TIMOTHY HULLING STUDIES

by

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The undersigned hereby certify that they have read and recommend to the Committee on Graduate Studies for acceptance, a dissertation on "Timothy Hulling Studies" submitted by Jos. Ficht, B.Sc., in partial fulfilment of the requirements for the degree of Master of Science.

Edmonton, May 1926.

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A THESIS

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INTRODUCTION

Growers of timothy seed have often experienced difficulty in securing a satisfactory grade for their seed owing to the loss of hulls during threshing. This has been especially noticeable in western Canada. It is commonly remarked that western-grown timothy seed is exceptionally plump; but this fact only tends to increase the loss of hulls. An analogous condition exists in the case of oats, where western-grown seed has a marked tendency to plumpness, but also loses a considerable percentage of the hulls during threshing.

Alberta farmers have been urged from time to time to engage in timothy seed production. It has been thought possible to supply profitably part of the Canadian demand for seed, most of which has formerly been supplied by the United States. Accordingly, farmers in several districts have grown timothy seed for market. In one case, at Pincher Creek, Alta., the timothy seed producers have formed an association. However, hulling of the seed has caused considerable discouragement in this district, although the quality of seed in other respects has been quite satisfactory.

The work reported herein has been carried on at the University of Alberta with the object of securing a better

understanding of the nature of the problem; and of devising if possible, practical means of control.

OUTLINE OF THE PROBLEM

Terms used:

In accordance with the report of the Committee on Standardization of Descriptive Terms, etc., (Scientific Agric. 4(8):242-246, Apr. 1924)

Hulled seed is taken to mean seed which has retained the hull.

Hulless seed is taken to mean seed from which the hull has been removed. These meanings will be implied throughout this thesis.

Seed grade requirements:

The following limits for percent hulless seed were set by the Canada Seeds Act of 1923:-

Grade	Max. % hulless (#)
Registered	10
Extra No.1	15
No. 1	25
No. 2	60
No. 3	100

Western Canada growers fround difficulty in getting a satisfactory grade for their seed under these regulations. It was thought advisable to amend the regulations in 1924.

(#) The term "hulled" is used in the Seeds Act with the same meaning as the term "hulless" in this thesis.

Therefore an extra 10% hulless was permitted in No. 1 and an extra 5% in No.2 seed from western Canada, the origin of such seed to be designated by the letters C.W. These regulations are still in force (1925 regulations), but the problem of hulling continues to be a source of trouble for the Alberta grower.

Lines of investigation;

The experimental work on this problem may be briefly described under the following headings:

I. An experiment to determine the relative value of hulled and hulless seed from a practical standpoint, and thus to ascertain in how far the present grades are justifiable.

II. Experiments to determine the differences in hulling which might exist in crops grown from seed from various sources; and to investigate the possibility of selecting pure strains which would retain the hull.

III. Tests of practical methods for reducing the loss of hull, including:

Curing samples in atmospheres of different humidities (on a small scale under carefully controlled conditions).

Cutting at various stages of maturity.

Curing for different periods, and exposure to weathering.

Adjusting the machine in different ways during threshing.

EXPERIMENTAL PART

I. Relative Value of Hulled and Hulless Seed.

All the seed used in this experiment was secured from Calgary. It was grown in 1919 and graded No.2 by the Dominion Seed Laboratory at Calgary. This sample contained 50 per cent of hulless seed.

Since the beginning of this experiment the seed has been stored in the experimental field barn. Samples have been taken each year for experimental purposes. These have been separated into lots of hulled seed, hulless seed and lots of the original mixture. From these lots yearly comparisons have been made of the per cent germination in the laboratory and in the field. In addition to this, each year rows from each lot have been seeded in the field in triplicate to make comparisons of the hay yield and general quality of the crop.

Laboratory germination tests.

The original test of the mixed seed, made by the Dominion Seed Branch at Calgary, gave 97.0 per cent germination in 6 days. An official test was made again in March 1926 with the following results after a 10-day test:

hulled seed	95%
original mixture	88%
hulless seed	71%

The loss of 9 per cent in the viability of the mixed seed corresponds quite well with the findings of Sifton (11), but this loss is not as great as would be expected according to the re-

sults of Dorph-Peterson (3). However, Sifton's results seem to agree more generally with various other longevity tests.

The details of the germination counts made in the laboratory at the University from 1920 to 1926 are shown in the following table:

Table 1.

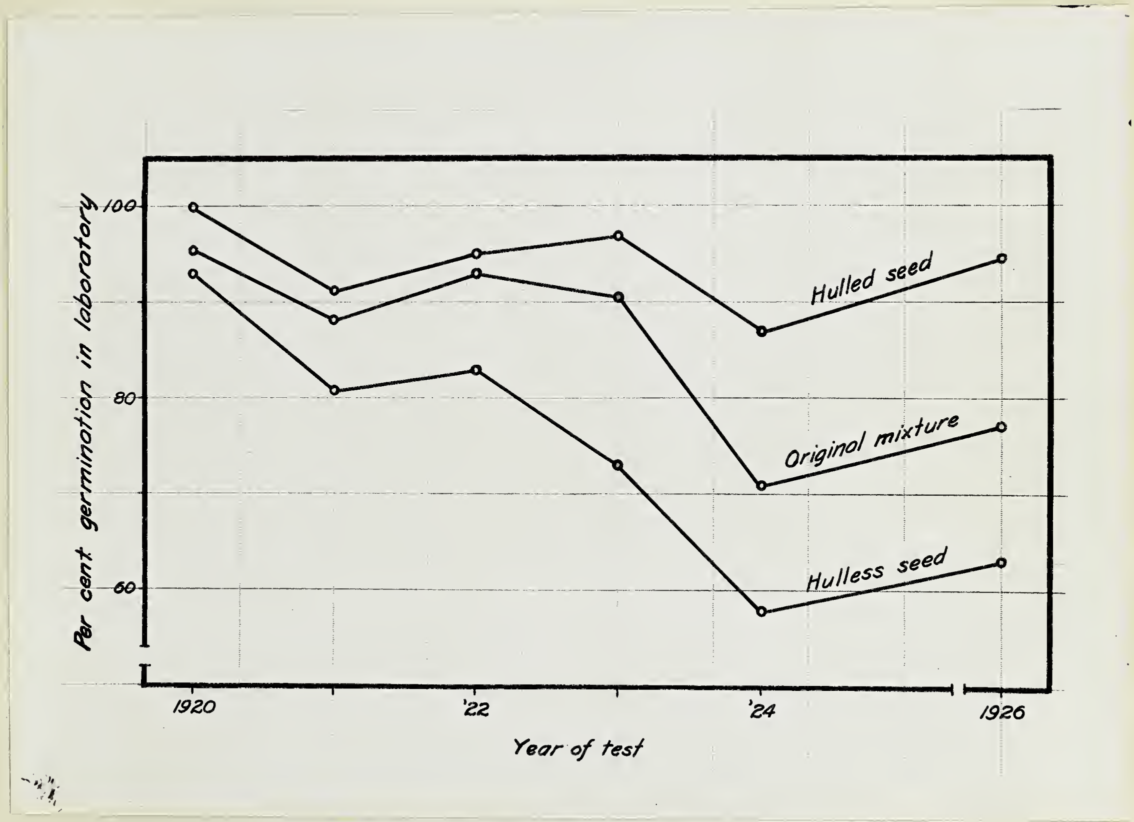
Per cent germination in laboratory of lots of seed selected from the same sample in successive years.

Year	Orig. mixture		Hulled seed only		Hulless seed only	
	5 day count	10 day count	5 day count	10 day count	5 day count	10 day count
1920	94.0	95.5	98.5	100.0	92.5	93.0
1921	67.0	88.3	74.3	91.3	76.3	80.7
1922	85.8	92.8	91.5	94.8	78.2	82.8
1923	61.8	90.5	54.2	96.8	45.8	73.0
1924(#)	52.5	70.8	70.0	87.0	52.8	57.8
1926	62.5	77.2	82.0	94.5	50.2	63.0

(#) Results for 1924 are for 6 and 12 day counts.

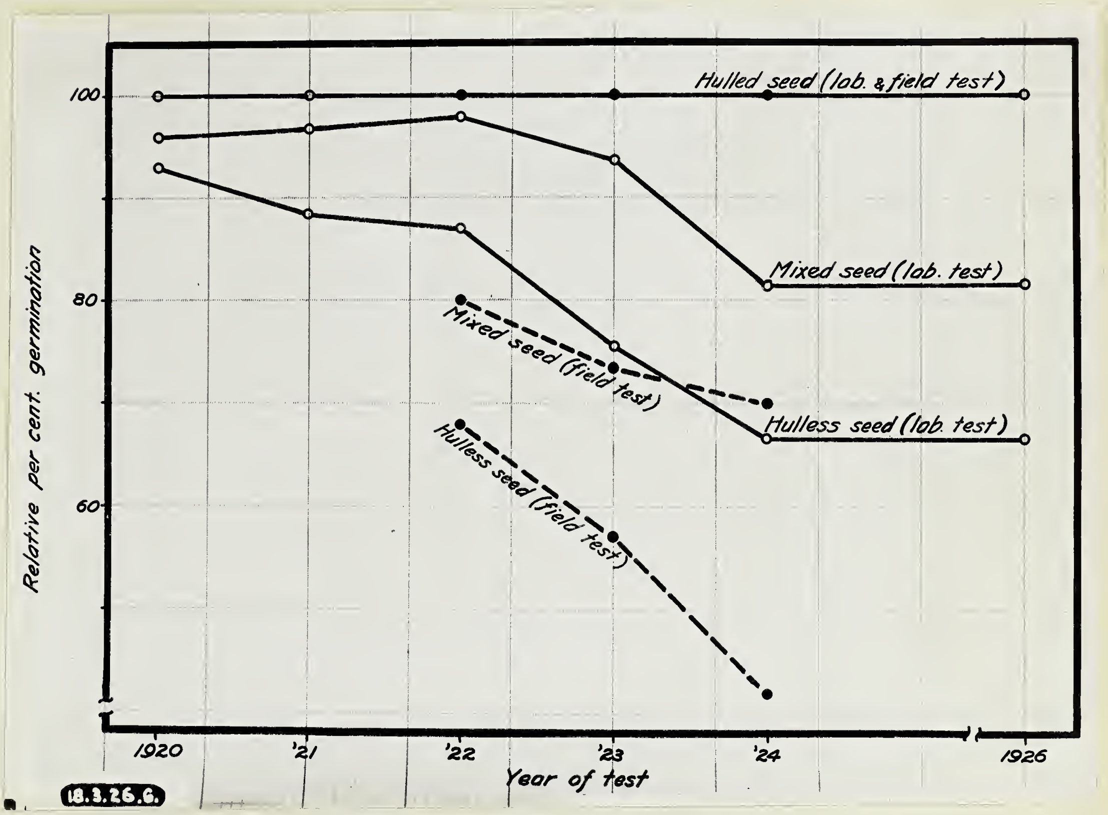
The 10-day counts from Table 1 are shown graphically in fig. 1. The failure of successive annual germination percentages to fall on a straight line is, no doubt, partly accounted for by the lack of accurate temperature and moisture controls on the germinator employed. However, the results show an interesting relation between the retention of viability in the different kinds of seed, which arrange themselves plainly in the order: hulled, mixed, hulless.

Figure 1.



Change in viability of hulled, hulless and mixed timothy seed, from the same sample. (Laboratory tests.)

Figure 2.



Changes in relative viability of hulled, hulless and mixed timothy seed, selected from the same sample. (Laboratory and field tests.)

This relation is brought out more plainly in Fig. 2 where the same data are rearranged to show the relative changes in viability. The germination of the hulled seed is taken as 100 each year; and the germinations of the other lots are expressed as percentages of that of the hulled seed for the same year. This arrangement of the data shows a marked tendency of the hulless seed to lose its viability more rapidly than the hulled seed; with the original mixture in an intermediate position as would be expected.

Field germination tests.

Counts of the field germination of hulled, hulless and mixed seed were made in the years 1921 to 1924 inclusive. The counts were made in the triplicate rows of each kind of seed which were planted each year. Three counts of spaces 2 feet long were made in each row, or a total of 18 feet for each sort. The number of seeds planted per foot was calculated from the rate of seeding and the weight per thousand kernels of each sort. The ratio $\frac{\text{av. no. of plants per ft.}}{\text{no. of seeds per ft.}}$ gives the field germination.

The results of the field germination counts are given in Table 2.

Table 2.

Per cent germination in the field of lots of seed selected from the same sample in successive years.

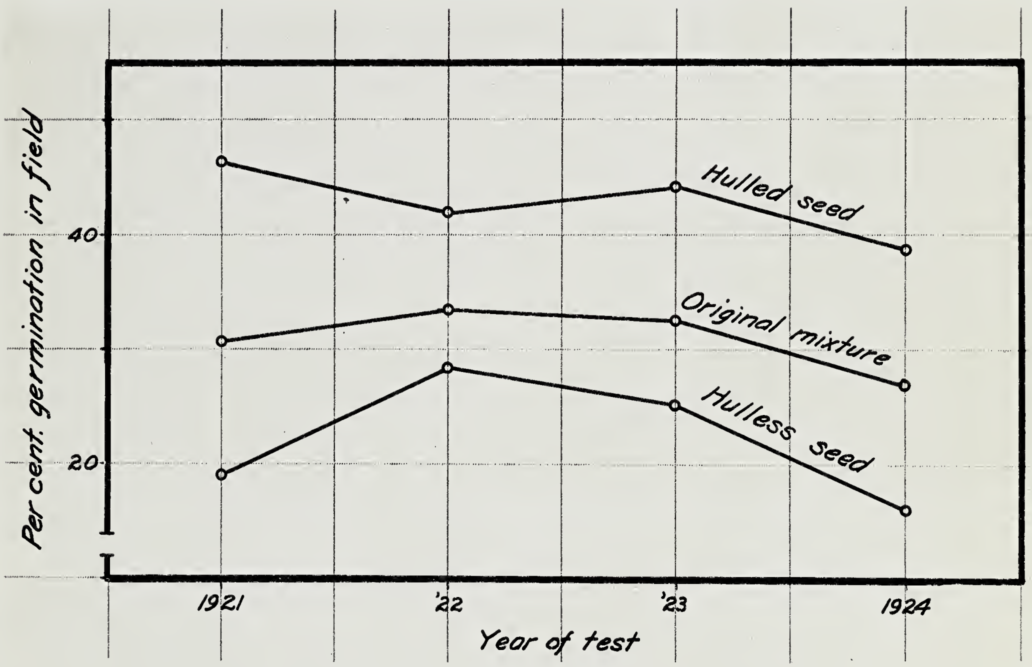
Year	Per cent germination Original mixture	Hulled seed only	Hulless seed only.
1921	30.7	46.5	19.0
1922	33.5	41.9	28.5
1923	32.6	44.2	25.2
1924	27.1	38.8	16.2

A statement is made in the 1921 field notes, that at the time of counting a number of tiny shoots were observed in the "hulless" rows, which appeared to be only a few days old, also a very few in the rows of "original mixture". This probably accounts for the comparatively low germination of these two lots. Unsatisfactory soil conditions must have been the cause of this delayed germination. The hulled seed, being more vigorous, had evidently succeeded in coming above ground before the count was made.

The field germination data are shown graphically in Fig. 3. Again we must expect deviations from a straight line relationship owing to variable soil conditions from year to year. However, with the exception of the results for 1921, in regard to which the field note quoted in the preceding paragraph seems to offer an adequate explanation, the figures for the remaining 3 years show a relative decrease in viability of the three lots, which agrees quite well with the results of the laboratory germination trials.

On examining Fig. 2 the relative difference in germination

Figure 3.



Field germination of hulled, hulless and mixed timothy seed, selected from the same sample.

of hulled and hulless seed is seen to be much greater in the field tests than in the laboratory tests. This would indicate that the differences in vigor of hulled and hulless seed, which show up fairly well in the laboratory, are greatly accentuated under field conditions. This non-agreement of field and laboratory tests is in harmony with the general findings of W.H. Wright (12), who observed fairly great differences between laboratory and field germination, especially in the grass seeds.

The difference in stand could be readily noticed in the seedling stage. For a short time the rows from hulled and mixed seed would appear much better than the rows from hulless seed. However, as the plants became larger and began to tiller these differences soon disappeared. This is further shown by the data for hay yield which will be discussed now.

Yield of hay from hulled, hulless and mixed seed.

The triplicate rows seeded each year were left down until 1925. The yield of hay was taken each year. The results are shown in Table 3.

Table 3.

Relative value of hulled and hulless seed.
Hay yields 1921 - 25 (Green wt. tons per acre)

Year	Year of seeding	Averages for triplicate rows		
		Orig. mixture	Hulled seed only	Hulless seed only
1921	1920	4.76	5.67	5.13
1922	1920	0.69	0.66	0.67
1922	1921	1.58	1.66	1.59
1923	1920	3.99	4.24	4.23
1923	1921	6.06	6.18	6.56
1923	1922	9.54	9.91	9.39
1924	1920	0.96	0.99	0.96
1924	1921	1.31	1.31	1.30
1924	1922	2.41	2.22	2.41
1924	1923	3.33	2.99	2.90
1925	1920	2.10	2.14	2.05
1925	1921	2.43	2.41	2.41
1925	1922	3.82	3.94	4.15
1925	1923	7.14	6.96	6.69
1925	1924	6.35	6.60	6.00
Average		3.765	3.859	3.763

The odds have been calculated by Student's Method(#) for the difference in yield from the hulled and hulless seed. The following values were obtained: N=15; Z=0.36. Hence the odds are approximately 9:1 that the difference is not due to chance variations. Very little importance can be attached to a difference giving such small odds.

(#) See section on experimental and statistical methods.
3 decimal places were used in calculating Z.

Per cent hulling in seed crop from hulled, hulless and mixed seed.

This part of the experiment was undertaken not because any difference in hulling tendency was expected, but to answer definitely any doubt which might exist as to the practical working of this system of seed selection, which might be considered as a form of mass selection. However, other work reported in this thesis will show that hulling is not sufficiently affected by hereditary influences to show any results from mass selection methods.

In 1925 a short portion of each row was allowed to ripen for seed. These samples were threshed and the per cent hulless counted. Details in regard to threshing and counting will be found in the section on experimental and statistical methods. The results are given in Table 4.

The greatest difference in average per cent hulling is shown between the crops from hulled and hulless seed. However no significance can be placed on this difference, as the odds by Student's method are only 7:1 against the difference being due to chance. On examination of the data in column (x-y), it is seen that most of this difference is due to the samples from the 1920 planting. The large differences in these samples are undoubtedly due to chance errors, as the stand was very poor in these oldest rows and the samples were consequently too small for accurate work. Disregarding the 1920 planting the odds would be in favor of the crop from hulless seed showing the larger per cent hulling; which might seem to agree

Table 4.

Per cent hulless seed in crop from lots of hulled, hulless and mixed seed selected from the same sample.

Year of planting	Row no.	%Hulless from orig. mixture	Row no.	% Hulless from hulled seed (x)	Row no.	% Hulless from hulless seed (y)	(x-y)
1920	1	40.6	2	57.1	3	24.1	33.0
1920	4	45.9	5	47.2	6	29.1	18.1
1920	7	42.3	8	50.6	9	26.9	23.7
1921	1	40.3	2	44.3	3	46.8	-2.5
1921	4	41.3	5	42.5	6	41.0	1.5
1921	7	35.6	8	35.2	9	36.8	-1.6
1922	1	34.4	2	32.8	3	37.9	-5.1
1922	4	29.7	5	29.4	6	36.7	-7.3
1922	7	26.7	8	27.4	9	30.8	-3.4
1923	1	37.7	2	46.9	3	42.4	4.5
1923	4	43.2	5	38.5	6	37.9	0.6
1923	7	51.5	8	38.0	9	40.1	-2.1
1924	1	27.8	2	32.7	3	27.2	5.5
1924	4	28.1	5	26.8	6	33.0	-6.2
1924	7	27.6	8	25.4	9	29.0	-3.6
Averages		36.8		38.3		34.6	

Comparing "hulled seed" and "hulless seed" by Student's method - $N = 15$, $Z = 0.32$

The odds are approximately 7:1 that the crop from hulled seed produced a greater per cent of hulless than the crop from hulless seed.

with expectation based on superficial reasoning. However, the results from the mixed seed do not support this view.

Discussion

The data presented show the hulless seed to have a marked tendency to lose its viability more quickly than the hulled seed.

The reason for this difference in longevity might be attributed to the hulless seed being more freely exposed to the oxygen of the atmosphere, thereby increasing respiration processes in the embryo, and possibly other chemical processes connected with after-ripening.

A somewhat analogous case has been observed with scarified and non-scarified alfalfa seed. L. F. Graber (4) compared the longevity of scarified and non-scarified alfalfa seed (5 samples each), stored for periods ranging from 2 to 4½ years, with the following results:

Average germination at start of period:

scarified seed - 86.4%, non-scarified seed -70.6%

Average germination at end of period:

scarified seed - 40.0%, non-scarified seed -74.4%

Considering the differences in both laboratory and field germination tests, the hay yields from the hulled and hulless seed are not as widely different as one would expect. This has resulted from the use of a heavy rate of seeding. The seed was sown 10 grams per row. The rows being 200 links long and 30 inches apart, the actual rate of seeding was 2.93 lbs. per acre. The same rate of seeding in 6 inch drill rows would

amount to nearly 15 lbs. per acre. While this rate might be necessary to secure a stand under broadcasting conditions; a perfect stand should be secured with a much lighter rate where the seeding is done as carefully as in this experiment. Therefore the observed differences in germination would undoubtedly affect the stand of the crop if a light rate of seeding was used.

Another factor in determining the relative value of seed is its appearance. The appearance of hulless seed is objectionable to most people. This may be partly a fad, but there is also a practical consideration involved. Many common weed seeds, e.g., Tumbling Mustard, are quite noticeable in a sample of timothy which is free from hulless seed; whereas they would only be found on careful examination of seed samples which are partly hulless.

The above considerations would suggest that the per cent hulling deserves some consideration in setting seed grades. However, the present regulations seem quite fair in this respect. Therefore it becomes the problem of the seed grower to reduce the percentage of hulless seed in any way possible.

II. Experiments Related to Varietal Differences in Percentage Hulling.

The data for this section have been derived from a plant breeding block of individual plants and a row test of different strains of timothy. Seed of the strains used was furnished by the Dominion Seed Laboratory at Calgary, the McDonald College, and the Murray Seed Company

Plant breeding block.

The plant breeding block consisted of from 70 to 262 plants of each of 15 strains spaced 32 inches each way. These plants were started in the greenhouse from seed and were set out during July 1919. Records were kept of various characters of each plant during 1920 and 1921. In addition to this the seed was threshed from each plant separately and the per cent hulless seed estimated.(#)

From this data an attempt has been made to answer the following questions:

1. Do different strains possess inherent differences for loss or retention of the hull?
2. Would pure line selection of plants showing low per cent hulless seed be of any value in producing strains resistant to hulling?

In answering the first question several points must be considered. In deciding how significant any observed difference in the average per cent hulless of two strains may be

(#) For description of technique see section on experimental and statistical methods.

it is necessary to know the degree of variability of each strain. However, there is another factor which should be considered first. One should know how closely the data of one year will compare with the next year's data from the same plants.

It has been shown by C. F. Clark (2) that yearly climatic changes may alter the relative standing of a group of plants with respect to any character. This yearly variation in the data may be shown by correlating the measurements of a character for one year with the measurements of the same character for the next year.

Tables 5 to 14 show such correlations for two characters, "length of head" and "height of plant". The data are given for 4 strains, each of which is, of course, presented separately.

Table 15 gives a summary of the results from Tables 5 to 14.

Fig. 4 (page 29) shows the lines of regression for the correlation data of Table 9. An examination of this figure shows the data to be quite well represented by a straight line relationship. Therefore, the ordinary coefficient of correlation may be considered as applying fairly well to these data. However, one should note the fact that many of the frequency distributions,(in columns labelled f), bear no resemblance to the normal curve of probability. Therefore, the values given for probable errors of the correlation coefficients are in many cases too low.

Table 5.

Correlation, "Length of heads" 1920 with 1921.
(Seattle #3296)

Length of head inches 1920

Length of head inches 1921.	2.0	2.5	3.0	3.5	4.0	4.5	5.0	5.5	6.0	6.5	7.0	7.5	f
1.0			2	2	3	1							8
1.5	1	1			15	2	13	1			1		34
2.0			2	3	12	14	26	8	9				74
2.5					5	3	9	7	10		1	1	36
3.0					1	2	10	4	1		1		19
3.5									2				2
	1	1	4	5	36	22	58	20	22		3	1	173

$r = 0.429 \pm 0.042$

Table 6.

Correlation, "Length of head" 1920 with 1921.
(Svalöf #523)

Length of head inches 1920

Length of head 1921.	1.5	4.0	4.5	5.0	5.5	6.0	6.5	7.0	f
1.5		1			1				2
1.75			1	2	1	1			5
2.0			6	4		1			11
2.25		2	3	6	2	4		1	18
2.5		1	1	7	2	3			14
2.75	1	2	4	9	2	3			21
3.0			2	4	2	4			12
3.25				2		2			4
3.5									
3.75								1	1
4.0						1			1
f	1	6	17	34	10	19		2	89

$r = 0.204 \pm 0.068$

Table 7.

Correlation, "Length of heads" 1920 with 1921.
(Lacombe #6290)

Length of head inches 1920

Length of head 1921.	3.0	3.5	4.0	4.5	5.0	5.5	6.0	6.5	7.0	f
1.0					2					2
1.25										
1.5				1	2					3
1.75			1	8	5		4			18
2.0	2	2	2	5	13	2	2	1	1	30
2.25			3	4	11	1	1			20
2.5		1	1	4	8	3	3			20
2.75			6	5	11	2	9	3	1	37
3.0			3	1	5		3	1		13
3.25			3		1	1	1			6
f	2	3	19	28	58	9	23	5	2	149

$r = 0.107 \pm 0.055$

Table 8.

Correlation, "Length of head" 1920 with 1921.
(Primus #12)

Length of head inches 1920

Length of head 1921.	2.5	3.0	3.5	4.0	4.5	5.0	5.5	6.0	6.5	7.0	f
1.25				1							1
1.5		1	2	1							4
1.75		1	2	9	4	6	2				24
2.0		2	3	11	8	11	3	6			44
2.25		1		4	4	9		3			21
2.5						4	1				5
2.75	1						1			1	3
3.0							1				1
f	1	5	7	26	16	30	8	9		1	103

$r = 0.340 \pm 0.059$

Table 9.

Correlation. Height of plants 1920 with 1921.
(Seattle #3296)

Height of plant 1920 (columns); Height of plant inches 1921 (rows).

	32	34	36	38	40	42	44	46	48	50	52	54	56	58	64	f
30	1				4	3	2	2								12
32			1	4	2	6	9	1	1							24
34		1	1	2	3	11	11	14	4							47
36		1		1	3	7	6	7	5	4	2	1				37
38				2		3	5	9	10	3	3		1		1	37
40						1	3	2	4	1	1					12
42									1	1						2
44										1			1			2
f	1	2	2	9	12	31	36	35	25	10	6	1	2		1	173

$r = 0.488 \pm 0.039$

Table 10.

Correlation. Height of plants 1920 with 1921.
(Svalöf #523)
(Using 1 inch class intervals)

Height 1920

	14	36	37	38	39	40	41	42	43	44	45	46	47	48	49	52	f
30							1										1
31																	
32		1						1			1						3
33			1			1	1			1			1				5
34	1				1		4		2	1		2					11
35			1	1	1	3	3	2	1	2	1		1		1		17
36				1		2	2	2	2	1	2	2	2				16
37						1	1	1	1	1	2	1	2	1			11
38				1		1	1	1	2	1		3			1		11
39									1	2	1	1	1	1			7
40								1								1	2
41											1	1		1			3
42														1	1		2
f	1	1	2	3	2	8	13	8	9	9	8	10	7	4	3	1	89

$r = 0.395 \pm 0.060$

Table 11.

Correlation. Height of plants 1920 with 1921.
(Svalöf #523)
(Using 2 inch class intervals).

Height 1921.	Height 1920										
	14	36	38	40	42	44	46	48	50	52	f
30					1						1
32		1			1		1				3
34	1(#)		1	2	5	4	2	1			16
36			3	6	9	6	5	3	1		33
38			1	2	4	5	6	3	1		22
40					1	3	2	2		1	9
42							2	2	1		5
f	1	1	5	10	21	18	18	11	3	1	89

$r = 0.376 \pm 0.061$
(#) (including plant which was 14 inches tall in 1920)

$r = 0.414 \pm 0.060$
(#) (excluding plant which was 14 inches tall in 1920)

Table 12.

Correlation. Height of plants 1920 with 1921.
(Lacombe #6290)

Height of plant 1920

Height of plant 1921.	36	38	40	42	44	46	48	50	52	54	f
30		1	1	1	2	1					6
32	1	2	1	4	4	4	2	1			19
34	1		2	5	4	11	6	5			34
36	1	1	3	5	4	11	6	6		1	38
38				2	3	4	7	6	4	1	27
40				1	2	4	3	2	2		14
42					1		3	4	1	1	10
44							1				1
f	3	4	7	18	20	35	28	24	7	3	149

$r = 0.442 \pm 0.044$

Table 13.

Correlation. Height of plants 1920 with 1921.
(Primus #12).

Height of plant 1920

Height of plant 1921.

	30	32	34	36	38	40	42	44	46	48	50	52	54	f
30					1									1
32				1	3	1	1		1					7
34				1	2	4	3	3	4	1				18.
36					5	6	4	4	4	1				24
38				2	2	3	3	7	4	2	2		1	26
40	1					3		6	4		1	1		16
42					1		1	1	3					6
44											2			2
46									1				1	2
48												1		1
f	1			4	14	17	12	21	21	4	5	2	2	103

$r = 0.426 \pm 0.054$

Table 14.

Summary of correlations showing yearly variations.

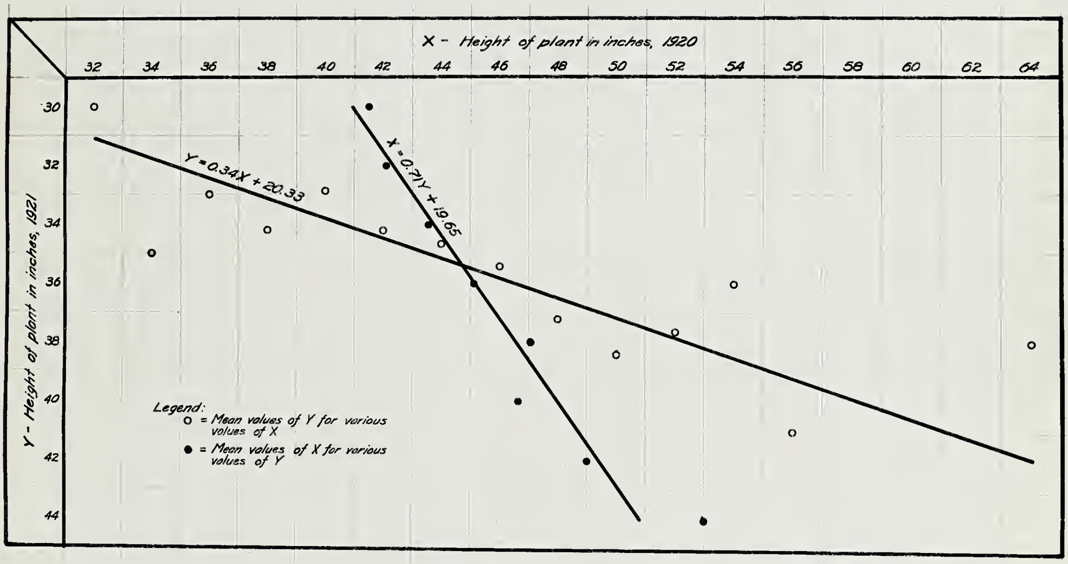
"Length of head" 1920 with 1921.

Strain	Coeff. of Corr. (r)
Seattle #3296	0.429 ± 0.042
Svalöf #523	0.204 ± 0.068
Lacombe #6290	0.107 ± 0.055
Primus #12	0.340 ± 0.059

Height of plant in inches 1920 with 1921

Strain	Coeff. of Corr. (r)
Seattle #3296	0.488 ± 0.039
Svalöf #523	0.395 ± 0.060 (using 1" class intervals)
Svalöf #523	0.376 ± 0.061 (using 2" class intervals)
Svalöf #523	0.414 ± 0.060 (using 2" class intervals and discarding 14" plant 1920).
Lacombe #6290	0.442 ± 0.044
Primus #12	0.426 ± 0.054

Figure 4.



Regression lines. Height of plant 1920 with 1921. From Table 9.

From the foregoing results it may be seen that the comparison between plants changes markedly from year to year. If the plants did remain in the same relative standing regarding length of head and height of plant, perfect correlations (1.0) would result.

However, the magnitude of the correlation coefficient depends upon the accuracy of the data as well as upon the real expression of the characters by the plants. This, no doubt, partly accounts for the low values obtained in correlating 2 years' results for length of head. The length of head, as reported, is a rough average for all the heads on the plant, which was of necessity quickly estimated. Obviously these values must include fairly great errors. Height of plant is subject to more satisfactory measurement, but even here difficulties are involved.

The "probable error" does not take account of these errors in measurement.

In this connection the differences obtained by dropping 1 plant from Table 11 should be noted. This plant differed widely from all the others in 1920.

By dropping this plant "r" (coefficient of correlation) is increased by 0.038, while a difference of only $\pm$0.001 occurs in the P.E. (probable error). From this it is seen that the P.E. is not sensitive to errors which might occur in the experiment; while the same errors might influence r considerably. Hence, unless one is working with characters

subject to accurate measurement, the correlation may be obscured by the inaccuracy of the data.

Therefore, while the correlations in the foregoing tables are at best quite low, we may safely presume that they really should be somewhat higher than shown by these data.

Only one year's results have been recorded for per cent hulless of these individual plants. The possible yearly variation of this character will, therefore, be discussed later in the light of the characters just dealt with, and of other data.

Before comparing the per cent hulless seed of different strains, we should examine their differences in respect to other characters which are more easily evaluated. Tables 15 to 20 show the frequency distributions and derived values for "date of bloom", "length of head", and "height of plant".

In comparing the mean values of the strains for these characters, it is seen that many of the differences are quite significant; providing we have sufficient data to warrant the application of the "probable error" method of comparison.

Figs. 5 and 6 show the type of frequency curve obtained from the data given.

The P.E. is a value based on the "normal curve of probability"; such that the "P.E.s" (probable error of a single determination) gives a range on each side of the mean which will include one half the total number of variates. A glance will show such a determination to be a poor approximation when applied to the curves given. Therefore, it cannot be said

with certainty that any of the differences observed are significant, even though they are several times as great as the P.E.

In comparing the mean per cent hulless seed (Tables 21 and 22), it is seen that all strains up to #5 compare very closely, with a change between #5 and #6. Strains 6 to 15 compare closely. This change between #5 and #6 may have been caused by different previous management of the soil; or by weather conditions interfering with the harvest at this point. Considering this difference (between #5 and #6) as due to growth or management conditions; most of the remaining differences are not of much significance when compared with their probable errors.

However, in comparing strains #10 and #13 a difference occurs of 9.6% ± 1.35 (#). With the ordinary interpretation of the P.E., the odds that this difference is significant would be high. But the sources of error in determining per cent hulless seed are more numerous than in determining height of plant, etc. We must also consider the limitations of the P.E. concept, as previously mentioned in regard to Figs. 5 and 6. Hence, we must conclude that the data do not demonstrate any differences in the mean per cent hulling of the strains tested.

(#) For the error of a difference use the square root of the sum of the squares of the errors.

Table 15.

Frequency distributions. Date of bloom 1921.

Strain no.	Date of bloom July 1921																				N
	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	19	23	
	Frequencies																				
1.Pincher Creek #167					1	8	28	33	20	10	10	29	9	4	3						155
2.Seattle #5976							1	5	30	37	19	55	27	5	5						184
3.F.C.I. #1045						1		5	36	13	19	41	30	7	4						156
4.Seattle#3296				1	13	16	1	7	33	1	18	47	25	11							173
5.Svalöf #523	1	1		2	15	15		3	22	1	14	14	1								89
6.Bridesville #9304		1			4	9		6	26	3	11	53	30	9	4			1	1		158
7.Lacombe#6290					2	4	1	2	16	9	8	45	45	7	8	2					149
8.Fort.Sask. #7454					1	6		7	31	1	5	42	40	18	6	5	1			1	164
9.Murray Seed Co.					2	1		4	5	1		7	17	15	3						55
10.Ottawa Standard		1			2	5		2	10		4	30	27	10	6						97
11.Seattle#1424					3			10	8		3	12	20	11	5		1				73
12.Primus #12						1		9	13		2	20	27	25	2	2	2				103
13.Primus					1	5		7	7		8	19	30	24	5	1	1	1			109
14.Primus #19						4		3	12		4	24	15	6	2						70
15.Strathmore #6099						1		4	12		3	16	17	7	3						63

Table 16.

Date of Bloom July 1921.

Determinations from preceding table of frequency distributions.

Strain No.	No. of plants	Mean date of bloom July	Error of mean (±)	Standard deviation	P.E. of single determination (±)
1	155	8.48	0.128	2.356	1.590
2	184	10.15	0.082	1.651	1.114
3	156	10.21	0.097	1.805	1.217
4	173	9.27	0.140	2.722	1.836
5	89	7.35	0.201	2.809	1.895
6	158	10.13	0.139	2.586	1.744
7	149	10.77	0.116	2.099	1.416
8	164	10.76	0.134	2.555	1.723
9	55	11.05	0.230	2.526	1.704
10	97	10.68	0.172	2.518	1.698
11	73	10.64	0.208	2.635	1.777
12	103	11.17	0.150	2.253	1.520
13	109	11.13	0.159	2.457	1.657
14	70	10.39	0.176	2.186	1.475
15	63	10.67	0.178	2.093	1.412

Table 17.

Length of head inches 1921, frequency distributions.

Strain No.	0.75	1.0	1.25	1.50	1.75	2.0	2.25	2.50	2.75	3.0	3.25	3.75	4.0	N
	Frequencies													
4	1	7	11	23	29	45	27	9	12	7	2			173
5				2	5	11	15	17	21	12	4	1	1	89
7		2		3	19	30	20	20	36	13	6			149
12			1	4	24	45	19	6	3	1				103

Table 18.

Length of head inches 1921.

Determinations from frequency distributions of Table 17.

Strain no.	No. of plants	Mean length of head.	Error of mean (±)	Standard deviation	P.E. of single determination(±)
4	173	1.97	0.026	0.498	0.336
5	89	2.52	0.033	0.460	0.310
7	149	2.36	0.026	0.471	0.318
12	103	2.02	0.019	0.285	0.192

Table 19.

Frequency distributions. Height of plant inches 1921.

Height of plant inches 1921.

Strain no.	29	30	31	32	33	34	35	36	37	38	39	40	41	42	43	44	45	46	47	N
	Frequencies.																			
4.	4	8	11	13	20	27	21	16	21	16	8	4	2		2					173
5.		1		3	5	11	17	16	11	11	7	2	3	2						89
7.	1	5	5	14	12	22	16	22	16	11	7	7	7	3	1					149
12.		1	2	5	9	9	11	12	15	12	7	9	3	3	2			2	1	103
Rows adj. to strain 12.																				
39-40	2	3	1	4	12	6	10	5	9	9	1	6	3		2					73
44-45		2	6	7	5	8	8	6	8	8	3	3	3	1			1			69

Table 20.

Height of plant inches 1921.
Determinations from frequency distributions of Table 19.

Strain no.	No. of plants	Mean height of plant.	Error of mean.(±)	Standard deviation.	P.E. of single determination.(±)
4	173	34.84	0.146	2.856	1.927
5	89	36.19	0.167	2.331	1.572
7	149	35.55	0.165	2.984	2.013
12	103	36.80	0.217	3.269	2.205
Rows adjacent to strain 12.					
39-40	73	35.62	0.253	3.204	2.161
44-45	69	35.51	0.260	3.206	2.162

Table 21.

Per cent hulless seed in 1921, frequency distributions.

Strain no.	10	20	30	40	50	60	70	80	90	100	Total no. of plants
					Frequencies						
1		2	2	6	11	29	28	34	31	12	155
2	1		5	4	16	47	40	38	23	10	184
3		1	3	3	14	32	30	37	27	9	156
4	1	1	2	8	9	27	37	48	34	6	173
5			1	3	8	17	20	20	14	6	89
6	1		1	3	7	23	25	39	44	15	158
7	2		3	4	5	16	14	28	47	30	149
8	1	1		2	7	13	15	32	46	47	164
9				1	2	3	4	14	17	14	55
10					3	4	9	18	36	27	97
11				2	4	6	10	17	23	11	73
12			1	4	9	13	13	20	27	16	103
13			1	1	10	17	16	20	32	12	109
14					1	8	16	17	20	8	70
15					1	4	10	21	16	11	63

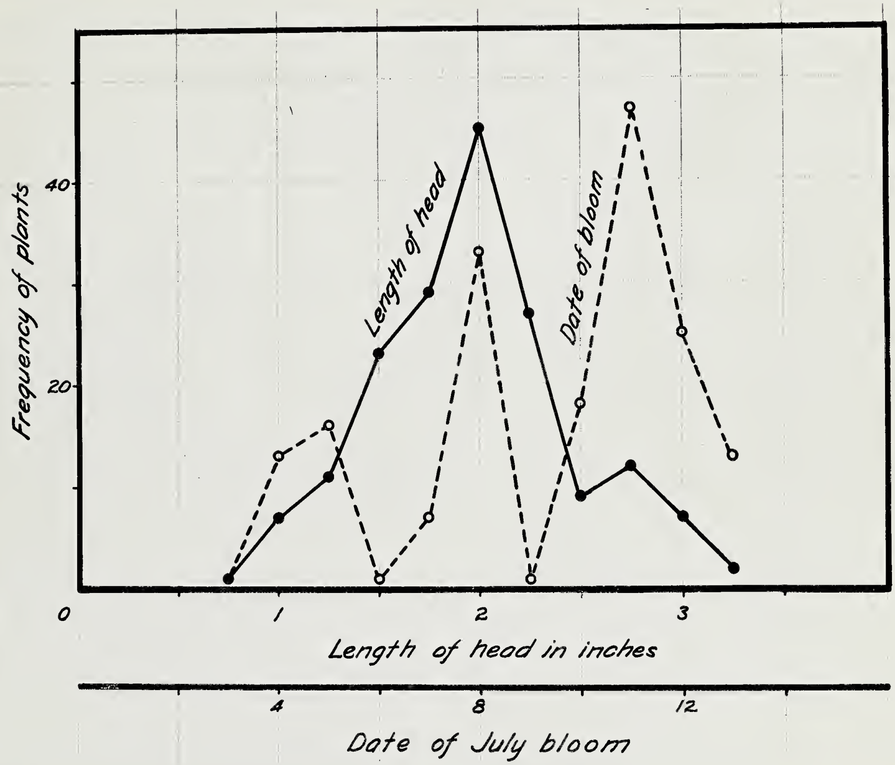
Table 22.

Per cent hulless 1921.

Determinations from preceding table of frequency distributions.

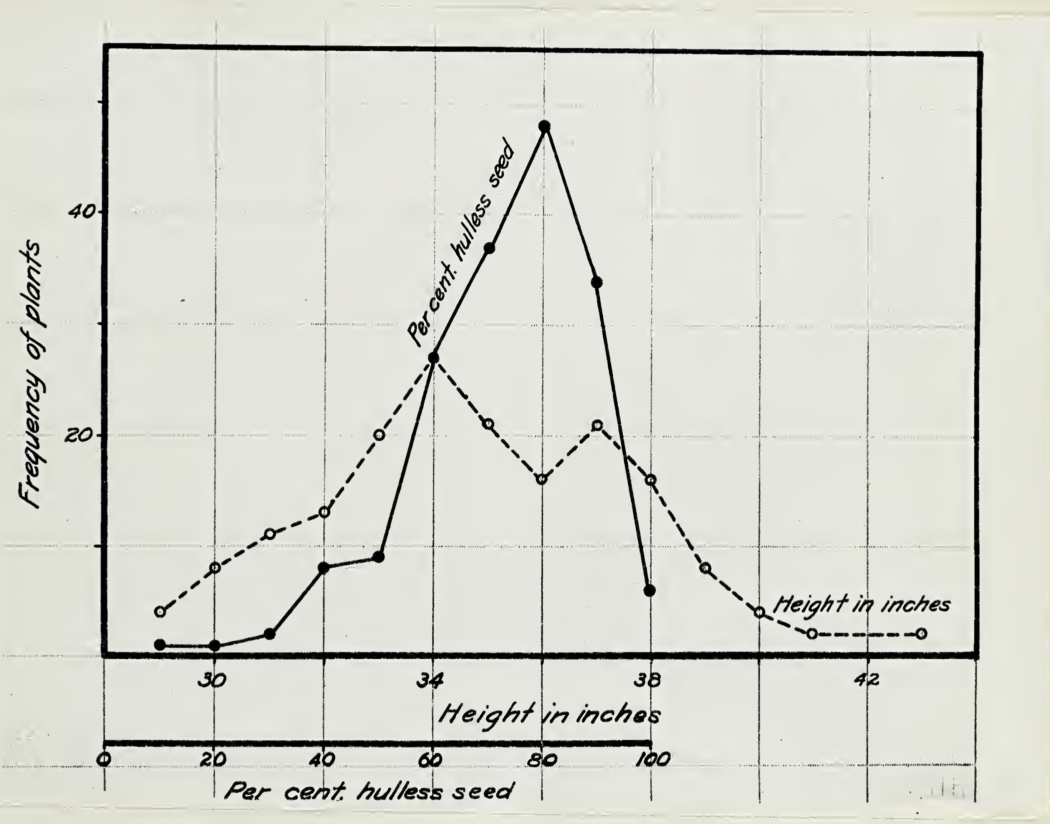
Strain no.	No. of plants	Mean per cent hulless	Error of mean(±)	Standard deviation	P.E. of single determination(±)
1	155	72.9	0.94	17.27	11.65
2	184	69.8	0.81	16.20	10.93
3	156	72.0	0.87	16.16	10.90
4	173	72.7	0.83	16.20	10.92
5	89	72.2	1.12	15.63	10.54
6	158	77.3	0.85	15.81	10.66
7	149	80.1	1.04	18.80	12.68
8	164	83.5	0.88	16.77	11.31
9	55	84.5	1.30	14.25	9.61
10	97	86.6	0.86	12.60	8.49
11	73	80.4	1.20	15.21	10.26
12	103	77.3	1.17	17.58	11.86
13	109	77.0	1.04	16.17	10.91
14	70	80.1	1.01	12.48	8.42
15	63	82.7	1.02	11.97	8.07

Figure 5.



Frequency distributions of plants in strain #4 for "length of head" and "date of bloom" 1921.

Figure 6.



Frequency distributions of plants in strain #4 for "height of plant in inches" and "per cent hulless seed" 1921.

Row Tests

The data from the row tests furnish further evidence of the similarity of all strains regarding hulling tendencies. This test included 13 check rows and rows from 60 different lots of seed, some of which represented strains which had undergone selection. The data include a record of the per cent hulless of the original seed of each strain, as well as the per cent hulless in the crops of 1919, 1920 and 1921.

Attempts were made to correlate per cent hulless of original seed with that of the 1919 crop (Table 23), and with an average of crops of 1919, '20 and '21. It was also attempted to correlate the crop of 1919 with that of 1920 (Table 24).

The results may be summarized as follows:

Correlation orig. seed with 1919 crop,	$r = -0.113 \pm 0.105$
" " " " av.1919-20-21 crops	$r = 0.164 \pm 0.126$
" 1919 crop with 1920 crop,	$r = -0.115 \pm 0.084$

This shows a decided lack of correlation in the results from year to year. Hence, we may conclude that no consistent differences in hulling tendencies exist between these strains.

This conclusion is strengthened by an examination of the results from the check rows. The 1921 results from the check rows vary from 28 per cent to 66 per cent hulless, while the results of all the other strains vary from 15 per cent to 67 per cent hulless. The check rows might easily cover the range of all the other strains if the number of checks was increased. This may be seen by arranging the check rows according to per cent hulless with class intervals of 10 per cent.

Table 23.

Correlation. Per cent hulless "original seed" with per cent hulless 1919 crop.

Per cent hulless "original seed"

Per cent hulless seed 1919 crop.	0	10	20	30	40	50	60	70	80	90	100	f
10				1								1
12				1	3							4
14					1		1	1				3
16						2						2
18	1		1					2			1	5
20								1				1
22			2		1	1						4
24			1									1
26	1					1						2
28		2		1			1					4
30		1						1				2
32	1	1	1			1		1				5
34							1					1
36						1						1
38					1							1
40												0
42						1						1
44				1		1						2
f	3	4	5	4	6	8	3	6	0	0	1	40

$$r = -0.113 \pm 0.105$$

Table 24.

Correlation. Per cent hulless seed 1919 crop with per cent hulless seed 1920 crop.

Per cent hulless seed 1920.	Per cent hulless seed 1919.								
	10	15	20	25	30	35	40	45	f
15		2							2
20			1					1	2
25	1		1		1		2		5
30	3	1	1	5	1			1	12
35	1	3	1		2	1		1	9
40		3	1		3			1	8
45			3		1	1			5
50	2	3	1	1	1		1		9
55	2	1							3
60		1	1	1					3
65		1		1	1	1			4
70			1						1
f	9	15	11	8	10	3	3	4	63

$r = -0.115 \pm 0.084$

Per cent hulless (class)	No. of check rows (frequency)
30	4
40	1
50	5
60	2
70	1
	13

Increasing the number of checks would, no doubt, increase the range of per cent hulless.

It has been amply shown that all the strains tested possessed the same hulling tendencies. However, we have not shown the individual plants all to be the same. Very little difference seems to exist in the mean values for "date of bloom", "length of head", and "height of plant" in the strains used. Even if slight differences do really exist in these means, we see that no significant difference exists between individual plants of the different strains, i.e. the "P.E.s" (probable error of a single determination) is always large in comparison to the differences in the means. Thus we see that the individuals of all strains vary widely in spite of efforts at artificial selection, and all strains contain roughly the same types of plants.

However, if selection processes were carried far enough, distinctly different types could, no doubt, be propagated. The question arises as to whether selection for a low per cent hulling would result in a strain possessing real advantages in this respect.

Attempts were made from the plant breeding data to correlate per cent hulless seed with other characters, with results as follow:

Per cent hulless seed 1921 with length of head 1921, $r = -0.117 \pm 0.051$

" " " " " " height 1921, $r = 0.134 \pm 0.050$

" " " " " " " 1921
(25 plants were selected with the same width of crown), $r = -0.088 \pm 0.134$

It seems impossible to correlate per cent hulless with any plant character. However, by correlating per cent hulless with "weight per 1000 kernels", Table 25 and Fig. 7, a coefficient of 0.497 ± 0.057(#) was secured. This result may be considered significant.

Weight per 1000 kernels may be a result of environmental conditions rather than a varietal characteristic. It is more reasonably thought of as such, since we have already failed to demonstrate definite differences between strains for such characters as height of plant. Also the check rows show a variation in weight per 1000 kernels from 0.41 grs. to 0.52 grs., while all the other strains only vary from 0.38 to 0.52 grs. This is similar to the previous observation for the

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(#) This correlation might be slightly increased by allowing for the weight of the hulls from samples containing a high percentage of hulless seed. The percentage hull (by weight) of a sample of "hulled seed" was determined by weighing, removing the hulls by rubbing, and re-weighing. The following results were obtained: Sample A, 10.06% hull, Sample B, 9.78% hull av. approx. 10% hull.

range of per cent hulless seed in this experiment. Therefore, we must consider weight per 1000 kernels and per cent hulless seed as two values varying with incidental changes in the environment, but both tending to vary in the same way.

This relation may be regarded in two ways:

1. That the variations in both values are caused by the same set of conditions; or
2. That one value (i.e. weight per 1000 kernels) varies with environmental conditions and exerts a causal influence on the per cent hulless seed.

The latter seems to be the more reasonable view, as large plump kernels would have a tendency to separate the lemma and palea.

However, we cannot hope to settle the problem of hulling on the grounds of any definite relation to size of seed. At best the correlation is small, and in the data of the experiment on "time and method of harvesting", discussed latter, an attempt at correlation of these two values failed to give significant results.

Discussion.

The wide variation of individual plants within all common strains of timothy make it difficult to demonstrate differences in the "mean" values of plant characters. Moreover, the "yearly variations" in the relative development of plants make it inadvisable to place too much reliance on one year's data. The per cent hulless seed seems to be more purely

Table 25.

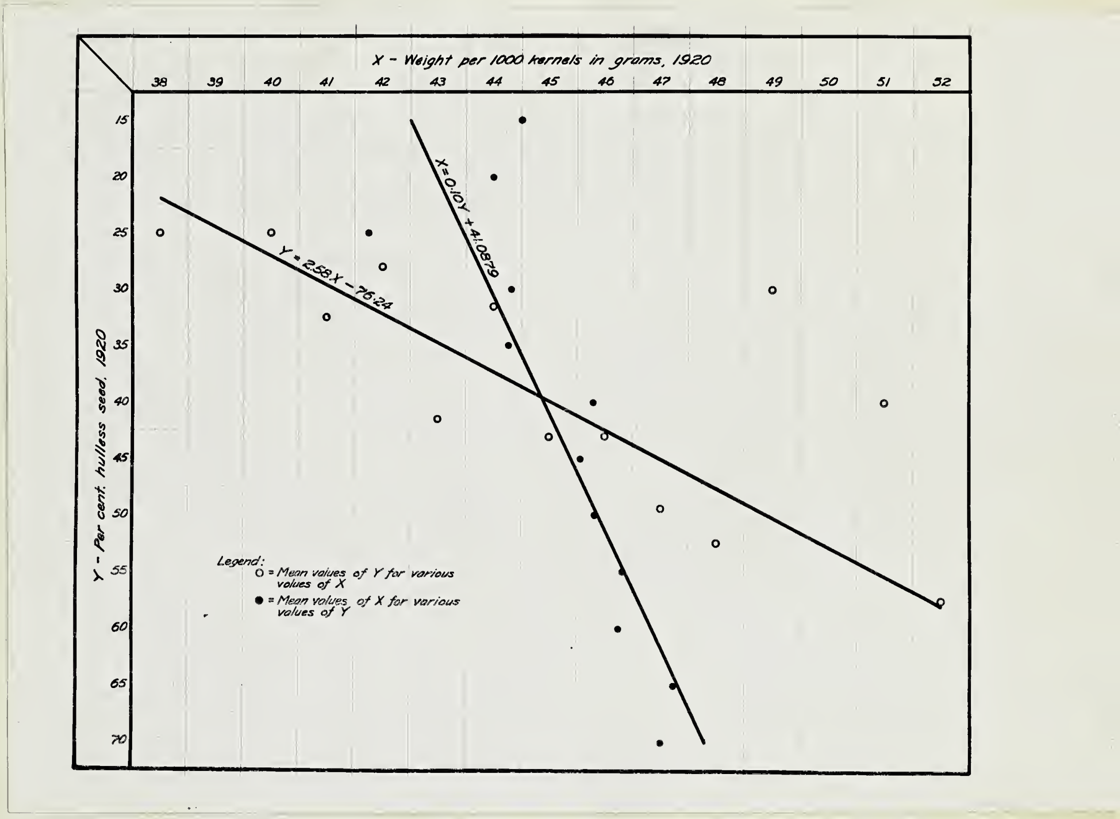
Correlation. Per cent hulless seed 1920 and weight per 1000 kernels 1920.
(Samples from row tests.)

Weight per 1000 kernels 1920 in hundredths grams.

Per cent hulless seed 1920.	38	39	40	41	42	43	44	45	46	47	48	49	50	51	52	f
15					1		1									2
20							3									3
25	1		1		3	2	1									8
30				1	2	2	4	1	4			1				15
35				1	1		5	2	1		1					11
40					1	2			4	1	1			1		10
45							2	2		3						7
50						2	1	2	3	2					1	11
55								1	1		1					3
60						1			1		2					4
65						1			1		1				1	4
70										1						1
f	1	0	1	2	8	10	17	8	15	7	6	1	0	1	2	79

$r = 0.497 \pm 0.057$

Figure 7.



Regression lines. Weight per 1000 kernels with per cent hulless seed. From Table 25.

an expression of environment than do the common characters, such as "height of plant", "date of bloom", etc. Hence, it is impossible to demonstrate differences in hulling tendencies of different strains. One might conjecture that very rigid selection would develop strains differing even in hulling tendencies. Our data do not disprove this view, but it is discouraged by the failure to correlate hulling with any common growth character. The only significant correlation obtained was between per cent hulless seed and weight per 1000 kernels, - two values which seem to be controlled by the environment.

The possibility of developing strains differing in hulling tendencies might be investigated by working with clonally propagated lines. Owing to its normal habit of cross fertilization, this is the only practical way of obtaining pure lines of timothy. Only by comparing the hulling tendencies of pure lines propagated in this way, could one definitely clear up this point.

We must conclude from this part of the work that the grower cannot, at present, obtain strains of timothy which will resist hulling. Moreover, there seems to be very little hope for improvement in this way in the future. Therefore, we must turn to the management of the crop for means of reducing the per cent hulless seed.

III. Practical Methods for Partially Controlling the Loss of Hull.

Effect of relative humidity of the atmosphere while curing.

As the problem of hulling seems to be more serious in western Canada than elsewhere, climatic influences during the curing process were thought possibly to have some effect. Consequently, an experiment was undertaken in 1925 to determine the effect of the relative humidity of the atmosphere during the curing process. In this experiment large desicators were used in which the small samples of timothy were stored before threshing. The relative humidity desired in the various desicators was obtained by using solutions of sulphuric acid calculated to give humidities as follow:

concentrated sulphuric acid	rel. hum.	0
469 c.c. acid in 1 litre of solution ...	rel.hum.	50
267 c.c. " " 1 " " " ...	" "	74
pure water	" "	100

The relative humidities of 74 and 50 were chosen to represent the mean hourly humidities of localities of the type of Toronto and Swift Current respectively. The heads of timothy for this work were selected as nearly of a uniform maturity as possible, (medium ripe), and were tied in very small bundles. This material was allowed to dry before putting it into the desicators. This fact probably makes a difference in the results obtained, as will be shown in the other experiments in this section. However, the possible effect of drying previous to re-moistening was not appreciated at the time of planning

this experiment.

The data obtained are shown in Table 26.

The data of Table 26 are not sufficient to demonstrate small differences which might exist between slightly different treatments. This fact is brought out by the wide variation between duplicate samples. Mention might be made here also of the possibility of considerable error being involved in estimating the per cent hulless seed in a sample. This is dealt with in the section on experimental methods, etc.

However, Table 26 shows a marked difference between samples which were very dry and those which were very wet at the time of threshing. But the retention of the hulls by the moist samples may depend on the fact that they were dried before being placed in the moist atmosphere. This will be shown more clearly in the following experiment.

Table 26.

Hulling in small samples of timothy cured in atmospheres of different relative humidities.

Sample no.	Treatment: 1st period July 29 to Aug.22	Treatment: 2nd period Aug.22 to Sep. 7	Date of threshing	% moisture in seed	% hulless seed	Averages
1.	R.H.100	Threshed	Aug.22	27	10	
2(a)	R.H. 74	"	" "	13	40)	31.0
(b)	R.H. 74	"	" "	12	22)	
3(a)	R.H. 50	"	" "	6	68)	67.5
(b)	R.H. 50	"	" "	6	67)	
4.	R. H. 0	"	" "	2	74	
5(a)	R.H. 74	R.H. 50	Sep. 7	6	35)	40.5
(b)	R.H. 74	R.H. 50	" "	6	46)	
6(a)	R.H. 50	R.H. 74	" "	10	71)	67.5
(b)	R.H. 50	R.H. 74	" "	11	64)	
7.	R.H.100	R.H. 0	" "	3	51	
8.	R.H. 0	R.H.100	" "	21	2	
9(a)	Dried in barn	Threshed	Aug.24	13	54)	46.5
(b)	Dried in barn	"	" "	13	39)	
10(a)	Dried in barn		Sep. 7	13	38)	42.5
(b)	Dried in barn		" "	13	47)	

R.H. = Relative Humidity.

Time and method of harvesting.

These experiments were planned to determine the effect on hulling of cutting the crop at various stages of maturity; and of handling it in different ways while curing. The first experiment of this kind was conducted during the years 1919, 1920 and 1921. An additional experiment was carried out in 1925.

The plan of the experiment as carried out in 1919, '20 and '21 may readily be seen from the first two columns in Table 27. The material was obtained from 4 rows in the row tests previously mentioned. Therefore, each series consisted of 4 rows almost 30 links long. Each row was handled separately with the average results as shown in Table 27. These figures, of course, represent the averages of figures which are subject to fairly wide fluctuation; but this fact will be taken account of in the following remarks, where no conclusions will be based on small differences in the data.

From Table 27 it will be seen that the lowest per cent hulless seed is shown by the samples cut slightly on the green side and dried in the field. It may be seen on close examination of the data that considerable variation has existed from year to year, due to the personal element in judging stages of maturity. For example, in 1920 the weight per 1000 kernels and the weight of seed per row would indicate that series A and B were only slightly less mature than the other series. In 1921 a similar examination reveals the fact that series A and B were very immature, while series C. and D seem, from the

Table 27.

Averages of results from time and method of harvest experiment.

1919, 1920, 1921.

Averages of 4 rows

Series	Management	1919			1920			1921			
		wt. of seed grams.	wt. per 1000 kernels grs.	% hulless seed.	wt. of seed. grams	wt. per 1000 kernels. grs.	% hulless seed.	wt. of seed. grams	wt. per 1000 kernels. grs.	% hulless seed.	% hulless seed 3 yr. av.
A	Cut on green side; cured in small sheaves in barn.	137	0.295	59	162	0.409	44	45	0.324	59	54
B	Cut on green side; cured in shock in the field.	205	0.308	34	182	0.404	12	59	0.353	40	29
C	Cut when ripe; cured in small sheaves in barn.	291	0.424	73	154	0.452	32	101	0.481	48	51
D	Cut when ripe; cured in shock in the field.	308	0.422	69	152	0.436	36	96	0.470	37	47
E	Cut when ripe; cured in shock in field; allowed to weather considerably.	190	0.420	40	112	0.428	19	80	no record	52	37
F	Cut when over-ripe; cured in small sheaves in barn.	229	0.423	67	159	0.446	26	83	0.523	40	44
G	Cut when over-ripe; cured in shock in the field.	273	0.437	62	124	0.452	41	98	0.522	46	50

weight per 1000 kernels, to have been slightly immature. In this connection we should note that series D shows the lowest per cent hulling in 1921. No difference of this kind should be expected between the ripe and over-ripe samples of 1919 and 1920, as the data show them both to be fairly well matured before cutting.

Curing the sheaves in the barn seems to have had a marked effect on the green cuttings. But as no data are available as to the moisture content of these sheaves at threshing time, the discussion of this point will be resumed in connection with the 1925 results.

Allowing the crop to become over-ripe before cutting seems to increase the hulling. This is again indicated by the 1925 results.

Exposing the sheaves to weathering has given rather surprising results as regards per cent hulling in several instances. That is, the per cent hulless seed in the weathered samples is usually low. However, the weight of seed from the weathered sheaves is invariably lower than that of the other sheaves cut at the same stage of maturity. This brings out the fact that the weathered sheaves were subject to considerable shattering both during weathering and subsequent handling. It is reasonable to believe that the seeds which were loose in their hulls would be the first to shatter. Hence, much of the seed which would be threshed naked is lost from the sample, thus reducing the per cent hulless. However,

in spite of this assumption, we must at least admit that weathering does not seem to have any tendency to increase the loss of hulls in threshing.

The data from 1925, as shown in Table 28, support the conclusions drawn from Table 27 as already mentioned. However, some special features of the 1925 results are worthy of mention. The good effect of drying the immature cuttings in the field rather than in the barn is demonstrated again in this table. One might assume this to be due to the samples remaining tough in the barn, thus having a tendency to retain the lemma and palea attached to the glumes and rhachis. Nevertheless, this theory does not explain the differences in Table 27; as all the samples in this experiment were stored in the barn for a long period before threshing. Threshing was not done until December in 1919 and '20; and on August 30th, 1921.

Again in Table 28 the moisture content of the seed shows the relationship to be quite complicated. The high moisture content in series 1 was due to a rain 4 days before threshing. But in spite of the fact that this series was quite damp, it threshed completely, the heads breaking up well. The low per cent hulless seed obtained from this series corresponds well with the results obtained from the desicators (Table 26). However, we see in series 2 that a high moisture content has failed to give a low per cent hulless seed. It should be mentioned in connection with series 2, that it did not thresh as completely as series 1. The heads came through without being broken up. With series 4 further removing the possibility

Table 28.

Averages of results from time and method of harvest experiment 1925.

Series no.	Management	Date cut	Averages of 3 rows		
			Weight of seed grams	% moisture in seed	% hulless seed
1.	Cut green; dried in field; threshed at once.	July 16	27[2]	26	3
2.	Cut green; dried in barn; threshed at once.	" "	22	22	38
3.	Cut green; weathered in field.	" "	15	10[1]	4
4.	Cut green; stored in barn.	" "	20	10[1]	51
5.	Cut medium ripe; dried in field; threshed at once.	" 27	66	18	24
6.	Cut medium ripe; dried in barn; threshed at once.	" "	69	25	8
7.	Cut medium ripe; weathered in field.	" "	52	10[1]	10
8.	Cut medium ripe; stored in barn.	" "	73	10[1]	47
9.	Cut over-ripe; dried in field; threshed at once.	Aug. 1	70	10	19
10.	Cut over-ripe; dried in barn; threshed at once.	" "	94	11	44
11.	Cut over-ripe; weathered in field.	" "	52	9[1]	20
12.	Cut over-ripe; stored in barn.	" "	66[2]	10[1]	41

[2] average of 2 figures.

[1] average of 1 figure.

of a simple relationship between moisture content and hulling; one is forced to the conclusion that some climatic effect of the open air, such as the sunlight, the dew, or both, must have a desirable effect in curing the immature cuttings.

Method of threshing.

This experiment was designed to determine the extent to which the speed and adjustment of the threshing machine might effect hulling. The machine used was a 20 inch overshot separator, with a normal speed of 1050 revolutions per minute. Large samples of seed were threshed with different adjustments of the concaves both at normal speed and at a speed of about 800 revs. per min. The latter speed was obtained by changing the cylinder pulley. Small samples were taken from the large ones by carefully mixing, coning and quartering. From these small samples the per cent hulless seed was estimated by counting the hulless in 2000 seeds from each sample, in lots of 100 each. The significance of the average differences were obtained by comparing the differences between successive hundreds by Student's method. The results, along with the probable errors of the means, are shown in Table 29.

The odds that the differences in Table 29 are significant seem very high. Of course, one should not place too literal an interpretation on the statistical terms used. For example, the only error included in the so-called "probable error" is part of the error in counting the percentage of hulless seed.

However, the differences are so regular in this experi-

Table 29.

Per cent hulless seed obtained by various methods of threshing.

Sample no.	Management	Mean % hulless seed.	P.E. of mean.
1.	Run fast - concaves in mesh $\frac{1}{4}$ inch.	30	± 0.5
2.	Run fast - concaves in mesh $1\frac{1}{2}$ inches.	34	± 0.8
3.	Run slow - concaves in mesh $\frac{1}{4}$ inch.	11	± 0.3
4.	Run slow - concaves in mesh $1\frac{1}{2}$ inches.	15	± 0.4

Difference	Odds that difference is significant. (Student's method)
Sample 2 - Sample 1 (34 - 30)	182 ; 1
Sample 4 - Sample 3 (15 - 11)	over 10000 : 1
Sample 1 - Sample 3 (30 - 11)	over 10000 : 1
Sample 2 - Sample 4 (34 - 15)	over 10000 : 1

ment that they seem worthy of attention. Therefore, it appears possible to reduce hulling considerably by reducing the speed of the thresher. It also appears possible to reduce the hulling by setting the concaves as far open as possible. Very little difference could be noticed in the completeness of threshing with the various adjustments described above. However, this is a consideration which would depend largely on the individual machine and the condition of the crop.

Discussion.

While no conclusions should be based on small differences in the foregoing data, the general trend of the results seem to justify the following remarks:

From the standpoint of reducing the loss of hulls, the most desirable stage of maturity seems to be just a little on the green side. Curing the crop in the open seems to be desirable. The best results seem to depend on getting the crop thoroughly dried at the beginning of the period. Threshing before the crop has lost its original moisture gives poor results. However, re-moistening after the crop has once become thoroughly dry seems to have a good effect in reducing the hulling. This would suggest that threshing while the crop is moist from dew or rain would give good results, provided the machine could be regulated to thresh clean. However, storing under shelter after the crop has been dried in the open does not have any bad effect. This might be de-

sirable to prevent weathering. While weathering does not seem to increase the per cent hulless seed, it may result in loss of considerable seed through shattering, as well as giving a very poor color to the seed sample. In addition to the consideration of time and methods of harvesting, we should bear in mind the importance of a proper adjustment of the threshing machine. As this point has already been discussed in connection with the experiment on methods of threshing, it will not be given further mention.

GENERAL REMARKS.

In addition to the regular experiments mentioned in this paper, samples of seed were available from plots of timothy seeded in rows of various spacings. Examination of these samples failed to establish any relation between distance of planting and hulling. This, of course, might be expected as the effect of the plots being in different stages of maturity when harvested might easily obscure any direct effect of distance of planting.

Data were also available for the nitrate and moisture content of the plots in the experiment on relative value of hulled and hulless seed. This data gives separate values for the plots occupied by each year's seeding. However, it would be impossible to relate hulling with nitrate or moisture content as here again the stage of maturity varied considerably with the different years of planting.

EXPERIMENTAL AND STATISTICAL METHODS.

With the exception of the experiment on methods of threshing, the samples used were quite small. In most cases they consisted of single sheaves. This made it necessary to use a special threshing machine, which consisted merely of a cylinder and concaves closed in,with a drawer to catch the seed and chaff. The sheaves were held by the butt ends while the heads were threshed off. The straw was then thrown away without being run through the machine. The seed was separated from the chaff with a small fanning mill. This method of threshing is not exactly comparable to ordinary threshing. However, it seems reasonable to assume that the comparisons obtained in the results from various samples would apply quite well to ordinary methods of threshing.

The per cent hulless seed was determined by actual counting in every experiment except the plant breeding block. In most cases the determination was based on the number of hulless kernels counted in 1000. In the earlier work the counting was reported directly on the basis of 1000 kernels; while in the later work the 1000 kernels have been counted in 10 lots of 100 each. In this way it has been made possible to determine part of the error in counting by examining the variability of the individual counts. However, this only gives part of the error, as one of the most important steps in the determination is working from a sample of a few ounces or more down to the 1000 kernels, which are to be counted.

This is done by coning and quartering; but as this procedure is usually gone through only once for the whole sample, there is a certain error involved which is not shown by the variability of the hundred kernel counts.

In some cases the probable error of the average per cent hulless has actually been calculated. These errors always seem very small, and as pointed out above, they are smaller than they really should be. However, in some of the tables the results given are averages of several samples; and here the error, as calculated for the average of all the samples, will tend to be more useful. For example, the probable errors were calculated for some of the averages given in Table 28. These averages represent 30 counts of 100 kernels each. Their probable errors range from ±0.23 in series 1, to ±1.78 in series 4.

The large amount of material from the plant breeding block made it necessary to use a more rapid method of estimating the per cent hulless seed. For this purpose the samples were spread out and compared with standard samples containing various percentages of hulless seed. All conditions, such as lighting, were made the same for sample and standards. The per cent hulless was then estimated according to the standards which the sample resenbled most closely.

In the 1925 experiments on time and method of harvesting and effects of relative humidity, it was thought useful to know the moisture content of the samples at the time of threshing. This was determined most conveniently by oven

drying a sample of the seed immediately after threshing. The results obtained by this method from duplicate samples checked very closely.

Statistical methods.

The statistical variables used are described in various articles and text books. No attempt will be made at giving a complete list of references for this part of the work. However, a few of the most easily available references will be given.

The probable error, (of a mean, and of a single determination) is described by Babcock and Claussen (1); Hayes (5); Jones (6); and Kemp (7).

The coefficient of correlation is explained by Babcock and Claussen (1) and Jones (6).

Student's method of calculating the significance of a difference is discussed by Love (8); Love and Brunson (9); and Salmon (10). The first two articles explain the use of the method in a very plain manner. The table of calculated odds given in (8) was used wherever Student's method was employed in this report.

SUMMARY.

The hulling of timothy seed in threshing has resulted in considerable loss to Alberta growers. Although special regulations exist, it is often impossible for western growers to keep the percentage of hulless seed low enough to secure top grades. This paper forms a report of experimental work on various phases of the problem. The data presented seem to justify the following remarks:

The present discrimination between hulled and hulless seed seems justifiable, as considerable differences in viability have been shown both in the laboratory and in the field, the differences being in favor of the hulled seed. Besides this, the hulless seed tends to spoil the appearance of the sample.

There appears to be very little possibility of selecting strains of timothy which would be especially resistant to hulling. However, such a possibility can only be directly disproven by comparing clonally propagated pure lines. The greatest opportunities for reducing hulling are to be found in the management of the crop during harvest and threshing.

Cutting the crop slightly on the green side has given the lowest percentage of hulless seed. Drying these green cuttings in the field has given much better results than drying them in the barn. Storing in the barn after drying

in the field has no bad effect. While weathering does not appear to increase the hulling, it is undesirable, as it causes shattering and gives the seed a poor color.

Once the crop has been properly dried, threshing it while moist from dew or rain should give good results as regards hulling.

Proper adjustment of the threshing machine is important. The percentage of hulless seed was reduced by lessening the speed of the separator. The adjustment of the concaves also made a noticeable difference.

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