–4–94–1	22	4.0							4	23	14	4	2							47	21.511±0.090	4.27±0.30
531–533	19–5–15–23	25	4.5							2	14	16	10	4							46	22.000±0.102	4.65±0.33
534–536	19–5–16–20	21	5.0						1	11	27	7	2								48	20.958±0.077	3.76±0.26
537–539	E. G.												3	12	15	10	10	2			52	25.346±0.120	5.07±0.34
540–542	G. 784			7	31	10	3	2													53	15.283±0.083	5.84±0.38
543–545	19–6–21–1	21	5.0					1	3	19	14	10	1								48	20.625±0.092	4.60±0.32
546–548	19–6–32–1	21	5.5			1	6	25	13	4		1									50	18.280±0.081	4.64±0.31
549–551	19–6–33–1	21	5.0					1	7	20	20	2									50	20.300±0.079	4.09±0.28
552–554	19–6–40–1	26	4.5									6	18	11	6	2	2	1			46	23.783±0.137	5.81±0.41
555–557	E. .G													5	16	9	5	1			36	25.472±0.111	3.87±0.31
558–560	G. 784			6	29	10	1														46	15.130±0.064	4.28±0.30