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:
Head to head and position to position variation was observed when the kernel plncker was evaluated to determine the performance and method of use for measuring kernel shatter in barley. Kernels were progressively more easily removed with the kernel pluoker from the base to the tip of spike. Due to rachis flexibility, the kernel pluoker was more difficult to operate near the tip of spike.

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.

A MECHANICAL METHOD OF MEASURING KERNEL SHATTER RESISTANCE IN 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

Approved:

Erhardt R. Hehn
Head, Major Department

Robert F. Eslick
Chairman, Examining Committee

Ass't K. Goering
Dean, Graduate Division

Montana State College
Bozeman, Montana
March 1965

ACKNOWLEDGEMENT

The author wishes to thank Professor R. F. Eslick for his advice, constructive criticism and encouragement throughout the course of this study. The author also wishes to thank Dr. E. A. Hockett for his cooperation and assistance.

An expression of appreciation is also due to the branch station agronomists who collected head samples which provided a portion of these data presented.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

ABSTRACT

Head to head and position to position variation was observed when the kernel plucker was evaluated to determine the performance and method of use for measuring kernel shatter in barley. Kernels were progressively more easily removed with the kernel plucker from the base to the tip of spike. Due to rachis flexibility, the kernel plucker was more difficult to operate near the tip of spike.

A two gram difference in pull could be measured with the kernel plucker 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.

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

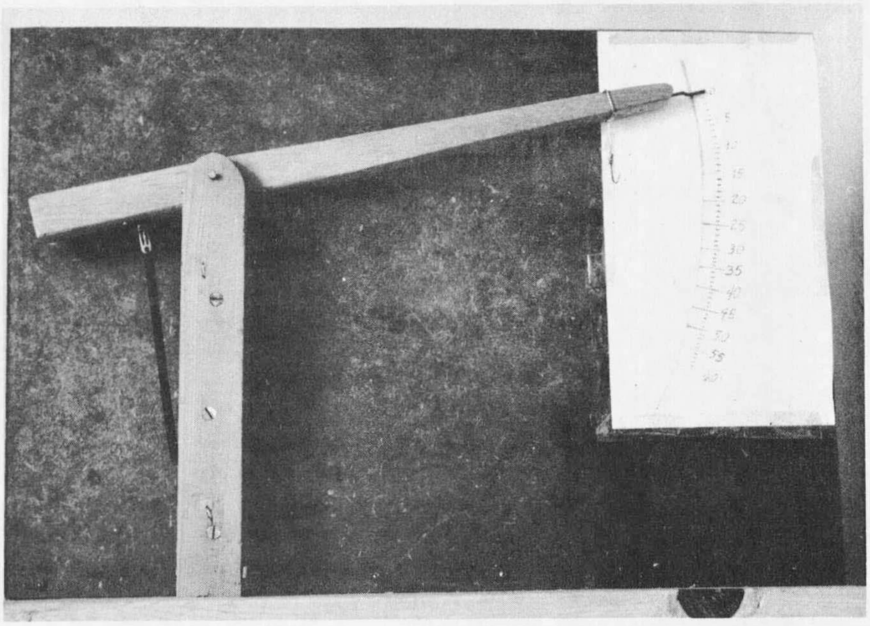

Figure 1. A view of the kernel plucker to show the general construction.

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.