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# The Effects of Simulated Hail Injury on Oats

D. L. Reeves

A study conducted by the South Dakota Agricultural Experiment Station through cooperation and funding by National Crop Insurance Association (formerly Hail Insurance Adjustment and Research Association) and Crop Insurance Research Bureau, Inc.

The author is associate professor, Department of Plant Science. Acknowledgement for assistance is extended to David G. Hanson and Dick Sterup.

The farmer, insurance adjuster, or research worker facing a field of hail damaged oats has little to help him in making an accurate loss estimate except his own experience. This is because most studies of hail damage or injuries simulating hail on small grains have been on wheat, with a few on barley. However, oats do not always respond to injury the same as other small grains.

The picture is changing, however. We have learned more about the response of oats to mechanical injury. Research at the South Dakota Experiment Station has produced knowledge that can be used in the field.

General statements supported by this research follow. They are elaborated in the text of this publication.

1. Different oat varieties will respond in the same way to the same damage.

2. Losses will be the same at different locations for injuries of the same intensity if similar growing conditions exist. Because of different growing conditions, the percentage loss may vary from year to year.

3. The grain from plump-kerneled varieties which are injured suffer more in appearance. The test weight, however, will not drop as much as the loss in plumpness would seem to indicate.

4. Head droppage is not predictable.

5. Higher yielding oats have a higher percentage yield loss.

6. The amount of natural blast in each variety depends upon the environmental conditions of that year. So no standard count for natural blast can be given. There is no completely reliable way to differentiate natural blast from that caused by injury, although location of the blast in the panicle helps somewhat.

## BACKGROUND

Most studies of hail damage or simulated injuries of small grains have been on wheat although some have included barley. Therefore, there have been many inferences made, based upon the response of wheat and barley, as to how oats respond to injury.

Effects of mechanical injury on oats were studied by Eldredge (5) and Knowles (13). The yield loss from injury depended considerably upon the stage of development when damaged. Older plants of oats, wheat, and barley recover less from injury. Laude and Pauli (14) found early injury on winter wheat was not too severe, since the plants were able to recover.

The environmental conditions after injury also affect recovery, especially during the early stages of growth. Knowles (13) reported yield reductions of 98% and 35% in consecutive years when oat plants were severly whipped at the jointing stage. This demonstrates the importance of the season in permitting recovery.

Yield losses from breaks low on the stem prevent, to a large extent, the harvesting of heads close to the ground. Oat stems broken at a higher point had the greatest yield reduction at the boot to heading stage (5,13).

Eldredge (5) bent the straw on oats at the boot stage and weekly thereafter. Losses at the boot stage averaged 47%; losses from injuries at successive weekly intervals were 37, 31 and 24%, respectively. Similar trends have also been reported for both wheat and barley (1,2, 11).

Greater yield losses occur from injuries between the flag leaf sheath and the bottom of the head. Bends in this area cause larger losses than bends lower on the stem because there is no leaf sheath to provide protection and support and more head droppage occurs.

In wheat and barley the highest percentages of heads are dropped when breaks are close to the head (1,2,11). Laude and Pauli (14) reported fallen spikes from injured stems of winter wheat varying from a trace to 52% in different years.

A varietal difference in the amount of head droppage has been noted in wheat. Busch (1) found less droppage from a bearded variety than a beardless variety given the same treatment. When all stems were treated, Laude and Pauli (14) reported a range of 14 to 28% head droppage for three varieties. They also showed a larger percentage of bent heads dropped as the frequency of treated heads declined.

Bruises on oats, wheat, and barley stems caused little or no reduction in yield or kernel weight according to Knowles (13). Eldredge (5) found injury from head bruising to be less severe in oats than in wheat or barley. This was attributed to the fact that the oat panicle is less dense than the wheat or barley spikes. When bruised in the boot to early heading stage there was no significant reduction in yield. Primary and secondary oat panicles were found to have 35 to 40% sterile spikelets, respectively, when bruised as compared to 16% for the untreated plot. Hella and Stoa (11) tried severe bruise treatments on wheat and found the greatest yield reductions occurred when injured at the boot and heading stages.

Reduction of grain size in wheat is greatest when stems are bent during the milk stage (1,5). Laude and Pauli (14) found kernel weight for winter wheat was reduced most when injuries were applied 11 to 15 days after heading. Hella and Stoa (11) observed kernel weight reductions of about 10 and 20%, respectively, for injuries before milk and at the milk stages. The size of barley kernels was reduced more by stem bending treatments at the soft dough than the heading stage, according to Deckard and Peterson (2). The percentage of plump kernels was reduced 35% when stems were bent below the head at soft dough, but only 21% for a similar treatment at heading time.

Blast in oats was defined by Johnson and Brown (12) as "a condition in which the growth of some of the spikelets is inhibited during the development of the panicle so that when the panicle emerges, the blasted spikelets are sterile and have a white, papery appearance." Three general causes have been listed: (1) a varietal characteristic; (2) unfavorable growing conditions, such as extremes in temperature, moisture and nutrients; and (3) injury to the developing spikelets while still in an early stage of growth. The most common forms of injury are hail, herbicide, insect damage, and disease.

Differences in the amount of natural blast between varieties have been observed in other studies (4,7,15). Elliott (7) noted that varietal differences in the amount of blast appeared to be fairly constant from season to season. Blast percentage ranges of 6 to 28, 17 to 46, and 11 to 45% were noted for 3 consecutive years. After observing over 300 varieties, Mackie (15) reported varietal resistance to blast to be quite stable.

Several environmental factors have been associated with blast (10). Frey and Browning (9) attributed a epiphytotic of blast in Iowa in 1957 to a period of cool, cloudy weather 30 to 40 days before heading.

Nutrient conditions prior to spikelet development had an influence on the number of spikelets per panicle, while nutrient conditions after spikelet initiation had an influence on the percentage of blast, according to Johnson and Brown (12). They also related seeding rate with blast frequency; with an increased rate the frequency dropped. At the lower seeding rates the plants were probably growing under more favorable conditions early in development, thus allowing more spikelets to be initiated than could be carried through to maturity. Conditions are often drier as plants approach heading, thus limiting their ability to develop a large number of spikelets. Drought during the time of active panicle elongation causes more blast than drought during an earlier period.

Empson (8) defoliated oat plants at seven growth stages which varied from two leaves to complete panicle emergence. The greatest amount of blasting resulted from defoliation at mid- and late-boot stages.

When defoliation occurred at the 2-, 3-, or 4-leaf stage, blast did not increase. Complete defoliation at the 7-leaf stage increased blast from 50% in the check to 86% in a fall study by Johnson and Brown (12). A similar treatment at the 6-leaf stage in a spring study showed 10% blast in the untreated and 34% in the defoliated plants. Field plants with leaves removed at the 5-leaf stage had 63% blast on the defoliated plants and 44% on the normal plants.

Mechanical injury of varying types increases the amount of blast. Eldredge (5) whipped plants in the late boot stage and increased blast nearly seven fold. Clay marbles, used by Knowles (13) to simulate hail, increased the percentage of blast. Most researchers agree that blast can be caused by adverse conditions or injury during the period of active spikelet differentiation and panicle elongation. This critical period usually occurs 6 to 8 weeks after seeding (3,9).

For a more complete review of the literature on oat blast, see Eldredge (5) or Hanson (10).

## MATERIALS AND METHODS

This study was conducted at two locations in South Dakota. The Brookings site was located on the eastern edge of the city of Brookings on a Vienna loam soil. The second site was on the North Sioux Valley Crops and Soils Research Farm 15 miles north of Watertown. For convenience it is referred to as the Watertown location in this report. The soil at the Watertown site is Kranzburg Brookings Vienna silty clay loam.

The oat varieties used throughout this study were Chief and Froker. Chief is considered a midseason variety, while Froker is classified late in these locations. Both varieties are medium height and have good straw strength. Chief and Froker both have good disease resistance; however, this was not a factor as diseases were minimal.

The experimental design used for each variety at each location was a randomized complete block with four replications. All treatments were randomized within each block regardless of treatment stage. Each variety was handled as a separate experiment; however, the two varieties were always adjacent. Each plot consisted of four rows one foot apart and 14 feet long. Treatments were applied to all four rows of each plot. Prior to harvest each plot was shortened to 12 feet to remove border effects. The two center rows were machine harvested.

### Stages of Growth Treated

Treatments were applied at four different developmental stages: early boot, late boot, heading, and soft dough. Plots were considered to be in a specific stage when 50% of the plants had entered or passed through that stage. A non-treated (control) plot was measured for each variety.

The last three growth stages and the locations of the bending treatments at each stage are shown in Figure 1. Those culms which had not yet reached the treatment stage were treated at the same point as those at the desired stage of growth. The very late tillers, of course, could not be treated in a similar manner so they were ignored.

Determination of the early boot stage was quite difficult the first year. Therefore, the method of Rowell and Miller (16) was used in 1974 and 1975. Plants were considered to be in early boot when 5 to 10 cm of the flag leaf sheaths were exposed. This proved to be an effective method of consistently determining this stage. Treatments for the late boot stage were applied just prior to the time the tip of the panicles began to emerge from the boot.

For the latest stage (treatments 15 through 20) the plans specified "when the peduncle is fully extended (about soft dough)." This description was from barley research, but for oats it was not as applicable. Therefore, these treatments were applied at soft dough, which for oats is sometime after full elongation of the peduncle. Soft dough in oats is

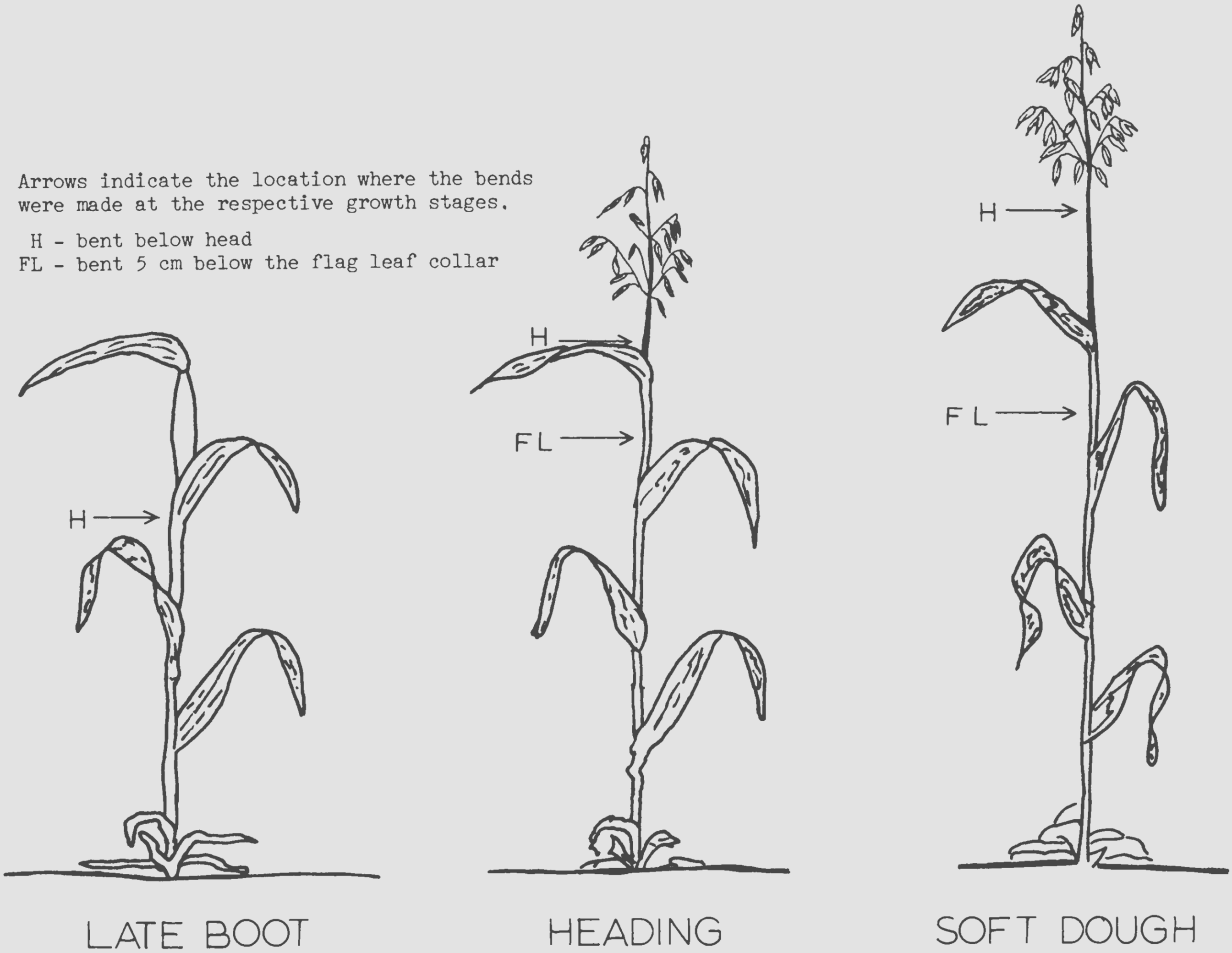


**Figure 1. Oat plant at three stages of growth showing the location of five stem bending treatments.**

somewhat difficult to determine because oat kernels have a softer texture than most other grains at maturity.

When applying a 1/3-frequency treatment, every third culm was treated. When applying a 2/3-frequency treatment, two culms were treated and one skipped. This assured that treated culms were evenly distributed throughout the plot.

Hitting treatments were applied by the unit pictured in Figure 2. Each stem was hit only once with the 1/2-inch plastic rod which was moved by a 24-volt solonoid.

Early boot treatments were applied to all stems:

(1a) Bend the leaf sheath just below the collar of the flag leaf (1973 and 1974).

(1b) Bend the leaf sheath at the base of the panicle (1975).

(2) Hit the sheath of the flag leaf where the center of the panicle is located.

Treatments applied at the late boot stage were:

(3) Bend 1/3 of the stems just below the base of the panicle.

(4) Bend 2/3 of the stems just below the base of the panicle.

Figure 2. Unit used to apply hitting treatments (batteries not shown).

(5) Bend all of the stems just below the base of the panicle.

(6) Hit 1/3 of the flag leaf sheaths near the center of the panicle.

(7) Hit 2/3 of the flag leaf sheaths near the center of the panicle.

(8) Hit all of the flag leaf sheaths near the center of the panicle.

The heading stage was when panicles were completely emerged from the boot. Treatments applied at this stage were:

(9) Bend 1/3 of the stems 2 inches below the flag leaf collar.

(10) Bend 2/3 of the stems 2 inches below the flag leaf collar.

(11) Bend all stems 2 inches below the flag leaf collar.

(12) Bend 1/3 of stems 1 1/2 - 2 inches below bottom joint of panicle.

(13) Bend 2/3 of stems 1 1/2 - 2 inches below bottom joint of panicle.

(14) Bend all stems 1 1/2 - 2 inches below bottom joint of panicle.

Soft dough stage treatments were applied shortly after complete elongation of peduncle:

(15) Bend 1/3 of stems 2 inches below flag leaf collar.

(16) Bend 2/3 of stems 2 inches below flag leaf collar.

(17) Bend all stems 2 inches below flag leaf collar.

(18) Bend 1/3 of stems about 3/4 distance from flag leaf collar up to bottom of panicle.

(19) Bend 2/3 of stems about 3/4 distance from flag leaf collar up to bottom of panicle.

(20) Bend all stems about 3/4 distance from flag leaf collar up to head.

Blast, as increased by hitting treatments, was determined by tagging 10 random culms at the time of treatment. These treated panicles were collected at the soft dough stage for determining blast percentages. To assess the importance and variability of natural blast, spikelet counts were made of all varieties in the standard variety oat trials at the Brookings and Watertown locations in 1974 and 1975.

Panicle droppage was determined by tagging a specified number of treated culms at the time the treatments were applied. Tags were applied in a number relative to the treatment frequency. Therefore, 10 treated culms were tagged for the 1/3 treatment frequency, 20 were tagged for the 2/3 frequence, and 30 were tagged on plots where all the culms were treated. The number of tagged heads which dropped was counted just prior to harvesting.

Data determined for all plots included grain yield (bushels per acre), test weight (pounds per bushel), 1,000 kernel weight, percent thin kernels (those going through a 0.074 x 3/8 inch screen as used for commercial grading), percent plump kernels (those staying on top of a 5 1/2 x 64 x 3/8 inch screen) and percent intermediate kernels (kernels going through the larger screen but not the smaller).

Climatic conditions during the growing seasons are summarized in Appendix Tables 1 and 2. During this test both stations had less than average precipitation. Temperatures at Brookings were often below average, while Watertown temperatures were more variable. The dates of the various operations and treatments are given in Appendix Table 3.

## RESULTS AND DISCUSSION

### Effects on Grain Yield

A range in yield from 36 to 90 bushels per acre was found in the control plots during this study (Appendix, Table 4). Plots which received hitting treatments showed little or no yield loss, even though plants had bruised sheaths and there was a slight increase in blasting.

The lack of a yield loss due to hitting treatments may have been due to the limited area of injury. With a maximum of one hit per panicle, the plants apparently had sufficient ability to compensate.

Bending below the collar of the flag leaf at the early boot stage did not trap heads as sometimes occurs with bearded wheat and barley. The Brookings locations averaged 9.6% loss for 1973 and 1974 with a range of 8.2 to 11.5%. The reason for the wide range in effects of this treatment at Watertown in 1974 is not known. The spread may be due to difference in treatment as applied by different people. This difference may have been distorted by low yield on the Froker check plots.

Bending treatments in early boot (below the head, about 3 inches above the ground) gave an average loss of 31% in 1975. Plants did not recover their upright growth habit and remained leaning at harvest.

Bending treatments in late boot had a considerable effect on yield when applied to 2/3 or 3/3 of the stems. Yield loss is summarized in Table 1. The effect of treatment intensity is quite evident in Figure 3. The difference in the slope of the line for late boot as compared to heading and soft dough treatments may well be related to the time of treatment. At the late boot stage, the plants have a longer period of time to compensate for injury than when damaged at heading or later. The treatment which produced the greatest yield loss was the 3/3 frequency of bending at the late boot stage. As can be noted in Appendix Table 4, the yield loss from this particular treatment was quite consistent.

Yield loss from bending treatments of heading and soft dough are easiest to compare in Figure 3. Bending below the head at the heading stage gave the greatest losses. The smallest losses occurred after bending below the flag leaf collar at soft dough.

When the structure of the plant as well as the physiologic processes are considered, the results would appear to be logical. The uniform slopes to the yield reduction lines are reassuring. They indicate that the basic response to these treatments is the same although they do differ slightly in respective losses.

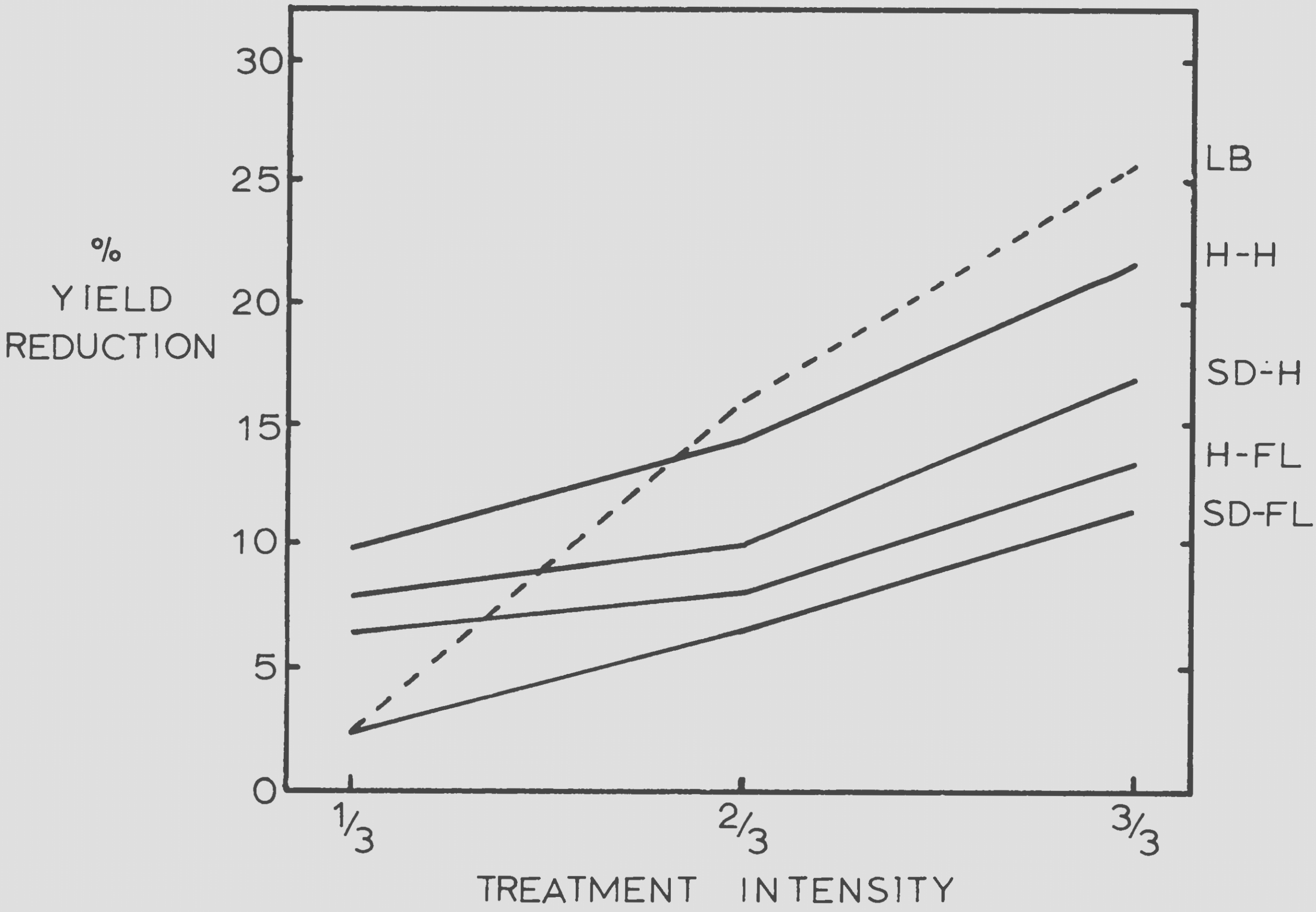


Figure 3. Grain yield reductions for Froker and Chief oats when averaged for two locations and 3 years.*

*Treatment symbols given here are:
LB; late boot, bent below head
H-H; heading stage, bent below head
SD-H; soft dough stage, bent below head
H-FL; heading stage, bent below flag leaf collar
SD-FL; soft dough stage, bent below flag leaf collar

In 1973 Froker was the higher yielding variety at Watertown, while Chief was higher in 1975. In each test the higher yielding variety had the greater percentage yield loss, indicating that loss percentages might have been higher if yield levels had been higher.

When the data for the 3-year period were analyzed, most factors and many interactions were statistically significant (see appendix for data tables). In spite of the many differences that were present, there were two important factors that were not significantly different: varieties and the location x year interaction.

This would indicate that there was no difference between the varieties in their response to the various treatments. Therefore, the adjuster can expect different varieties to respond in a similar manner to a given type of damage.

A comparison of the oat yield reductions obtained in this study with wheat and barley is in Table 2. Treatments were quite similar in all studies; therefore, the differences in results

Table 1. Percent yield loss for Froker and Chief oats. Values are averages for two locations and 3 years.

| Bend Location | Treatment Frequency | Stage of Treatment Late Boot | Heading | Soft Dough |
|---|---|---|---|---|
| Below flag leaf | 1/3 | -- | 6 | 2 |
| | 2/3 | -- | 8 | 7 |
| | 3/3 | -- | 13 | 12 |
| Below panicle | 1/3 | 2 | 9 | 8 |
| | 2/3 | 16 | 14 | 10 |
| | 3/3 | 26 | 22 | 17 |

would be due mainly to plant structure or response.

The greatest differences are present when the stem is bent below the head at heading and soft dough. When ranked from most to least loss at these stages, the ranking is wheat-barley-oats. If these crops were ranked according to straw hardness, wheat would be the stiffest and oats the softest. This indicates stiff-strawed plants have a greater yield reduction when the breaks occur above the flag leaf. The treatment which gave about equal losses in all crops was bending below the flag leaf collar at soft dough.

## Effects on Test Weight

Generally test weights were lower from plots in which culms were bent at the

Table 2. Comparison of stem bending effects on grain yields of barley, wheat, and oats. Values given are percent yield reduction when all stems are treated.

| Stage | Treatment | Barley[a] | Wheat[b] | Oats[c] |
|---|---|---|---|---|
| Late Boot | bent below head | 10 | 39 | 26 |
| Heading | bent below head | 34 | 61 | 22 |
| Heading | bent below flag leaf collar | 18 | 39 | 13 |
| Soft Dough | bent below head | 39 | 51 | 17 |
| Soft Dough | bent below flag leaf collar | 7 | 16 | 12 |

[a]Mean of 1971, 1972, and 1973 studies for Conquest and Dickson at Fargo, N.D.; E. L. Deckard and G. A. Peterson (2).

[b]Waldron wheat at Fargo, N.D. for 1969, 1970, and 1972 (1). The milk stage factors for wheat are compared to the heading stage of barley and oats.

[c]Values are averages of Chief and Froker for 1973, 1974, and 1975 at Brookings and Watertown, South Dakota.

Table 3. Percent reduction in test weight of Chief and Froker oats. Values are averages of 3 years and two locations.

| Bend Location | Treatment Frequency | Stage of Treatment Late Boot | Heading | Soft Dough |
|---|---|---|---|---|
| Below flag leaf | 1/3 | -- | 1.8 | +0.4 |
| | 2/3 | -- | 5.0 | 1.9 |
| | 3/3 | -- | 10.1 | 3.7 |
| Below panicle | 1/3 | +1 | 2.1 | 0.8 |
| | 2/3 | 1.5 | 5.9 | 0 |
| | 3/3 | 5.4 | 10.0 | 3.1 |

heading stage (Table 3). Results were similar for both treatments applied at that time.

Test weight was about 5% lower where all plants were bent at the late boot stage and 3 to 3.7% lower where all culms were bent at the soft dough stage. Reduction in test weight at the soft dough stage was most likely caused by limiting the filling of the youngest kernels.

The early boot bend at the base of the head was applied only in 1975. Test weight from these plots was similar to that of plots treated at heading time and lower than from plots treated in the late boot.

Test weights for the two varieties were very similar when compared for the various years and treatments. The greatest difference (4 pounds) in test weight between the two varieties occurred at Watertown in 1975 and correlates well with the yields from there that year. The Watertown location was not favorable for late oat varieties in 1975. Froker (the later variety) had much lower yield and test weight.

When the data for the 3 years were pooled, the location x treatment and the location x treatment x variety interactions were nonsignificant, indicating that the effects of a specific treatment are not dependent upon the location where applied. Therefore, when adjusting hail losses a specific damage should have equal effects at different locations within the same year. However, the variation in growing conditions may cause a considerable difference between years. When moisture is below optimum during part of the growing season, varieties will show differing yield losses.

In many localities, oat varieties with a considerable range in maturity are grown. Therefore, the varieties which suffer most from the lack of moisture will be the ones which were in the heading-blooming stage when moisture was most deficient. Because of this relationship and the variation in time of rainfall, the varieties of a given maturity will not always be the highest yielding. The heading-blooming stage is the most critical stage for moisture in grain crops because the daily water requirement is the greatest at this time.

## Effects on Kernel Size and Weight

### Effects on 1,000-Kernel Weight

The stages of development when simulated hail treatments generally had the greatest effects on kernel size were the same as those which resulted in the largest reductions in test weight. Kernel weight reductions at the heading stage were about the same as test weight reductions when 1/3 and 2/3 of the culms were bent, but when all culms were bent the test weight showed greater losses. The 1,000-kernel weight change was similar to yield response in that bending below the head at the heading stage was the most detrimental.

Slight reductions were also obtained from plots treated at the soft dough stage, but these were quite small. Average kernel weight for these two varieties usually responded to treatments in a similar way at each location. However, in 1975 at Brookings, Chief had an increase in kernel weight for all treatments, while that of Froker was reduced or only slightly higher. This difference in response was presumably due to the difference in stage of development when moisture was most available.

## Grain Size

Since 1,000-kernel weight represents only average grain size, the percentage of the kernels which were in the intermediate size category is also reported here. Table 4 contains only the percentage of the kernels in the intermediate size group because the percentage thin kernels showed very little variation within each year. Therefore, a change in percentage of intermediate sized kernels would be accompanied by an equal change, in the opposite direction, in the percentage of plump kernels.

The percentage of intermediate-sized kernels in Chief had the greatest decrease when plants were bent at the late boot stage or hit in early boot. A slight but consistent decrease in percentage of intermediate sized kernels occurred when bending was done below the flag leaf collar at the heading stage, with the percentage increasing as treatment frequency increased.

Froker has a plumper kernel, as evidenced by the much lower percentage of intermediate sized kernels in the control plots. It responded differently than Chief. When treatments were applied at either the heading or soft dough stage, kernel size of Froker changed considerably. In each treatment (bending below flag leaf and below the head) there was a consistent increase in the percentage of intermediate sized kernels as the treatment frequency increased.

These results would indicate that in varieties with very plump kernels, such as Froker, the amount of plump kernels will be affected much more than the test weight when compared on a percentage basis. Since this change in size is greater than the actual change in test weight, it would be very easy for a farmer to believe the test weight was reduced more than the actual amount. However, if the loss in test weight does drop the oats below a premium weight, this fact will do little to console the farmer.

Table 4. Percent intermediate sized kernels when all culms were treated. Percentages listed are averages for 3 years and two locations.

| Treatment Stage | Location of bend | Variety | |
|---|---|---|---|
| | | Chief | Froker |
| Check | | 69 | 33 |
| Late boot | Below head | 61 | 31 |
| Heading | Below flag leaf | 63 | 39 |
| " | Below head | 67 | 41 |
| Soft dough | Below flag leaf | 67 | 37 |
| " | Below head | 70 | 38 |

## Head Droppage

The number of heads dropped was counted just prior to harvest (Table 5). It is apparent that there is a considerable amount of variability in the percentage of treated heads dropped within a treatment. The least amount of droppage occurred in 1973 and at Watertown in 1974. These large fluctuations were presumably due to the difference in growing conditions.

The greatest amount of droppage occurred when the stem was bent below the head in late boot, but the percentage of damaged heads that dropped from this treatment was usually about the same regardless of the treatment frequency. The high amount of droppage caused by this treatment was probably due to the tenderness of the stem at the time of treating. Although bends below the head at early boot were made only in 1975, it should be noted that this also resulted in a high percentage of heads being dropped.

Bending below the head caused much more head droppage than bending below the flag leaf collar (Figure 4). As expected, bends below the head resulted in more droppage when treated at the heading stage rather than soft dough. This is logical as the heads had a longer time in which to be blown about.

An interesting trend occurred when bends were below the head at heading. The percentage of droppage decreased as the frequency of bent heads increased. In the plots with the high percentage of bent heads there was more tangling of the panicles. This tangling of the oat panicles apparently restricts the amount they can be blown about and thereby reduces head droppage.

Since droppage was rather variable, the droppage was summarized by variety and location in Table 6. In most of the treatments, Chief had a higher droppage frequency than Froker. This difference was particularly evident when bends were below the head at the 2/3 and 3/3 frequencies. A difference of about 10% was also present when bends were below the flag leaf at heading time. It is not known why these varieties had these differences. However, it does point out that varieties seem likely to differ in number of heads dropped when they receive approximate equal injury.

These differences in head droppage due to the same treatments indicate that head droppage is something that is not highly predictable. It can vary considerably depending upon variety, location, stage of injury, and storm intensity.

Table 5. Percent of bent heads which were dropped prior to harvest when bending occurred at the heading stage. Values are averages for two locations and 3 years.

| Bend Location | Treatment Frequency | Chief | Froker |
|---|---|---|---|
| Below flag leaf | 1/3 | 14 | 1 |
| | 2/3 | 12 | 2 |
| | 3/3 | 6 | 1 |
| Below panicle | 1/3 | 34 | 25 |
| | 2/3 | 26 | 10 |
| | 3/3 | 23 | 5 |

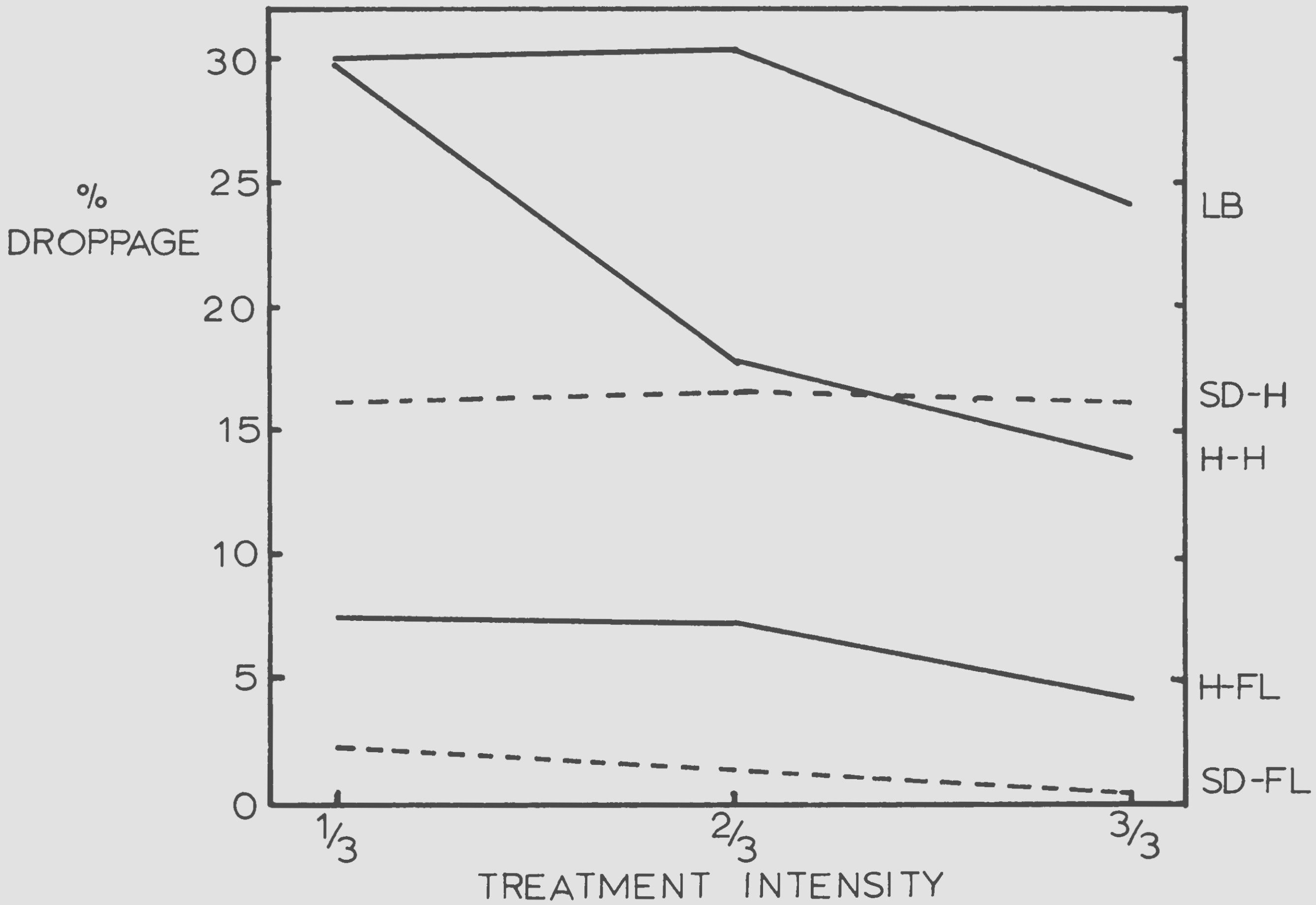


Figure 4. Percentage of treated heads which were dropped prior to harvest. Values are an average of two varieties at two locations for 3 years.*

*Treatment symbols given here are:
LB; late boot bent below head
H-H; heading stage, bent below head
SD-H; soft dough stage, bent below head
H-FL; heading stage, bent below flag leaf collar
SD-FL; soft dough stage, bent below flag leaf collar

## Blast

Natural blast in this experiment varied from 6 to 17% (Table 7). Most of the variation in blast occurred between years.

Blast was 2 to 5% higher on plots receiving hitting treatments than on control plots. Hitting treatments consisted of a single hit per head with a small dowel. Therefore, it is easy to see how large hail stones or multiple hits per panicle could cause considerable blast.

There was a large increase in blasting on plants that were bent at the base of the head in either early or late boot. This blast was presumably due to the restriction of water and nutrient flow into the panicles. It could not have been due to direct mechanical injury similar to the hitting treatments.

Counts of total spikelet number and blast percentage were also made in several oat varieties in 1974 and 1975 (Tables 8 and 9). Counts from these 2 years show that varieties which are presently being grown differ in panicle size as well as percentage natural blast. This is in agreement with some older studies. Unfortunately for the hail adjuster, the amount of natural blast

Table 6. Average percentage of treated heads which dropped prior to harvest. All averages include data from 1973-1975. Droppage is summarized by variety and by location.

| Stage-- | Late Boot | | | Heading | | | | | | Soft Dough | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Treatment location-- | Head | | | Flag Leaf | | | Head | | | Flag Leaf | | | Head | | |
| Frequency-- | 1/3 | 2/3 | 3/3 | 1/3 | 2/3 | 3/3 | 1/3 | 2/3 | 3/3 | 1/3 | 2/3 | 3/3 | 1/3 | 2/3 | 3/3 |
| Chief | 37.7 | 42.4 | 34.8 | 13.9 | 12.3 | 7.5 | 34.2 | 25.7 | 22.8 | 1.3 | 0.9 | 0.7 | 16.0 | 24.0 | 23.8 |
| Froker | 21.0 | 39.0 | 30.2 | 1.0 | 2.4 | 1.2 | 25.6 | 10.0 | 5.0 | 3.4 | 2.2 | 0.1 | 16.3 | 9.3 | 8.7 |
| Brookings | 17.3 | 41.8 | 44.1 | 6.8 | 4.3 | 7.1 | 37.5 | 21.0 | 15.9 | 1.3 | 0.9 | 0.8 | 20.1 | 23.0 | 20.2 |
| Watertown | 36.5 | 38.8 | 38.1 | 8.2 | 10.4 | 1.5 | 22.3 | 14.7 | 11.9 | 1.7 | 0.9 | 0.0 | 12.2 | 10.3 | 12.3 |

within each variety depends upon the environmental conditions present that year. Therefore, it is not possible to have an accurate figure for "average natural blast."

The high coefficient of variability (C.V.'s of 35 and 40%) in both of these years is a further indication that the blast percentage varies considerably among panicles of the same variety of oats. Eldredge (5) in a study of oats found 16.4% sterility in the primary panicles, while secondary panicles (tillers) had 40% sterility. He suggested this difference was probably due to the main stems having an advantage in moisture and nutrients. This type of variability might help explain the high C.V.'s obtained in the counts made in this study.

In the 2 years these counts were made, there was no consistent relationship between blast percentage and yield. Even though accurate blast predictions are not possible, these counts do show how much blast can occur at these locations under natural conditions.

Throughout the term of this study we were looking for some means of distinguishing natural blast from that caused by injury. We were not able to find any visible difference in appearance of blasted spikelets that would indicate the cause. The only guide that appears to be available is the location of the blast in the panicle.

Natural blast in our observations occurs primarily at the bottom of the panicle in the center in the most immature spikelets. A small amount of blast was present at higher points in the panicle, but the preponderance was

Table 7. Percent of total blast on injured oat panicles.

| | Location and Variety | Control | Early Boot Hit | Early Boot Bend | Late Boot Hit | | | Late Boot Bend | Base of Head | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | 3/3 | 3/3 | 1/3 | 2/3 | 3/3 | 1/3 | 2/3 | 3/3 |
| 1973 | Brookings | | | | | | | | | |
| | Chief | 15.3 | 25.3 | | 16.0 | 16.5 | 30.9 | | | |
| | Froker | 13.6 | 17.8 | | 13.7 | 15.5 | 17.0 | | | |
| | Watertown | | | | | | | | | |
| | Chief | 8.9 | -- | | 9.9 | 13.8 | 19.3 | | | |
| | Froker | 11.1 | 14.7 | | 11.4 | 13.4 | 15.4 | | | |
| 1974 | Brookings | | | | | | | | | |
| | Chief | 11.4 | 20.9 | | 21.0 | 19.0 | 18.0 | | | |
| | Froker | 17.4 | 21.4 | | 18.0 | 19.9 | 19.6 | | | |
| | Watertown | | | | | | | | | |
| | Chief | 15.1 | 13.6 | | 17.4 | 12.1 | 13.2 | | | |
| | Froker | 14.9 | 14.9 | | 17.4 | 14.0 | 14.0 | | | |
| 1975 | Brookings | | | | | | | | | |
| | Chief | 5.8 | 18.9 | 23.7 | 14.2 | 13.3 | 9.7 | 28.7 | 23.4 | 24.6 |
| | Froker | 8.9 | 17.8 | 21.5 | 12.7 | 12.4 | 11.8 | 27.1 | 24.3 | 24.7 |
| | Watertown | | | | | | | | | |
| | Chief | 11.4 | 15.0 | 23.3 | 16.0 | 14.6 | 18.2 | 21.7 | 41.7 | 25.7 |
| | Froker | 7.8 | 11.7 | 44.2 | 9.1 | 8.3 | 11.6 | 27.5 | 26.1 | 22.6 |
| | Average | 11.8 | 17.5 | 28.2 | 14.7 | 14.4 | 16.6 | 26.3 | 28.9 | 24.4 |

Table 8. Yield, percent blast, and spikelet numbers of oats in 1974 Standard Variety Oats at two locations.

| Variety | Brookings* Yield Bu./A | Brookings* Spikelet No./Panicle | Brookings* Blast % | Watertown** Yield Bu./A | Watertown** Spikelet No./Panicle | Watertown** Blast % |
|---|---|---|---|---|---|---|
| Trio | 30.9 | 25.3 | 4.7 | 56.1 | 25.6 | 10.5 |
| Dupree | 31.1 | 31.7 | 5.7 | 47.7 | 28.1 | 7.1 |
| Nodaway 70 | 36.1 | 24.9 | 10.4 | 50.2 | 24.0 | 9.2 |
| Portal | 25.4 | 34.0 | 11.2 | 48.1 | 22.5 | 18.2 |
| Allen | 41.7 | 30.5 | 12.1 | 52.7 | 26.0 | 14.2 |
| Diana | 37.6 | 28.8 | 12.2 | 48.9 | 24.7 | 9.3 |
| Random | 25.7 | 45.7 | 13.1 | 41.8 | 38.4 | 26.0 |
| SD 711035 | 36.6 | 17.4 | 13.2 | 42.2 | 17.1 | 10.5 |
| Lyon | 38.7 | 32.3 | 13.6 | 45.8 | 27.1 | 13.7 |
| Froker | 32.6 | 29.5 | 14.2 | 48.1 | 28.3 | 13.8 |
| Noble | 39.5 | 36.0 | 14.4 | 50.4 | 29.7 | 13.8 |
| Stout | 38.2 | 27.6 | 14.5 | 56.8 | 28.0 | 16.4 |
| Astro | 36.7 | 30.9 | 14.6 | 48.0 | 23.1 | 12.1 |
| Burnett | 33.6 | 30.8 | 14.9 | 48.7 | 30.9 | 12.3 |
| SD 711045 | 39.9 | 19.1 | 15.7 | 50.2 | 17.8 | 9.6 |
| Wright | 37.4 | 37.8 | 16.4 | 54.4 | 33.1 | 15.4 |
| Dal | 35.7 | 32.2 | 16.8 | 40.9 | 30.7 | 25.1 |
| Kelsey | 37.3 | 38.6 | 16.8 | 43.7 | 28.6 | 24.1 |
| Otee | 39.5 | 29.5 | 17.3 | 46.4 | 28.9 | 13.5 |
| Cayuse | 31.4 | 31.1 | 19.3 | 49.6 | 28.8 | 12.5 |
| Chief | 33.5 | 39.1 | 19.4 | 47.4 | 36.4 | 12.4 |
| Grundy | 34.2 | 28.8 | 19.8 | 47.3 | 30.2 | 12.9 |
| M-73 | 29.0 | 36.4 | 19.8 | 44.3 | 34.9 | 13.5 |
| Spear | 35.3 | 33.6 | 20.2 | 45.6 | 26.2 | 23.4 |
| Lodi | 35.4 | 38.8 | 21.6 | 42.6 | 35.0 | 20.6 |
| Holden | 36.8 | 28.7 | 22.3 | 51.1 | 26.0 | 16.5 |
| Hudson | 21.6 | 35.0 | 22.6 | 35.1 | 40.6 | 21.9 |
| Otter | 33.2 | 40.6 | 26.4 | 43.4 | 39.4 | 21.8 |
| Goodland | 44.0 | 31.0 | 26.8 | 40.7 | 27.9 | 27.2 |
| Garland | 39.5 | 37.3 | 27.9 | 48.7 | 28.5 | 14.7 |
| Average | 34.6 | 32.1 | 22.6 | 47.2 | 28.9 | 15.7 |

* Average of 4 replications with 10 heads per replication.
C.V. = 39.8% LSD (.05) = 23.5

** Average of 2 replications with 10 heads per replication.

Table 9. Yield, percentage blast, and spikelets per panicle for oats grown at Brookings and Watertown in 1975. Varieties are ranked from least to most blast when averaged for both locations.

| | Brookings* | | | Watertown* | | | Average | |
|---|---|---|---|---|---|---|---|---|
| Variety | Yield Bu/A | % Blast | Spikelets/ panicle | Yield Bu/A | % Blast | Spikelets/ panicle | % Blast | Spikelets/ panicle |
| Trio | 35 | 10.8 | 18.2 | 70 | 5.3 | 22.0 | 8.0 | 20.1 |
| E-74 | 36 | 12.8 | 17.9 | 66 | 10.8 | 23.0 | 11.8 | 20.4 |
| Nodaway 70 | 47 | 21.5 | 18.1 | 64 | 16.0 | 22.4 | 18.8 | 20.2 |
| SD 711045 | 46 | 20.8 | 15.7 | 55 | 18.5 | 22.2 | 19.6 | 19.0 |
| Froker | 43 | 19.3 | 19.9 | 58 | 20.5 | 23.9 | 19.9 | 21.9 |
| Lyon | 35 | 25.3 | 19.7 | 66 | 20.3 | 30.4 | 22.8 | 25.0 |
| Stout | 45 | 20.3 | 18.8 | 65 | 26.3 | 25.9 | 23.3 | 22.4 |
| Dal | 39 | 10.8 | 23.0 | 53 | 41.5 | 30.2 | 26.1 | 26.6 |
| Portal | 40 | 26.8 | 23.0 | 64 | 28.0 | 25.2 | 27.4 | 24.1 |
| Holden | 42 | 30.5 | 19.9 | 67 | 25.5 | 28.1 | 28.0 | 24.0 |
| Peterson 747 | 38 | 32.3 | 21.9 | 65 | 28.8 | 30.9 | 30.5 | 26.4 |
| Grundy | 42 | 33.5 | 21.7 | 67 | 28.3 | 27.5 | 30.9 | 24.6 |
| Noble | 50 | 41.8 | 24.1 | 74 | 20.0 | 27.5 | 30.9 | 25.8 |
| Astro | 52 | 22.5 | 22.1 | 43 | 39.5 | 28.3 | 31.0 | 25.2 |
| Spear | 45 | 43.0 | 22.8 | 70 | 19.3 | 28.7 | 31.1 | 25.7 |
| Diana | 43 | 36.8 | 22.9 | 68 | 25.5 | 27.0 | 31.1 | 24.9 |
| Lang | 55 | 23.5 | 22.2 | 74 | 39.0 | 27.6 | 31.3 | 24.9 |
| Wright | 43 | 33.8 | 20.0 | 60 | 30.3 | 25.6 | 32.0 | 22.8 |
| Allan | 35 | 34.0 | 21.5 | 73 | 31.3 | 26.5 | 32.6 | 24.0 |
| Otee | 46 | 36.8 | 22.4 | 65 | 31.3 | 26.1 | 34.0 | 24.2 |
| Chief | 39 | 42.0 | 24.8 | 67 | 30.5 | 34.4 | 36.3 | 29.6 |
| Burnett | 46 | 47.3 | 24.4 | 66 | 25.8 | 24.0 | 36.5 | 24.2 |
| M-73 | 38 | 49.3 | 23.8 | 62 | 33.3 | 26.5 | 41.3 | 25.2 |
| Goodland | 47 | 62.0 | 22.4 | 45 | 51.5 | 27.6 | 56.8 | 25.0 |
| Avg. | 43 | 30.7 | 21.3 | 64 | 26.9 | 26.7 | 28.8 | 24.0 |

*At each location 10 panicles per replication were counted with four replications for each variety.
C.V. = 35%

in the central portion in the youngest spikelets. In contrast to this, blast due to mechanical injury can occur at any place in the panicle.

Sheals (17) found the distribution of blast to be 85.3, 14.1, and 0.6% respectively in the lower, middle and upper thirds of the panicle. These observations are in agreement with those of Knowles (13) who used clay marbles to simulate hail damage. He found that "ordinary blast seldom occurs at the top of the panicle, among the first formed spikelets, whereas blast due to hail is distributed fairly evenly." When total blast on untreated plants was 37.1%, the upper three joints of the panicle had only 4.9% blast. Blast caused by herbicide injury, on the other hand, usually occurs at the top of the panicle.

Since there does not appear to be an accurate method of distinguishing between natural blast and that caused by hail, experience will be very valuable for the adjuster who is working with hail loss on oats.

When the hail occurred during the boot stage and appears to have caused blasting, experienced adjusters look for a bruise on the flag leaf sheath where the hail stone would have hit. Although this does not identify how much damage was done, it does reassure the adjuster that a hail stone did hit the plant. Some estimate of the amount of natural blast occurring in an area is needed before adjusting the hail damaged oat field.

## SUMMARY

Responses to all treatments indicated straight-line relationships. Therefore, adjustment factors can be readily determined for the appropriate percentage of damage. However, a comparison of these results with similar treatments on wheat and barley indicates that identical loss factors are not appropriate.

Yield losses were greatest when 2/3 or more of the panicles were bent below the head at the late boot stage. At lower treatment frequencies other treatments gave larger losses. The location of the bend was of greater importance than the date of treatment when bent at heading or later. Bends below the head consistently gave greater yield losses than bends below the flag leaf collar.

Reductions in test weight were consistent when stems were bent at the heading stage. Some reduction resulted from late boot bending at the higher frequency of treatment. Observations indicate that bending will cause plump kerneled varieties to have a greater change in appearance than varieties with more slender kernels.

The percentage of bent stems which dropped prior to harvest was about equal for all frequencies for each treatment except for bending below the head at heading time. Treatments resulting in the greatest droppage were at the late boot and bending below the head.

Blast will continue to be a problem when adjusting hail losses in oat fields which were damaged prior to heading. Variability due to variety, year, and environmental conditions will continue to make it difficult to accurately access the amount of blast caused by hail.

## REFERENCES

1. Busch, R.H. 1975. The effect of simulated hail injury on spring wheat. N.D. Agr. Exp. Sta. Bul. 497. 18 pages.

2. Deckard, E.L. and G.A. Peterson. 1974. Final report on the barley hail study. N.D. State University Agronomy Department unpublished mimeo report. 28 pages.

3. Derick, R.A. and J.L. Forsyth. 1935. A study of the causes of "blast" in oats. Sci. Agr. 15:814-824.

4. Derick, R.A. and D.G. Hamilton. 1939. Further studies on oat blast. Sci. Agr. 20:157-165.

5. Eldredge, J.C. 1937. The effect of injury in imitation of hail damage on the development of small grain. Iowa Agr. Exp. Sta. Bul. 219.

6. Elliott, C. 1922. Sterility of oats. USDA Bul. 1058.

7. Elliott, C. 1925. Oat blast. Phytopath 15:564-567.

8. Empson, D.W. 1958. "Blast" produced by the artificial defoliation of oats. Plant Path. 7:85-87.

9. Frey, K.J. and J.A. Browning. 1959. Yield losses from atypical oat blast in central Iowa in 1957. Iowa Acad. of Sci. 66:129-136.

10. Hanson, D.G. 1974. The effect of simulated hail damage on oats. Unpublished M.S. Thesis, S.D. State University.

11. Hella, A.N. and T.E. Stoa. 1964. Simulated hail injury to wheat and flax. N.D. Agr. Exp. Sta. Res. Report No. 12.

12. Johnson, T. and A.M. Brown. 1940. Studies on oat blast. Sci. Agr. 20:532-550.

13. Knowles, D.B. 1941. The effects of hail injury on wheat and other grain crops. Saskatchewan Agr. Res. Bul. No. 102.

14. Laude, H.H. and A.W. Pauli. 1959. Simulated hail injuries to winter wheat. Kansas Agr. Exp. Sta. Bul. 402.

15. Mackie, W.W. 1928. Inheritance of resistance to blast in oats. Phytopath. 18:948.

16. Rowell, P.L. and D.G. Miller. 1971. Induction of male sterility in wheat with 2-chloroethylphosphoric acid (ethrel). Crop Sci. 11:629-631.

17. Sheals, J.G. 1950. Observations on blindness in oats. Ann. of App. Biol. 37:397-406.

Appendix Table 1. Precipitation data for the Brookings and Watertown experiment locations.

| | Monthly Average (in.) | Deviation from Average | | |
|---|---|---|---|---|
| | | 1973 | 1974 | 1975 |
| **Brookings** | | | | |
| April | 2.88 | -1.05 | -0.61 | +0.83 |
| May | 1.25 | -1.01 | +1.26 | -1.95 |
| June | 3.91 | -2.73 | -3.01 | +0.67 |
| July | 0.77 | +0.39 | -0.88 | -2.07 |
| **Watertown** | | | | |
| April | 4.15 | -0.92 | -0.90 | +2.03 |
| May | 2.18 | 0.0 | +0.18 | -1.01 |
| June | 4.76 | -2.70 | -2.30 | +1.01 |
| July | 1.25 | -0.62 | -1.08 | -1.92 |

Appendix Table 2. Temperature data for the Brookings and Watertown experiment locations.

| | Monthly Average (°F) | Deviation from Average | | |
|---|---|---|---|---|
| | | 1973 | 1974 | 1975 |
| **Brookings** | | | | |
| April | 44.6 | -2.7 | 0 | -7.5 |
| May | 52.2 | -4.4 | -4.0 | +2.0 |
| June | 63.5 | -0.7 | -2.2 | -1.6 |
| July | 74.4 | -3.1 | +3.3 | +2.5 |
| **Watertown** | | | | |
| April | 45.0 | -0.9 | +2.3 | -5.0 |
| May | 52.5 | -0.9 | -2.2 | +3.1 |
| June | 65.3 | +1.1 | +0.6 | +0.6 |
| July | 76.0 | -1.1 | +5.3 | +4.8 |

Appendix Table 3. Dates of planting, treatment applications and harvest for the simulated hail study on oats.

Brookings

| Treatment | Chief | | | Froker | | |
|---|---|---|---|---|---|---|
| | 1973 | 1974 | 1975 | 1973 | 1974 | 1975 |
| Planting | 4/5 | 4/16 | 5/1 | 4/5 | 4/16 | 5/1 |
| Early Boot | 6/8 | 6/14 | 6/13 | 6/12 | 6/18 | 6/17 |
| Late Boot | 6/11 | 6/17 | 6/18 | 6/14 | 6/21 | 6/20 |
| Heading | 6/18 | 6/25 | 6/24 | 6/21 | 7/1 | 6/30 |
| Soft Dough | 7/2 | 7/12 | 7/11 | 7/6 | 7/15 | 7/14 |
| Harvest | 7/23 | 7/24 | 7/21 | 7/27 | 7/25 | 7/23 |

Watertown

| Treatment | Chief | | | Froker | | |
|---|---|---|---|---|---|---|
| | 1973 | 1974 | 1975 | 1973 | 1974 | 1975 |
| Planting | 4/18 | 4/19 | 5/8 | 4/18 | 4/19 | 5/8 |
| Early Boot | * | 6/24 | 6/23 | 6/18 | 6/24 | 6/26 |
| Late Boot | 6/15 | 6/26 | 6/27 | 6/21 | 6/27 | 7/1 |
| Heading | 6/25 | 7/8 | 7/3 | 6/27 | 7/9 | 7/7 |
| Soft Dough | 7/11 | 7/18 | 7/21 | 7/16 | 7/22 | 7/23 |
| Harvest | 7/26 | 7/23 | 7/30 | 7/26 | 7/26 | 8/4 |

* This treatment was not applied.

Appendix Table 4. Percent yield loss for Froker and Chief oats for all treatments at Brookings and Watertown for 1973 to 1975.

| | | Yield of Control Plots (Bu.) | Early Boot | | Late Boot | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | Bend | Hit | Bend | | | Hit | | |
| | | | 3/3 | 3/3 | 1/3 | 2/3 | 3/3 | 1/3 | 2/3 | 3/3 |
| 1973 | Brookings | | | | | | | | | |
| | Chief | 66.1 | 11.5 | 7.9 | +1.2 | 23.1 | 2.3 | 9.7 | 6.2 | 7.7 |
| | Froker | 71.4 | 8.7 | 6.3 | 16.1 | 32.1 | 48.5 | +1.5 | 0 | 15.1 |
| | Watertown | | | | | | | | | |
| | Chief | 66.4 | -- | -- | 3.3 | 9.8 | 19.4 | 2.7 | 6.0 | 9.6 |
| | Froker | 89.5 | 5.1 | 4.7 | 11.8 | 17.1 | 28.3 | 5.8 | 14.1 | 3.0 |
| 1974 | Brookings | | | | | | | | | |
| | Chief | 35.9 | 9.8 | +11.1 | +22 | +4.7 | 17.6 | 1.4 | 6.7 | +13.9 |
| | Froker | 36.4 | 8.2 | +10.4 | +15.1 | 2.5 | 18.1 | +7.4 | +2.2 | +2.2 |
| | Watertown | | | | | | | | | |
| | Chief | 54.8 | 1.6 | +3.1 | 4.9 | 25.7 | 30.5 | +2.4 | 1.3 | +2.6 |
| | Froker | 45.2 | +18.1 | +11.3 | +6.4 | 20.1 | 29.9 | +20.6 | +13.3 | +10.2 |
| 1975 | Brookings | | | | | | | | | |
| | Chief | 61 | 25† | +4.4 | 6.8 | 11 | 25 | +8.8 | +8 | +4.7 |
| | Froker | 57 | 30† | 13 | 5 | 23 | 23 | 14 | 5 | 15 |
| | Watertown | | | | | | | | | |
| | Chief | 88 | 40† | 6.5 | 25 | 26 | 35 | 10 | 16 | 12 |
| | Froker | 61 | 29† | +23 | +1 | 5.6 | 29 | +17 | +4.6 | +8.3 |
| | Average | -- | 3.8 | ? | 2.3 | 15.9 | 25.6 | +1.2 | 2.3 | 1.7 |

† These plots were bent below the head instead of below the flag leaf collar as in the two preceeding years.

Table 4. (cont.)

| Heading | | | | | | Soft Dough | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Flag Leaf | | | Head | | | Flag Leaf | | | Head | | |
| 1/3 | 2/3 | 3/3 | 1/3 | 2/3 | 3/3 | 1/3 | 2/3 | 3/3 | 1/3 | 2/3 | 3/3 |
| 8.9 | 26.9 | 24.2 | 5.0 | 20.7 | 21.7 | 7.6 | 19.1 | 19.1 | 10.9 | 10.1 | 11.3 |
| 14.3 | 17.6 | 27.6 | 22.8 | 29.0 | 33.5 | 6.4 | 14.6 | 28.8 | 11.3 | 11.9 | 11.6 |
| 4.7 | 25.1 | 34.0 | 9.2 | 10.8 | 31.9 | 3.3 | 22.9 | 29.8 | 10.2 | 14.6 | 7.5 |
| 12.3 | 26.0 | 28.8 | 12.4 | 18.7 | 33.0 | +2.9 | 13.1 | 18.5 | 9.6 | 8.5 | 10.3 |
| 8.6 | +26.7 | +3.3 | 12.3 | 26.7 | 21.5 | +10.6 | +18.1 | +14.8 | 18.4 | +3.6 | 32.6 |
| +0.8 | +4.4 | 1.4 | +3.6 | 2.2 | 15.7 | 25.3 | 9.3 | 27.2 | +0.3 | 5.2 | 18.1 |
| 1.6 | 14.2 | 8.2 | 12.2 | 19.0 | 19.9 | 0.2 | 2.9 | 1.1 | +3.3 | 6.0 | 7.1 |
| 7.1 | 4.9 | 19.2 | 3.8 | 10.4 | 26.1 | +12.2 | 0.2 | 15.9 | +13.5 | +2.2 | 1.3 |
| +4.1 | +7.2 | +6.8 | +1 | 2.6 | 6.2 | +9.0 | 7.0 | +18.0 | 9.8 | 22 | 47 |
| 5 | 10 | 16 | 14 | 4 | 12 | 8 | +1 | 6 | 16 | 16 | 12 |
| 18 | 16 | 12 | 23 | 20 | 36 | 14 | 7 | 11 | 33 | 31 | 45 |
| 0 | +5.2 | +2.1 | +3.3 | 7.5 | 1.6 | +4.1 | 2 | 13.6 | +7.5 | 0.7 | +1.8 |
| 6.3 | 8.1 | 13.3 | 8.9 | 14.3 | 21.6 | 2.2 | 6.6 | 11.5 | 7.9 | 10.0 | 16.8 |

Appendix Table 5. A summary of the percent reduction in test weight due to simulated hail damage.

| | | Control (Lb/Bu) | Early Boot Bend 3/3 | Early Boot Hit 3/3 | Late Boot Bend 1/3 | Late Boot Bend 2/3 | Late Boot Bend 3/3 | Late Boot Hit 1/3 | Late Boot Hit 2/3 | Late Boot Hit 3/3 |
|---|---|---|---|---|---|---|---|---|---|---|
| 1973 | Brookings | | | | | | | | | |
| | Chief | 33.3 | 0 | +0.3 | +1.5 | 8.7 | +0.6 | 8.6 | 2.4 | 1.5 |
| | Froker | 33.9 | +1.8 | +1.5 | 2.1 | 8.3 | 18.6 | +2.7 | +1.2 | +2.7 |
| | Watertown | | | | | | | | | |
| | Chief | 31.6 | -- | -- | 2.2 | 6.3 | 4.7 | 2.2 | 1.3 | 2.8 |
| | Froker | 31.5 | 1.6 | 1.3 | 2.2 | 7.6 | 7.0 | 6.7 | 3.5 | 3.5 |
| 1974 | Brookings | | | | | | | | | |
| | Chief | 28.3 | +0.7 | +1.8 | +3.5 | +6.4 | 3.2 | +2.5 | +4.2 | +4.2 |
| | Froker | 27.0 | +1.5 | +1.5 | +3.0 | +3.3 | 6.3 | +3.0 | +3.7 | +3.7 |
| | Watertown | | | | | | | | | |
| | Chief | 30.0 | +3.7 | +2.0 | 1.7 | +1.0 | 0 | +3.0 | +8.3 | +6.0 |
| | Froker | 28.3 | +15.9 | +3.5 | +10.6 | +10.6 | +1.1 | +11.3 | +8.1 | +7.8 |
| 1975 | Brookings | | | | | | | | | |
| | Chief | 30.4 | 6.6† | 4.9 | 0 | +0.7 | 6.3 | +1.3 | +1.6 | 0 |
| | Froker | 29.6 | 12.5† | 0.7 | 2.0 | 3.4 | 8.8 | 0.3 | 2.0 | 2.7 |
| | Watertown | | | | | | | | | |
| | Chief | 36.4 | 15.0† | 0 | 1.1 | 5.2 | 3.0 | 1.1 | 0.8 | 0.8 |
| | Froker | 32.5 | 11† | 0.9 | 1.2 | 0.6 | 8.0 | +1.5 | +8.6 | +4.0 |
| | Average | -- | 3.7 | 0.2 | +0.5 | 1.5 | 5.4 | +0.5 | 2.1 | +1.4 |

† These plots were bent below the head instead of below the flag leaf collar as in the two preceeding years.

Table 5. (cont.)

| Heading | | | | | | Soft Dough | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Flag Leaf | | | Head | | | Flag Leaf | | | Head | | |
| 1/3 | 2/3 | 3/3 | 1/3 | 2/3 | 3/3 | 1/3 | 2/3 | 3/3 | 1/3 | 2/3 | 3/3 |
| 3.9 | 4.2 | 7.5 | 3.6 | 6.9 | 12.9 | +0.9 | 4.2 | 4.5 | 3.9 | 4.2 | 3.9 |
| +0.5 | 3.8 | 7.1 | 7.4 | 10.0 | 18.0 | +1.5 | +2.7 | 5.0 | 2.1 | 0.3 | 1.5 |
| 4.7 | 5.7 | 11.7 | 5.1 | 9.8 | 9.8 | 3.2 | 7.6 | 8.9 | 1.9 | 2.5 | 6.3 |
| 0.6 | 8.6 | 17.8 | 3.2 | 5.1 | 9.8 | 0.3 | 0.3 | 0.6 | 1.9 | 6.3 | 3.5 |
| 4.9 | 8.1 | 8.5 | 1.8 | 6.7 | 13.1 | +0.7 | 1.4 | 1.8 | 4.9 | +0.4 | 8.1 |
| 4.4 | 5.6 | 11.9 | 0.4 | 4.4 | 9.6 | 5.2 | 3.7 | 3.7 | +1.9 | +1.5 | 0.4 |
| +0.3 | 2.3 | 7.0 | +1.0 | 11.3 | 7.0 | +7.7 | +3.7 | 0.3 | +3.7 | +6.7 | +1.3 |
| +7.8 | +3.9 | 7.8 | +5.7 | +2.5 | 8.5 | +11.0 | +6.4 | 0 | +10.6 | +12.4 | +6.4 |
| 2.0 | 5.3 | 6.9 | 0.3 | 2.6 | 9.2 | 2.0 | 7.6 | 4.3 | 0 | 1.3 | 2.6 |
| 2.7 | 8.8 | 12.2 | 2.7 | 4.4 | 4.4 | 1.0 | +0.7 | 2.0 | 3.7 | 2.0 | 0.7 |
| 5.2 | 6.9 | 12 | 4.1 | 5.2 | 7.1 | 3.6 | 6.3 | 9.6 | 4.9 | 4.9 | 9.6 |
| 2.2 | 4.3 | 11 | 3.7 | 7.4 | 11.0 | 1.8 | 4.9 | 3.7 | 2.2 | +0.3 | 7.7 |
| 1.8 | 5.0 | 10.1 | 2.1 | 5.9 | 10.0 | +0.4 | 1.9 | 3.7 | 0.8 | 0.02 | 3.1 |

Appendix Table 6. A summary of the percent reduction in 1,000 kernel weight due to simulated hail treatments.

| Year | | Control (grams/ 1000) | Early Boot | | Late Boot | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | Bend | Hit | Bend | | | Hit | | |
| | | | 3/3 | 3/3 | 1/3 | 2/3 | 3/3 | 1/3 | 2/3 | 3/3 |
| 1973 | Brookings | | | | | | | | | |
| | Chief | 32.4 | 0 | +1.5 | +5.6 | 3.4 | 3.7 | 2.8 | 5.9 | 2.8 |
| | Froker | 37.8 | +4.0 | +3.7 | +2.7 | 5.8 | 9.3 | +0.5 | 4.2 | +0.5 |
| | Watertown | | | | | | | | | |
| | Chief | 24.0 | -- | -- | 0.4 | 3.3 | +1.3 | 2.5 | +2.9 | +1.3 |
| | Froker | 28.4 | 1.4 | +2.1 | +1.1 | 0.3 | 2.8 | +3.5 | +6.0 | +2.1 |
| 1974 | Brookings | | | | | | | | | |
| | Chief | 17.7 | +9.0 | +6.2 | +4.0 | +14.1 | +18.1 | +0.6 | +6.2 | +9.0 |
| | Froker | 18.5 | +2.2 | +1.1 | +2.2 | +8.6 | +13.0 | 0.5 | +4.3 | +5.9 |
| | Watertown | | | | | | | | | |
| | Chief | 22.0 | +1.4 | +3.2 | +2.3 | +6.4 | +1.4 | 4.1 | +3.6 | +3.2 |
| | Froker | 23.9 | 3.8 | +2.9 | +1.3 | 0.8 | 0.4 | 4.2 | 0 | +1.3 |
| 1975 | Brookings | | | | | | | | | |
| | Chief | 20.6 | +7.3† | +11 | +8.3 | +14 | +7.8 | +7.3 | +12 | +11 |
| | Froker | 24.4 | 7.0† | 1.2 | +0.8 | 0.8 | 3.7 | +2.9 | +1.6 | 0 |
| | Watertown | | | | | | | | | |
| | Chief | 24.8 | 10† | 1.6 | 0.4 | 1.2 | 4.0 | 1.6 | 4.8 | 1.2 |
| | Froker | 23.8 | 5.9† | 1.3 | 0.4 | 4.6 | 0.4 | 1.3 | +1.7 | +1.7 |
| | Average | 24.9 | | +2.5 | +2.3 | +1.9 | +1.5 | +0.2 | +2.0 | +2.7 |

† These plots were bent below the head instead of below the flag leaf collar as in the two preceeding years.

Table 6. (cont.)

| Heading | | | | | | Soft Dough | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Flag Leaf | | | Head | | | Flag Leaf | | | Head | | |
| 1/3 | 2/3 | 3/3 | 1/3 | 2/3 | 3/3 | 1/3 | 2/3 | 3/3 | 1/3 | 2/3 | 3/3 |
| 2.8 | 6.6 | 6.9 | 4.4 | 5.2 | 14.8 | 4.3 | 6.8 | 3.4 | 5.6 | 6.5 | 9.3 |
| 1.1 | 10.8 | 8.7 | 2.9 | 12.0 | 12.0 | +1.9 | 0.8 | +2.1 | 8.2 | 9.5 | 2.1 |
| 3.7 | 3.7 | 1.2 | +0.4 | +1.7 | 5.4 | 0.8 | 4.6 | 0.8 | +6.3 | 3.3 | +3.3 |
| +2.1 | 5.6 | 11.3 | +0.4 | 8.1 | 9.8 | 0.7 | 0.3 | 2.1 | 5.6 | +5.3 | +7.4 |
| 0 | 2.3 | 5.6 | +3.4 | 0.6 | +1.1 | +4.5 | 0 | 0.6 | +2.3 | +1.7 | +1.7 |
| +1.1 | 2.2 | 3.2 | 2.2 | +2.2 | 3.2 | +1.1 | +1.1 | +1.6 | +6.5 | +3.8 | +2.7 |
| +0.5 | +0.5 | 3.6 | 5.0 | 6.8 | 8.6 | 0 | 6.4 | 4.1 | 2.7 | 9.1 | 0.5 |
| 1.3 | 5.4 | 7.1 | 1.3 | 9.6 | 10.0 | 3.3 | 1.3 | 2.1 | +1.3 | 2.1 | 5.9 |
| +4.9 | +2.9 | +1.0 | +7.8 | +6.8 | 1.0 | +6.8 | +5.3 | +11 | +8.7 | +9.7 | +6.8 |
| 4.9 | 9.8 | 10 | 5.7 | 4.9 | 9.0 | 2.0 | +0.8 | 3.7 | 5.3 | 11 | 1.6 |
| 8.1 | 8.5 | 14 | 7.7 | 11 | 13 | 11 | 6.5 | 11 | 12 | 6.5 | 9.7 |
| 7.6 | 8.4 | 11 | 6.7 | 5.9 | 11 | 5.5 | 8.8 | 11 | 5.0 | 10 | 7.1 |
| 1.8 | 5.0 | 6.8 | 2.0 | 4.5 | 8.9 | 1.1 | 2.4 | 2.0 | 1.6 | 3.1 | 1.2 |

Appendix Table 7. A summary of the percentage of intermediate sized kernels in all treatments.

| | | | Early Boot | | Late Boot | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | Bend | Hit | Bend | | | Hit | | |
| | | Control | 3/3 | 3/3 | 1/3 | 2/3 | 3/3 | 1/3 | 2/3 | 3/3 |
| | | | | | CHIEF | | | | | |
| 1973 | Brookings | 39.7 | 35.5 | 36.1 | 34.9 | 37.8 | 36.2 | 38.4 | 32.5 | 35.2 |
| | Watertown | 81.9 | -- | -- | 72.5 | 72.4 | 67.8 | 75.5 | 76.4 | 76.3 |
| 1974 | Brookings | 74.7 | 76.1 | 76.0 | 74.0 | 70.8 | 65.6 | 77.7 | 76.5 | 77.6 |
| | Watertown | 73.5 | 69.0 | 68.2 | 69.7 | 62.9 | 69.5 | 72.4 | 77.2 | 68.0 |
| 1975 | Brookings | 75.0 | 72.4† | 62.4 | 64.4 | 63.4 | 61.9 | 64.6 | 68.9 | 64.9 |
| | Watertown | 67.1 | 62.4† | 62.6 | 61.3 | 58.4 | 62.8 | 64.3 | 69.1 | 66.0 |
| | Average | 68.7 | -- | 61.1 | 62.8 | 61.0 | 60.6 | 65.5 | 66.8 | 64.7 |
| | | | | | FROKER | | | | | |
| 1973 | Brookings | 9.0 | 8.4 | 9.2 | 10.3 | 11.1 | 15.3 | 8.6 | 8.3 | 9.0 |
| | Watertown | 34.4 | 27.2 | 30.2 | 29.5 | 28.2 | 23.8 | 30.4 | 35.7 | 30.8 |
| 1974 | Brookings | 57.8 | 57.3 | 57.6 | 54.6 | 47.1 | 40.0 | 58.0 | 54.9 | 59.6 |
| | Watertown | 27.3 | 33.6 | 28.1 | 34.3 | 33.2 | 30.4 | 35.1 | 29.9 | 28.8 |
| 1975 | Brookings | 22.5 | 29.1† | 23.7 | 26.1 | 26.3 | 29.8 | 27.5 | 27.9 | 26.5 |
| | Watertown | 48.9 | 42.6† | 45.2 | 43.6 | 45.5 | 48.1 | 46.9 | 48.7 | 50.4 |
| | Average | 33.3 | -- | 32.3 | 33.1 | 31.9 | 31.2 | 34.4 | 34.2 | 34.2 |

† These plots were bent below the head instead of below the flag leaf collar as in preceeding years.

Table 7. (cont.)

| Heading | | | | | | Soft Dough | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Flag Leaf | | | Head | | | Flag Leaf | | | Head | | |
| 1/3 | 2/3 | 3/3 | 1/3 | 2/3 | 3/3 | 1/3 | 2/3 | 3/3 | 1/3 | 2/3 | 3/3 |
| CHIEF | | | | | | | | | | | |
| 35.9 | 39.2 | 36.1 | 39.1 | 49.5 | 55.4 | 39.1 | 38.9 | 37.6 | 40.0 | 38.0 | 47.2 |
| 80.5 | 77.8 | 71.8 | 78.8 | 76.0 | 74.4 | 61.8 | 78.1 | 74.6 | 82.9 | 78.2 | 77.2 |
| 75.6 | 72.0 | 68.9 | 74.5 | 73.4 | 68.5 | 73.5 | 76.2 | 74.1 | 74.2 | 75.3 | 75.6 |
| 68.4 | 65.0 | 61.4 | 72.6 | 61.7 | 63.3 | 72.2 | 76.5 | 73.9 | 76.5 | 79.0 | 73.1 |
| 69.2 | 67.5 | 68.5 | 66.7 | 70.3 | 66.5 | 68.3 | 65.6 | 64.6 | 66.8 | 63.0 | 72.1 |
| 70.8 | 67.9 | 71.8 | 69.8 | 68.3 | 73.9 | 71.8 | 72.1 | 74.1 | 72.5 | 71.6 | 73.8 |
| 66.7 | 64.9 | 63.1 | 66.9 | 66.5 | 67.0 | 64.5 | 67.9 | 66.5 | 68.8 | 67.5 | 69.8 |
| FROKER | | | | | | | | | | | |
| 10.6 | 13.9 | 15.6 | 16.5 | 19.3 | 34.3 | 10.4 | 10.3 | 11.8 | 11.6 | 10.3 | 13.0 |
| 40.6 | 46.5 | 42.4 | 36.5 | 39.5 | 42.6 | 35.5 | 44.8 | 40.2 | 38.1 | 47.1 | 42.6 |
| 55.7 | 54.0 | 47.8 | 55.1 | 49.0 | 46.9 | 58.2 | 58.1 | 55.8 | 54.7 | 54.8 | 54.5 |
| 33.4 | 30.8 | 38.4 | 35.7 | 40.5 | 39.4 | 35.6 | 35.6 | 30.7 | 32.7 | 36.7 | 34.5 |
| 28.1 | 31.7 | 32.7 | 30.1 | 30.4 | 26.5 | 27.9 | 27.5 | 28.6 | 30.7 | 29.1 | 27.2 |
| 48.6 | 53.6 | 57.2 | 50.9 | 50.4 | 55.5 | 54.8 | 55.1 | 57.2 | 51.9 | 57.1 | 56.6 |
| 36.2 | 38.4 | 39.0 | 37.5 | 38.2 | 40.9 | 37.1 | 38.6 | 37.4 | 36.6 | 39.2 | 38.1 |

Appendix Table 8. A summary of the percentage of treated heads which were dropped prior to harvest.

| | | E. Boot | Late Boot | | | Heading | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Head | Head | | | Flag Leaf | | | Head | | |
| | | | 1/3 | 2/3 | 3/3 | 1/3 | 2/3 | 3/3 | 1/3 | 2/3 | 3/3 |
| 1973 | Brookings | | | | | | | | | | |
| | Chief | | -- | -- | -- | 0 | 0 | 0 | 10 | 2.5 | 4.2 |
| | Froker | | 35 | 65 | 56 | 0 | 2.5 | 0 | 33 | 16 | 9.9 |
| | Watertown | | | | | | | | | | |
| | Chief | | -- | -- | -- | 5 | 0 | 0.8 | 5 | 0 | 3.3 |
| | Froker | | -- | -- | -- | 2.3 | 0 | 0.8 | 0 | 2.3 | 0 |
| 1974 | Brookings | | | | | | | | | | |
| | Chief | | 27.5 | 18.8 | 15.0 | 27.5 | 1.3 | 9.2 | 47.5 | 35.0 | 28.3 |
| | Froker | | 7.5 | 12.5 | 5.0 | 0 | 1.3 | 0.8 | 27.5 | 10.0 | 4.2 |
| | Watertown | | | | | | | | | | |
| | Chief | | 12.5 | 41.3 | 17.5 | 2.5 | 0 | 0 | 25.0 | 21.3 | 7.5 |
| | Froker | | 0 | 16.3 | 5.8 | 0 | 2.5 | 0 | 2.5 | 7.5 | 4.2 |
| 1975 | Brookings | | | | | | | | | | |
| | Chief | 47.2[†] | 65.0 | 76.2 | 60.1 | 13.1 | 14.2 | 30.3 | 40.5 | 55.6 | 47.6 |
| | Froker | 39.0[†] | 100.0 | 36.7 | 45.5 | 0 | 6.3 | 2.5 | 66.4 | 6.8 | 1.0 |
| | Watertown | | | | | | | | | | |
| | Chief | 60.9[†] | 45.9 | 33.4 | 46.5 | 35.5 | 58.0 | 4.5 | 77.0 | 39.9 | 46.0 |
| | Froker | 67.9[†] | 66.6 | 64.3 | 38.6 | 3.6 | 1.6 | 3.0 | 24.2 | 17.1 | 10.4 |
| | Average | | 30 | 30.4 | 24.2 | 7.5 | 7.3 | 4.3 | 29.9 | 17.8 | 13.9 |

[†] These plots were bent below the head at early boot.

Table 8. (cont.)

| Soft Dough | | | | | |
|---|---|---|---|---|---|
| Flag Leaf | | | Head | | |
| 1/3 | 2/3 | 3/3 | 1/3 | 2/3 | 3/3 |
| 0 | 0 | 0.8 | 2.5 | 1.3 | 0 |
| 0 | 0 | 0 | 0 | 5 | 0.8 |
| 0 | 0 | 0 | 0 | 1.3 | 0.8 |
| 0 | 0 | 0 | 0 | 0 | 0 |
| 5.0 | 2.5 | 2.5 | 12.5 | 21.3 | 16.7 |
| 0 | 0 | 0.8 | 17.5 | 11.3 | 7.5 |
| 0 | 0 | 0 | 0 | 0 | 0 |
| 0 | 0 | 0 | 0 | 0 | 0 |
| 2.5 | 2.7 | 0.9 | 35.0 | 66.9 | 70.2 |
| 10 | 7.6 | 0 | 53.3 | 32.0 | 25.7 |
| 0 | 0 | 0.1 | 46.2 | 52.9 | 55.0 |
| 10.4 | 5.5 | 0 | 26.7 | 7.5 | 18.0 |
| 2.3 | 1.5 | 0.4 | 16.1 | 16.1 | 16.2 |