A mechanical method of measuring kernel shatter resistance to barley
by Harold Reinhold Guenthner

A THESIS Submitted to the Graduate Faculty in partial fulfillment of the requirements for the degree of Master of Science in Agronomy
Montana State University

Abstract:
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A two gram difference in pull could be measured with the kernel pluoker at the five percent level of significance by making one random determination from eleven heads. When one determination was made per head from the same position, a sample of nine was required.

Evaluation of head curvature types with the kernel plucker showed that kernels were more easily removed from the inside portion of the head curvature.

Kernel plucker determinations made on sterile florets showed that these should be avoided.

A date of sampling study revealed that significant differences could be measured on heads collected at any date of sampling or on heads that were uniformily dried.

If small differences are to be measured with the kernel plucker, determinations should be made on head samples collected from more than one location.

Correlation of kernel plucker results with field shatter data obtained from two locations revealed that 88 to 89 percent of the field kernel shatter could be explained on the basis of the kernel plucker determinations.

Evaluation of genetic material with the kernel plucker revealed that the kernel shatter resistance of a backcross selection approaches the shattering resistance of the backcross parent.

The barley varieties that were evaluated with the kernel plucker showed a range of 10 to 43 grams pull to remove a kernel. Varieties which require more than 20 grams pull to remove a kernel would not be expected to shatter with normal harvest procedures.

Of Montana's recommended varieties, barley growers should not experience losses due to field kernel shatter with the varieties Unitan, Vantage and Compana. Without proper management or optimum weather conditions, growers of Freja and Betzes should expect some kernel shattering.

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ABSTRACT

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INTRODUCTION

The loss of grain by shattering has been recognized for some time as an important problem in the production of small grains. When harvesting consisted of binding and threshing, the crop was usually harvested at or just before maturity. Shattering losses were not as readily noticed at that time as they are with the present harvesting method with the use of the combine.

During the period immediately following maturity, a considerable portion of the crop is exposed to climatic and environmental conditions such as wind, rain and varying temperatures prior to the harvesting operation. These conditions tend to contribute to the loss of grain by shattering.

In the western Great Plains and western Intermountain areas of the United States and Canada, attention has been centered on the importance of shattering losses. Barley producers desire varieties which at least have moderate shattering resistance.

There are three distinct types of shattering which occur in barley. These were first described by Platt and Wells (6). They are: (1) kernel shatter, where the individual kernel becomes detached from the rachis; (2) rachis shatter, where a portion of the rachis is broken and part of the head is lost; and (3) neck breaking, where a break occurs near the base of the head and as a result the entire head is lost.

Depending on the variety, shattering losses in the barley production areas of Montana may be principally of the kernel shattering type.

This study was undertaken to develop a method of evaluating kernel shatter resistance of varieties and parent material which are being utilized in a barley breeding program. In some instances conditions are such that it is rather difficult to determine the field shattering resistance or susceptibility of a variety or selection. If an evaluation technique could be developed which could be used to determine the kernel shattering resistance of a variety or a selection and particularly on single plants this then would be an important tool to the barley breeder in developing desirable shattering resistant varieties.

Based on suggestions by R. F. Eslick and E. A. Hockett, an appartus was constructed to measure kernel shatter in barley. This device determines the pull necessary to detach a kernel from the rachis. It will be designated as the "kernel plucker".

LITERATURE REVIEW

The primary method used in determining the shattering susceptibility or resistance of a variety has been field evaluation. Usually the border or guard rows of the yield nurseries are left standing for a period of time after maturity. An estimate is taken of the amount of shattering that has occurred in these rows.

Since conditions associated with shattering do not occur regularly, attempts have been made to determine the shattering resistance or susceptibility by other means.

One of the first attempts to measure shattering was made by Jung (5) when he dropped rye heads on a glass plate and then counted the kernels which had been knocked out. Other techniques such as the use of the rolling pin, etc. have been used to measure shattering; however results were not consistent.

Investigations have been conducted to determine the inheritance of shattering. It has been interpreted as extremely complex and influenced by various factors and combinations of circumstances (4, 6, 7).

Vogel (8) in 1938 reported that the proportion of lignified tissue at the breaking point of the outer glume in wheat was greater in varieties which appeared to be resistant to kernel shattering. Because of variability in determinations within a variety, small differences could not be detected. He suggested that the actual measurement of glume strength could be used to give an indication of resistance.

In 1941, Vogel (9) reported on studies involving such measurements. Using a special measuring device which consisted of a small spring balance, he classified a number of wheats as to their resistance to kernel shattering. He reported that shattering resistance depends not only on glume strength but also upon other morphological characters such as length, shape and position of floral parts, type of head, and erectness and height of the plant.

Chang (2) in 1943 constructed and described a paddle device which subjected the heads to a beating action which could be used for the measuring of shattering in wheat. Morphological studies of several varieties indicated that the shorter the lemma, the narrower the grain, the shorter the rachis internode and the smaller the weight of the kernel that a variety possess, a higher degree of kernel shattering resistant was evident.

Further tests of Chang's paddle device by Harrington and Waywell (4), indicated that the results of the paddle method did not agree exactly with the known behaviour of the wheat varieties evaluated; however, the grouping of the resistant types as compared with the susceptible types was good.

Harrington and Waywell (4) also reported on the relation of shattering and the strength of the glume attachment which provided additional evidence for Vogel's thesis concerning this relationship.

Truscott (7) and Beck[1] later conducted additional tests with

[1]Beck, T.V. A study of shattering and weathering in wheat and barley. Master's Thesis. University of Saskatchewan. 1951

the paddle device and measurement of glume strength. Tests using the paddle device on wheat and barley varieties did not give accurate determinations of the shattering resistance of the varieties tested. Measurement of glume strength in wheat gave high correlation with the amount of shattering occurring under field conditions.

Truscott (7) in 1950 constructed a waving device in which reciprocating arms were employed to simulate the waving motion occurring as a result of air movement under field conditions. Results of the tests using this device indicated that it might yield results of value in determining kernel shatter resistance in barley.

"A hybrid glume strength tester" was later developed by Truscott (7). The principal mechanism consisted of a spring and a plunger with a wedge shaped tip that operated on somewhat the same principal as Vogel's glume puller. This device was portable and provided a rapid determination. Several wheat varieties were evaluated with this device but the differences obtained resulted in reduced accuracy even though the time involved was considerably reduced.

Another attempt was made by Beck[1] to simplify the determination of glume strength with a device which consisted of a spring loaded lever. This lever was centrally mounted on a small handle. Tests conducted with this machine showed that it was impossible to obtain accurate readings in determining the shattering resistance of wheat varieties. The principal difficulty with the use of this device was

[1]Beck, T.F. A study of shattering and weathering in wheat and barley. Master's Thesis. University of Saskatchewan. 1951.

the precision of the depth of insertion of the tip of the lever to determine the glume strength. Readings taken were only accurate to five grams.

Research conducted on the various mechanical methods of measuring shattering resistance in wheat indicated that the glume puller as developed by Vogel is perhaps the most reliable mechanical method.

MATERIALS AND METHODS

Kernel plucker determinations were based on the grams pull required to remove the barley kernel from the rachis. The kernel plucker was attached at the base of the awn in the area where the palea joins the lemma. This makes it possible to compare hooded, awned, and awnless types of barley.

This study was undertaken in three principal phases:

1. The design and operation of the kernel plucker.

a. Design of the machine. In Figure 1 is shown the kernel plucker which was used in this study. The machine employed a small coil spring and a hook properly oriented on a fulcrum. The arm which is $16\frac{1}{4}$ inches long was constructed from a pine board and mounted on a pine upright which was $11\frac{1}{4}$ inches high. The fulcrum was situated $4\frac{1}{2}$ inches from the left end of the arm. The spring was mounted two inches from the fulcrum on the left end of the arm and the hook was placed 10 inches to the right of the fulcrum. A pointer was placed on the right end of the arm. The gram increments were established by placing known gram weights on the hook. If the desired gram increments cannot be obtained, the position of the spring on the arm or the fulcrum position can be altered.

b. Sample size required to measure a specified difference. Before comparisons of kernel plucker determinations can be made, it is necessary to first know how many determinations are required for the desired precision and secondly, at what positions on the

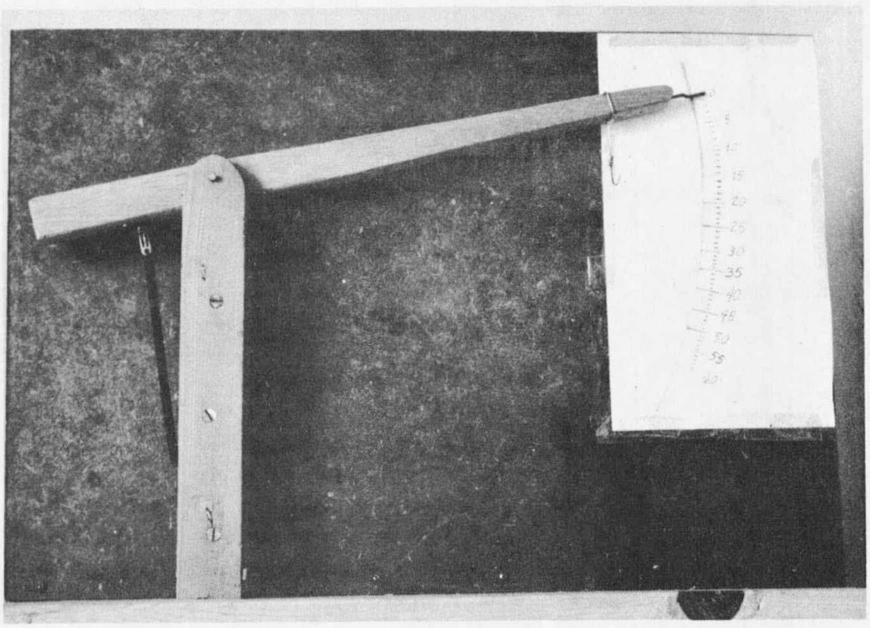

Figure 1. A view of the kernel plucker to show the general construction.

rachis. The grams pull to remove a kernel from each kernel position was determined for fifty random heads of the variety Betzes for this purpose.

c. Causes for within head variation. Three studies were conducted within this category: (1) Location on the spike was evaluated from the fifty random heads of Betzes employed to determine the appropiate sample sizes, (2) the effect of head curvature on the within head variation was determined from five kernel plucker determinations from each kernel position on both sides of the rachis on five head curvature types selected from the variety Betzes, and (3) to determine the effect of sterile florets, kernel plucker determinations were made on three heads and five positions on each head from male sterile heads collected from seven varietal selections which were being backcrossed to provide male sterile lines for the breeding program.

d. Source of head sample. A number of head samples were evaluated with the kernel plucker removing five kernels from positions two through six from three heads. Head samples were evaluated from three sources. (1) To determine the effect of the stage of maturity and the effect of dry storage, six varieties: Betzes, Unitan, Dekap, Freja, Traill, and Compana were sampled at three-day intervals beginning approximately ten days after heading. At each sampling, a kernel plucker determination was made and the percent moisture for the straw and the grain was determined.

Moisture determinations were obtained by oven air-drying for a 48-hour period. At each date, a head samples from each variety were oven air-dried and then stored at room temperature for six months when another kernel plucker determination was made. (2) To determine the effect of location, a sample of ten heads was collected from three replications of the barley advanced yield nursery grown in 1959 at Bozeman, Sidney, Huntley, Moccasin, and Creston. Head samples were obtained from both dryland and irrigated conditions. Kernel plucker determinations were made on the samples collected in the manner previously described.

2. Relation of the pull to remove a kernel to field kernel shatter.

a. Relationship of kernel plucker results at maturity with field kernel shatter determined at four dates after maturity. Field kernel shatter was determined from a twenty random head sample collected at weekly intervals after maturity from each plot of the irrigated barley advanced yield nursery grown at Bozeman in 1959. Kernel plucker determinations were made at maturity for each replication of each variety for each harvest date.

b. Correlation of kernel plucker readings with actual field kernel shatter counts. Kernel plucker determinations and field kernel shatter were determined as previously described on thirty-nine varieties from the two-row barley yield nursery grown at Reese Creek and at Bozeman in 1959.

3. Evaluation of genetic material with the kernel plucker.

a. Evaluation of the two-row and six-row backcross types. A number of two and six-row pairs of a Titan x Munsing^7, F_3, and Munsing x Titan^7, F_3, backcrosses were collected for kernel plucker evaluations.

b. The effect of head characteristics such as seed size, head compactness, and awn type. Kernel plucker determinations were made from head samples collected from Betzes and Betzes Erectoides to determine the effect of a compact head. The crosses of Engleawnless with Compana, Ingrid, Dekap, Betzes and Freja provided a range of genotypes from awnless to awned for evaluation of the effect of awn length and its relation to kernel shatter. A number of large seeded Compana and Betzes selections were evaluated to determine the effect of large and small seed size on kernel shatter resistance.

In the evaluation of six-row barley varieties with the kernel plucker, only the central florets were used for the kernel plucker determinations.

Field shatter was determined by counting the kernels missing and the total number of kernels from 20 heads of each replication of a variety. Dividing the total kernel positions of 20 heads into the total kernels missing provides the actual percent field kernel shatter.

The analysis of variance technique was used for the analysis of data and the F-test as the test of significance. Duncan's

Multiple Range Test (3) was used to determine the significant groups or classes.

RESULTS

1. The design and operation of the kernel plucker.

a. Sample size required to measure a specified difference. In Table 1 is presented the analysis of variance of the individual kernels from the 50 random Betzes heads. Utilizing the within head within position variance to test for differences between heads and between positions, significant head to head and position to position variation was revealed. Since significant head to head variance exists, it was reasoned that as many heads as possible and necessary, should be sampled for the desired precision to determine the mean grams pull to remove a kernel. This reduced the occurence of Type I error (rejecting a hypothesis when it is actually true) when evaluating treatments.

The mean grams pull for each kernel position as determined by the kernel plucker is presented in Table II. From the data collected it appeared as though the first kernel on the rachis was the most difficult to remove and that kernels were progressively more easily removed from the base to tip of spike.

Before a statistical comparison of the kernel position means could be made it was assumed that determinations for each position had a common variance. Application of Bartlett's test of homogeneity of variance (1) confirmed this assumption.

Table 1. Analysis of variance of kernel plucker determinations in grams pull for a 11 positions on 50 heads of Betzes barley

Source of variation	Degrees of freedom	Sums of Square	Standard error of a single observation
Among heads	49	787.4 **	4.009
Among positions on heads	10	593.6 **	7.705
Position x heads (error)	457	1155.8	
Total	516	2536.8	

** Significant at the 1% level

Table II. The means grams pull to remove a kernel and the standard error of a single observation as determined for each kernel position on the rachis of 50 heads of Betzes barley.

Kernel position	Mean pull to remove a kernel	Standard error of a single observation
11 (tip)	8.64 fg	1.6156
10	8.95 fg	1.4142
9	8.98 fg	1.4799
8	9.57 ef	1.4283
7	10.00 dc	1.8193
6	9.94 de	1.6583
5	10.56 cd	1.6912
4	10.96 bc	2.1190
3	10.70 cd	2.1024
2	11.57 ab	2.0929
1 (basal)	11.92 a	1.9339

* Those means followed by the same letter are not significantly different from each other at the 5 percent level of probability.

Although the kernel positions had a common variance at the significance level selected, there appeared to be a consistent pattern of differences in variances associated with the positions.

Examination of the mean grams pull for each position, as given in Table II, indicates a range of 8.64 to 11.92 grams. It is apparent that stratification for position reduced within head variance. Since the variance due to positions includes the effect of heads within positions, it was necessary to calculate a standard error of the means for within positions which included the effect of heads within positions. Substraction of the variance due to positions from the total variance provided the variance due to the effect of heads within position. Values obtained from Table I show that the variance due to heads within position means was 3.8403 providing a standard error of a single observation of 1.96 grams.

Utilizing the calculated standard error of a single observation, an appropriate standard error for the position means can be obtained. Application of Duncan's Multiple Range Test (3) in Table II shows that there are certain positions which are not different from each other. Since significant differences in pull, depending on positions, were observed, it is obvious that variance can be reduced by stratification for position.

If a single determination is made at the same position on each head, the effect of position is eliminated. The standard error of a single observation (1.96 grams) for variation of heads within a position can be utilized to calculate theoretical "t" values based on different numbers of heads when mean differences to be measured are established at some specified level.

The calculated "t" values presented in Table III show that nine heads are required to measure a two gram difference, four heads for a four gram difference and three heads for a six gram difference between two means tested if one determinations is made per head at the same position on each head and if one is satisfied with the 5% level of probability.

A standard error of a single observation for random kernels can be determined from the total variance of kernels from all positions on the 50 heads which were choosen at random. Calculated "t" values can be obtained which would ignore the effect of positions within heads. These values are presented in Table III.

To measure a two gram difference between two means tested at the 5 percent probability level when one determination per head is made at random, would require a sample of 11 heads. To measure a four gram or six gram difference between two means tested would require four heads or three heads, respectively.

These results show that when it is wished to measure a two gram difference or less between two means the error can be reduced by stratification for position.

Since more time was required to remove fewer kernels from a larger number of heads, it appears to be advantageous to remove more kernels from fewer heads, particularly when the differences expected are large. There also was some difficulty encountered in removing

Table III. Calculated "t" values for specified differences between two means for various sample sizes and two methods of sampling bases on standard errors established from the analysis of 50 heads of Betzes barley.

No. of heads in sample	One determination per head, same position each head, s=1.96 — difference between two means tested			One determination per head, random position ea. had., s=2.215 — difference between two means tested		
	2-grams	4-grams	6-grams	2-grams	4-grams	6-grams
			Calculated "t" values			
2	1.02	2.04	3.06	.903	1.806	2.709
3	1.25	2.50	3.75 *	1.106	2.212	3.318 *
4	1.44	2.88 *	4.32 **	1.128	2.553 *	3.829 **
5	1.61	3.22 *	4.84 **	1.428	2.857 *	4.286 **
6	1.77	3.54 **	5.31 **	1.565	3.130 *	4.695 **
7	1.90	3.81 **	5.71 **	1.689	3.378 **	5.068 **
8	2.40	4.08 **	6.12 **	1.807	3.613 **	5.420 **
9	2.17 *	4.35 **	6.52 **	1.916	3.831 **	5.747 **
10	2.28 *	4.56 **	6.84 **	2.020	4.040 **	6.061 **
11	2.39 *	4.785 **	7.177 **	2.119 *	4.237 **	6.356 **

* Significant at 5% level
** Significant at 1% level

kernels near the tip of the head because of rachis flexibility. Upon consideration of these observations it was apparent that under certain conditions that a number of kernels could be removed advantageously from the positions near the base of the head. In this event fewer heads would be needed.

b. Causes for within head variation. The kernel position selected by the kernel plucker operator was one source of within head variance. The previous discussion on sample size has shown that the variation due to positions can be minimized by stratification for position.

To determine the effect of head curvature on within head variation, kernels were removed from both sides of the rachis from the five curvature types which were classified from the variety Betzes. The mean grams pull to remove a kernel for each position for the five curvature types are shown in figure 2. Analysis of variance of the data is presented in Table IV.

Kernels were generally more easily removed from the inside of a head curvature. A highly significant variation due to the head curvature type was evident. The significance of the inside determination versus outside determination by head curvature type interaction was of interest. The head curvature types IV and V had higher kernel plucker values for the inside determination.

Male sterile lines of seven varieties were evaluated with the kernel plucker to determine the effect of the absence of the kernel in the floret. The data obtained and the analysis of variance are

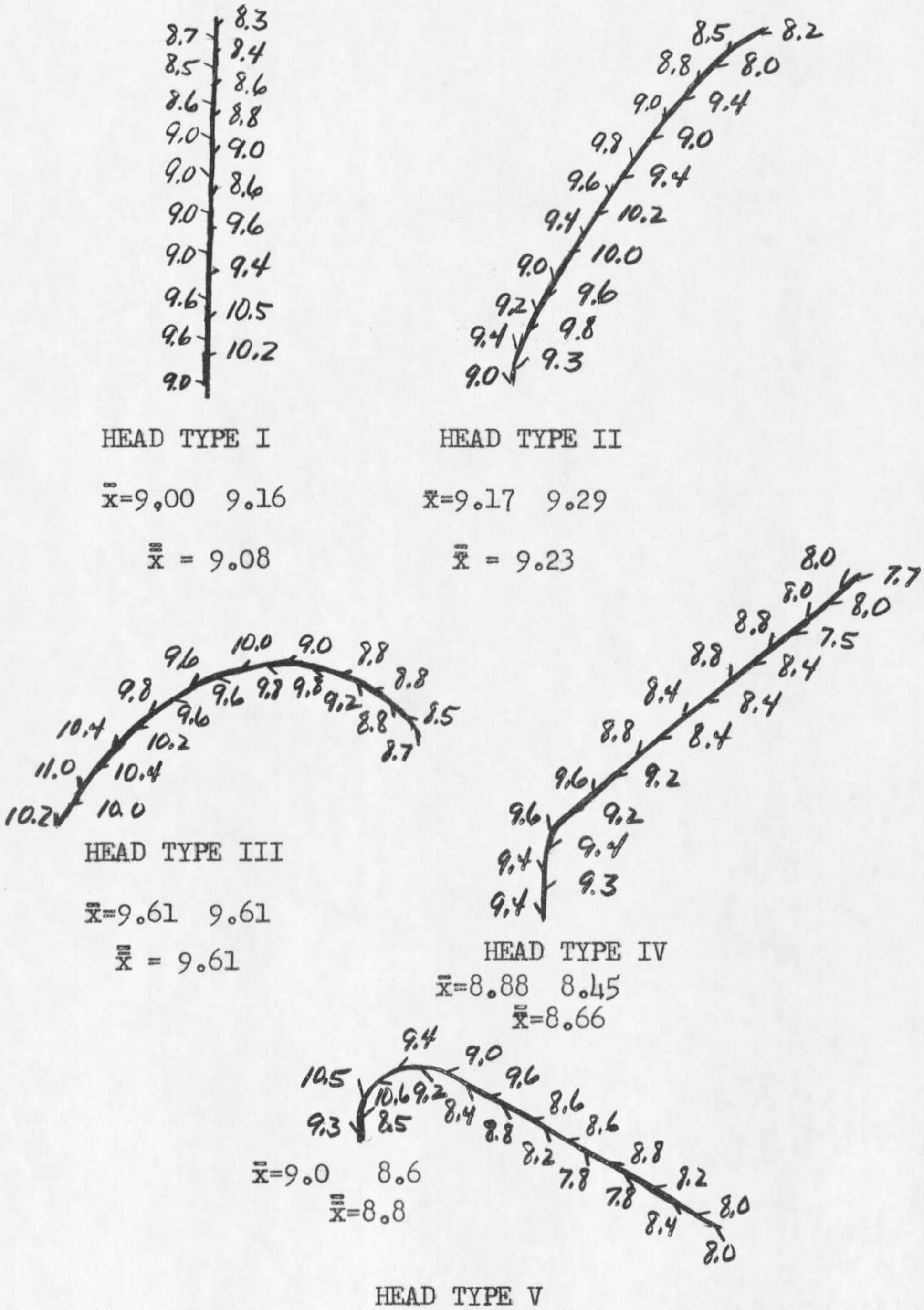

Figure 2. Mean grams pull to remove a kernel for each kernel position of five head curvature types selected from the variety Betzes.

Table IV. Analysis of variance of the kernel plucker determinations (grams) by kernel position for head curvature types selected from the variety Betzes.

Source of variation	Degrees of freedom	Mean Square
Inside versus outside of head curvature	1	.55 *
Head curvature type	4	2.81 **
Kernel position	9	2.97 **
Inside versus outside of head curvature x head curvature types	4	.34 **
Inside versus outside of head curvature x kernel positions	9	.024
Head curvature type x kernel position	36	1.94 **
Error (inside versus outside x curvature type x kernel position)	36	.118

* Significant at the 5 percent level
** Significant at the 1 percent level

presented in Table V. The variation due to varieties would be expected to be significant from past observations. Significance of the fertile lines versus male sterile lines interaction indicated that differences existed. Application of the L.S.D. to test the significances of presence or absence of the kernel showed that four of the seven comparisons made were significant. This evidence would show that sterile florets should not be used to determine the mean grams pull required to remove a kernel with the kernel plucker.

Source of head sample. As one portion of this study, six barley varieties, Betzes, Unitan, Deakp, Freja, Traill and Compana were sampled at three-day intervals beginning ten days after heading and continuing for 17 sampling dates. A kernel plucker determination was made on each date of harvest and a portion of the sample stored. Kernel plucker determinations were made on dried samples after six months of storage. For this trial the mean grams pull to remove five kernels per head from three heads was used as the experimental unti. Three replications were used.

Temperature and precipitation for the sampling period are presented in Table VI. At each sampling date mositure determinations on the straw and seed were obtained for each variety. The average percent moisture in the straw was higher than the seed at all sampling dates except July 22nd. Grain with 12 percent moisture could have been combined on August 18th, Figure 3.

Kernel plucker determinations were difficult to make on freshly

Table V. Mean grams pull to remove a kernel for the fertile and a lemma and palea from male sterile selections of seven varieties.

Variety	Mean grams pull to remove a floret	
	Fertile	Male sterile
Compana	28.1	15.0 *
Hannchen	11.0	12.7
Betzes	12.1	8.3 *
Ingrid	18.6	11.0 *
Domen	16.9	11.2 *
P.I. 170975	11.0	11.2
Brunes Wisa	16.6	11.6 *

* Male sterile type significantly different from fertile type

Analysis of variance

Source of variation	Degrees of freedom	Mean square
Varieties	6	83.63 **
Fertile versus male sterile	1	234.3 **
Replications	2	0.44
Varieties x fertile verus male sterile	6	16.86 **
error	26	6.364

** Significant at the 1 percent level

Table VI. Daily maximum temperatures and precipitation during the sampling period of the maturity study at Bozeman, Montana in 1959.

	July		August		September	
Day	Max. Temp.	Prec.	Max. Temp.	Prec.	Max Temp.	Prec.
1	83		90		63	.01
2	85		79	.16	68	
3	73	1.02	89		84	
4	65		85		74	
5	82		81		70	
6	77		81		74	Trace
7	64	.90	84		87	
8	66	.10	88		83	
9	76		90		71	
10	86		86		86	
11	80		84			
12	83		78			
13	82		71	.13		
14	83		75			
15	86		81			
16	85		86			
17	86		90			
18	86		80	Trace		
19	86		73	Trace		
20	86		78	.01		
21	90		80			
22	87		74			
23	92		79			
24	89	Trace	82			
25	83		80			
26	89		77			
27	88		82			
28	89		88			
29	81		80			
30	83		76	Trace		
31	90		68	Trace		

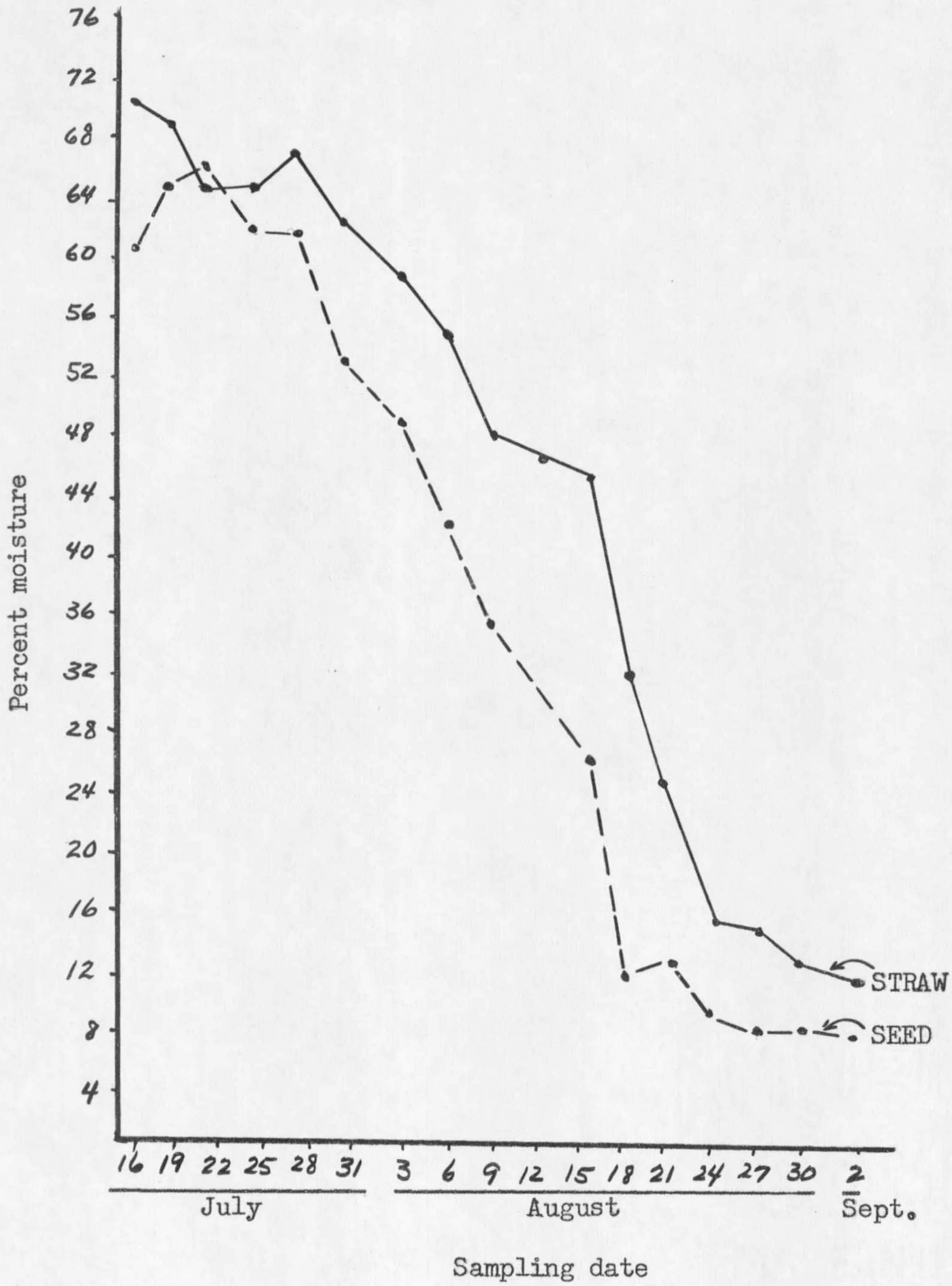

Figure 3. The mean percent moisture in the straw and the seed as obtained for the sampling periods on six varieties of barley in the maturity study.

harvested samples at the early sampling dates. The kernel was not removed by the kernel plucker; however, the main structure of the kernel attachment was fractured.

The analysis of variance of the kernel shatter data collected is presented in Table VII. A highly significant mean square was obtained for each source of variation. The kernel plucker determinations obtained from the newly harvest and stored samples revealed that the kernels of the varieties evaluated are more easily removed at time of harvest than after drying, Figure 4. Varieties with well attached kernels at the time of harvest were even more firmly attached after drying. This accounts for the significant harvest versus stored by variety interaction.

The mean grams pull to remove a kernel for each variety is shown in Table VIII. Application of Duncan's Multiple Range Test (3) shows that each variety was significantly different from each other. Unitan and Compana were resistant to kernel removal whereas Betzes and Freja kernels were the mostly easily removed.

The analysis of variance also shows that sampling date are highly significant. Figure 5 contains the mean determination for the harvest and stored samples at each sampling date. The mean grams pull to remove a kernel for the harvest samples and stored samples increased for each successive sampling date. The significant harvest versus stored by sampling date interaction was accounted for by the tendency of newly harvested and stored sample determinations to become more nearly

Table VII. Analysis of variance of the kernel plucker determinations from the maturity study conducted at Bozeman in 1959.

Source of variation	Degree of freedom	Mean square for grams pull to remove a kernel
Harvest versus stored determination	1	4,303.08 **
Varieties	5	5,669.40 **
Sampling dates	16	374.52 **
Variety x sampling dates	80	33.34 **
Harvest versus stored x variety	5	159.38 **
Harvest versus stored x sampling date	16	21.66 **
Harvest versus stored x varieties x date	80	77.63 **
Error (heads within plots)	408	3.92

** Significant at the 1 percent level

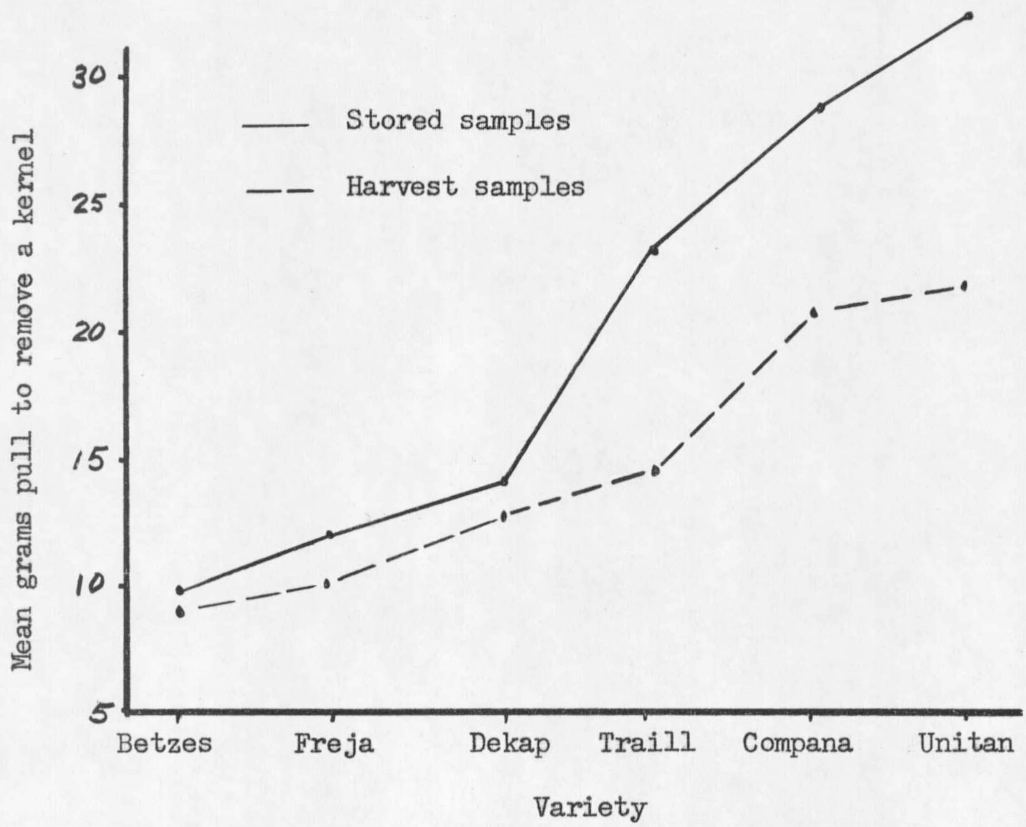

Figure 4. Comparison of the kernel plucker determinations taken at the time of harvest and after six months dry storage.

Table VIII. Mean grams pull to remove a kernel and multiple range test for the six varieties evaluated in the maturity study.

Variety	C.I. Number	Head Type	Mean grams pull to remove a kernel *
Unitan	10421	six-row	27.5 a
Compana	5438	two-row	24.7 b
Traill	9538	six-row	19.0 c
Dekap	3351	two-row	14.7 d
Freja	7130	two-row	10.7 e
Betzes	6398	two-row	9.2 f

* Mean followed by the same letter are not significantly different from each other at the 1 percent level of probability.

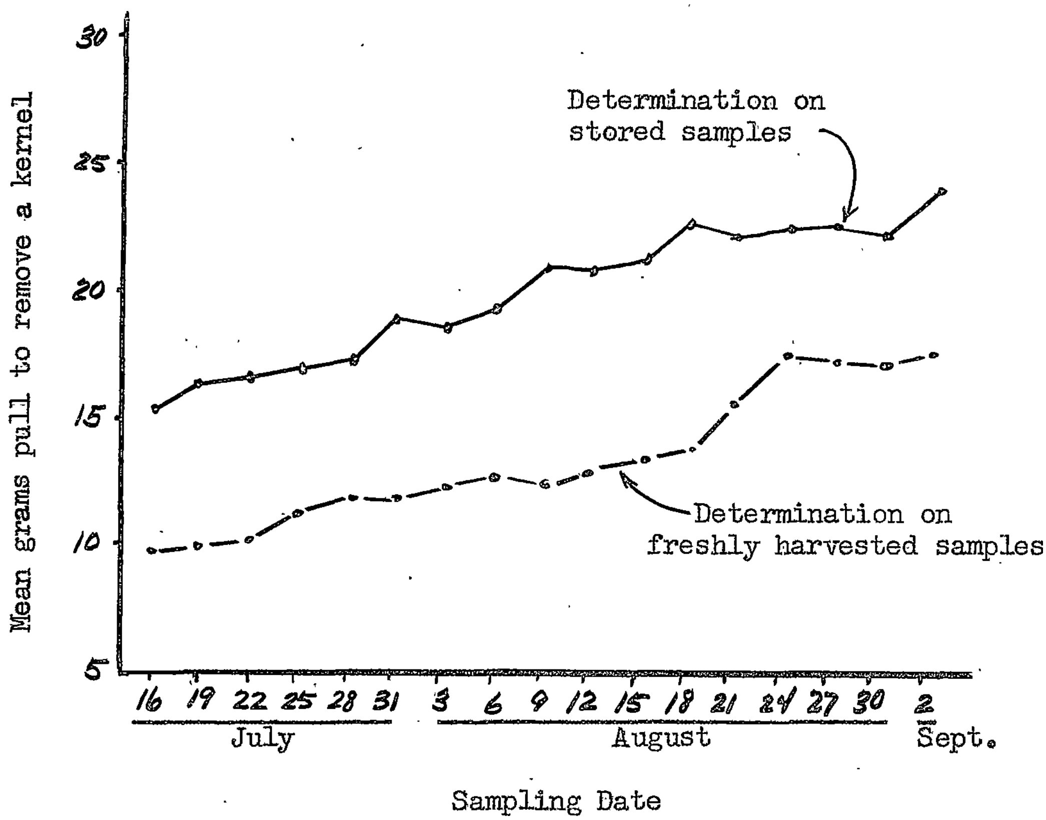

Figure 5. Mean grams pull to remove a kernel at each sampling date for determinations made on freshly harvested samples and samples dried and stored.

alike with the ripening of the barley.

All varieties become progressively more resistant to shattering at each successive sampling date, Figure 6. On any given date of harvest the varieties maintained the same order with regard to grams pull to remove a kernel. As maturity progressed the differences between varieties became greater.

It may be concluded that determinations should be made as nearly as possible on material from one harvest date and on either freshly harvested samples or on samples that have been uniformly dried.

In another study, head samples were collected from the barley advanced yield nursery which was grown at 8 locations throughout Montana in 1959. Four were grown without irrigation and four were grown with irrigation. The head samples collected at each location provided the material to determine the effect of the location where the barley was grown on varietal response to the kernel plucker determinations.

Table IX presents the data obtained on heads from each replication of each location. With the use of Duncan's Multiple Range Test (3) the varieties can be grouped in accordance with their respective kernel plucker determination for each location. At most locations Unitan, Vantage, and Compana were situated in the resistant group. Unitan was the most resistant of the varieties evaluated except at Creston when grown under either dryland or irrigated conditions. Betzes, Freja, and Haisa II were usually in the more susceptible

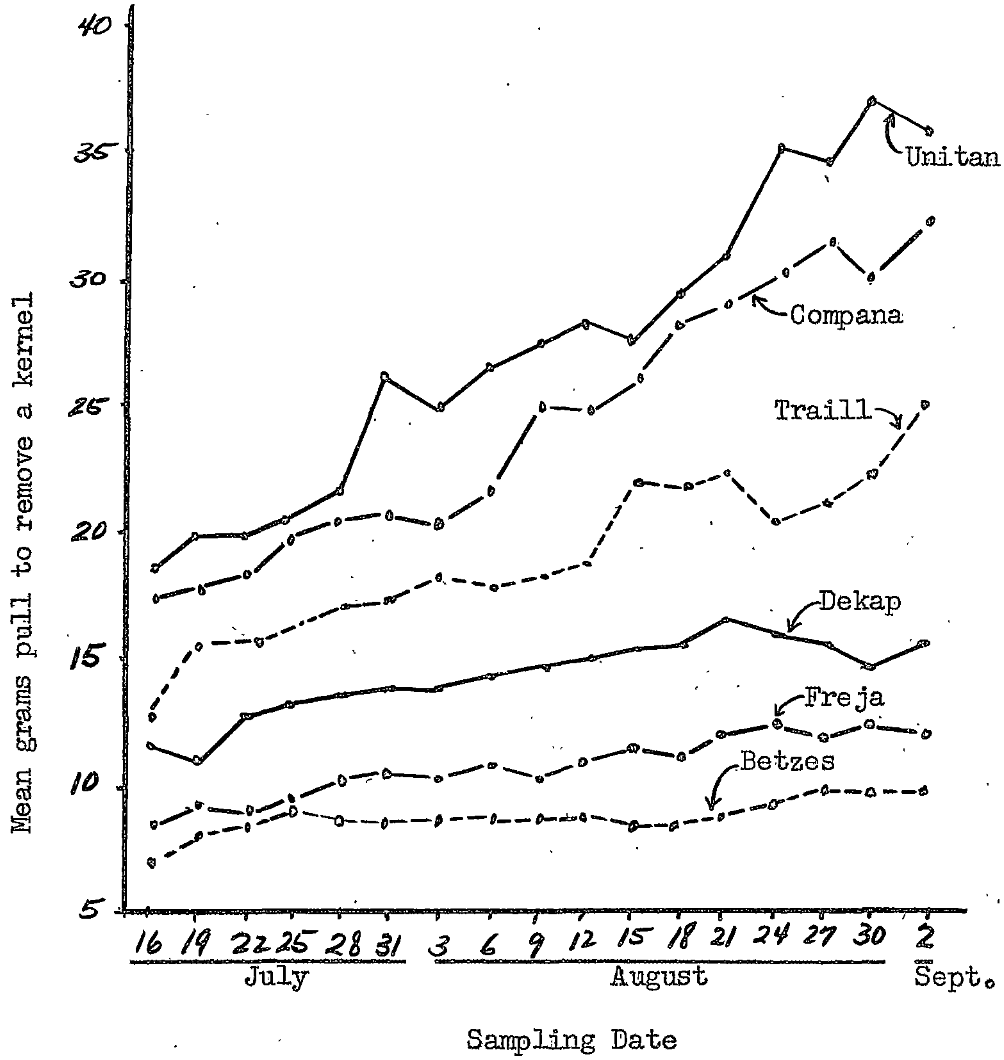

Figure 6. Mean grams pull to remove a kernel for each variety at each sampling date of the maturity study.

Table IX. Mean grams pull to remove a kernel for the varieties grown in the barley advanced yield nursery grown at eight locations in Montana in 1959

	C.I.	Dryland				Irrigated				Irrigated
Variety	Number	Moccasin	Creston	Huntley	Sidney	Creston	Huntley	Sidney	Bozeman	Mean
Unitan	10421	32.6a*	27.4ab	27.7a	29.6a	24.4a	29.9a	32.1a	39.1a	31.5a
Vantage	7324	28.9ab	28.8a	23.9a	25.5ab	25.4a	25.9b	28.8ab	29.0b	27.3b
Compana	5438	25.8b	23.7b	24.3b	24.8b	25.7a	25.9b	24.6bc	26.7b	25.7b
Titan	7055	33.2a	23.4b	24.8b	13.8cd					
Traill	9538					17.0b	22.0c	20.6cd	28.3b	22.0c
Sanalta	6087	18.5c								
Dekap	3351	17.6cd	16.7c	17.8c	15.2c					
Piroline	9558	18.3c	16.3c	14.7d	16.0c					
Hiland	9530					15.4b	14.3d	17.8de	17.6c	16.3d
Ingrid	10083					14.7bc	13.0de	14.8ef	15.4c	14.5e
New Moravian	10107	13.7de								
Svalof 50-109	--					11.6cd	10.9f	11.8f	15.7c	12.5f
Haisa II	10420	12.2e	11.4d	10.7e	12.6cd	12.9bd	11.5ef	11.6f	11.2c	11.8fg
Freja	7130	10.9e	9.9d			10.6cd	11.1cd	10.1f	12.3c	11.0fg
Betzes	6398	11.0e	10.6d	10.4e	10.2d	9.8d	9.9d	10.8f	11.8f	10.6g
$SE\bar{x}$ (grams)		1.10	0.85	0.55	1.03	1.01	0.54	1.11	1.89	

* Means followed by the same letter are not significantly different from each other at the 1 percent level of probability.