A STUDY OF THE EFFECT OF SIMULATED HAIL INJURIES TO WHEAT

by

GEORGE LOUGHRIDGE SCRUGGS, JR.

B. S., Oklahoma Agricultural and Mechanical College, 1949

A THESIS

submitted in partial fulfillment of the

requirements for the degree

MASTER OF SCIENCE

Department of Agronomy

KANSAS STATE COLLEGE
OF AGRICULTURE AND APPLIED SCIENCE

1950

TABLE OF CONTENTS

INTRODUCTION

Hailstorms occur in nearly all parts of the country and are especially severe in the high plains area which lies west of the 100th Meridian (21).

The geographical distribution of hail in Kansas is the reverse of the annual precipitation. Hail hazard increased steadily from the eastern to the western border of the state, while the normal precipitation decreases toward the western border (21).

Weather bureau records show that hailstorms can be expected to occur from 2 to 4 times as frequently in central and western Kansas as in the southeastern part of the state (7).

The hailstorms are most prevalent in May and June, and occur at the time wheat approaches maturity. In many cases, hail injuries sustained by wheat plants cause unusually severe damage in limited areas (21).

Hail is often associated with heavy rains and thunderstorms and are more damaging in a wet year than in a dry one (21, 7). There are several reasons for this; in wet years hailstorms are more frequent and their greater severity account for increased damage. In dry years the rain accompanying the hail proves to be quite beneficial to the moisture starved plants in the surrounding area (21, 35).

The best estimate available indicated that the average annual loss over a 10-year period, ending with 1945, had been only 4 per cent of the total wheat yield of the state. This loss is relatively small and probably no greater than the loss occurring due to improper harvesting, threshing, and spoilage (21).

Individual hailstorms, however, do cause severe damage in the area where they occur. In 1915 the estimated loss due to hail was $8,450,000 and in 1928 the loss was estimated to be $12,400,000. In June of the same year 2 hailstorms in western Kansas caused losses estimated at $3,000,000 each (21).

For the years 1928 through 1945 the average number of hailstorms in Kansas were estimated at 45 and the annual damage as reported to the United States Weather Bureau at $2,839,791 (21). Figure 1 shows the average number of hailstorms in Kansas and the loss of wheat in bushels annually for 18-year period ending with 1945 (21).

Artificial injuries to plants that may be devised to simulate hail damage are, at best, imitations of the real damage which results from actual hailstorms. However, since it is not possible to conjure up hailstorms at desired periods in the development of plants, nor in the event of an actual hailstorm to establish needed check plots, one must be content in the study of this problem with the use of artificial types of damage to simulate the effects of hail on plants. Despite the fact that this study constitutes such a problem and has its limitations, it would appear to merit further investigation.

As yet, very little work has been done in the study of this question, and much basic information is needed. This particular investigation was undertaken to obtain detailed information re-

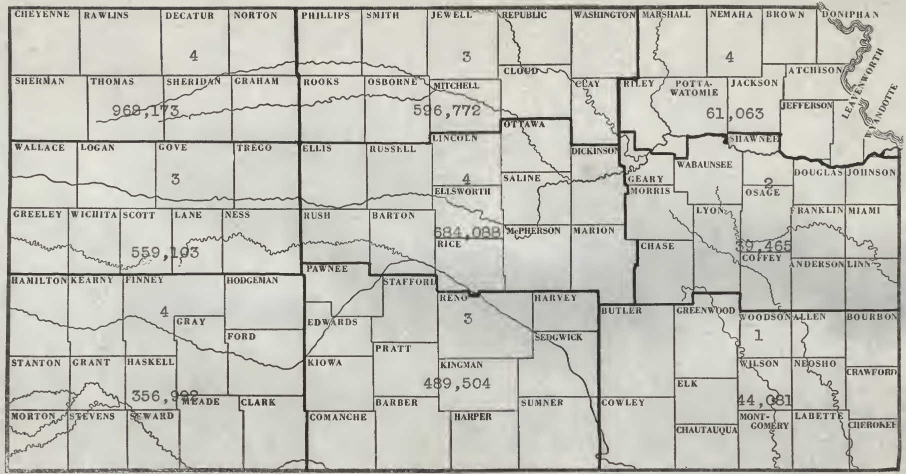


Fig. 1. Top figures give average annual number of hailstorms per unit area of 5,000 sq. miles as reported to weather bureau over 18-year period ending with 1945. Bottom figures give average annual number of bushels of wheat lost on account of hail per unit area of 5,000 square miles, as obtained by applying ratio of loss of insured wheat to harvested wheat over 10-year period ending with 1945.

garding the effects of simulated hail injuries to wheat, emphasizing especially the effect upon yield of grain, and development of the heads and kernels. Such information should aid in determining or estimating hail losses with greater accuracy. This study was made possible by the funds contributed, in part, by the Western Hail and Adjustment Association of Chicago, Illinois.

REVIEW OF LITERATURE

A review of the literature reveals that in comparison to other phases of agronomy, little has been done toward the study of hail damage to crops. However, studies of the effect of simulated hail have been conducted in several places and on a number of different crops. Most of the work has been with corn and small grains, but some work has been done on soybeans, flax, and onions.

Klages (36) observed that flax and small grains were damaged similarly by simulated hail. He found that recovery of flax from damage was greatest when the plants were in the early vegetative stages of growth. The removal of leaves was most detrimental to yield at the budding and flowering stage. Results indicated that mechanical injuries to the stems caused considerably more reduction in yield than removal of leaves.

Hawthorn (28, 29) reported the results of a 2-year study of defoliation of onions. In that study (1) 1/2 of the foliage, and (2) all of the foliage were removed from rows of 2 varieties of onions. Removal of foliage extended over a period ranging from 1 to 11 weeks before harvest in each of the 2 years 1943 and 1944. The most serious loss in yield resulted in both varieties, when foliage was removed during the beginning of bulb formation. The losses varied from 84 to 100 per cent.

Eldredge (17, 18, 19) reviewed hail studies over a 5-year period on the effect of injury imitating hail damage on development of the corn plant. He found the greatest reduction in yield of grain occurred when damage (leaf stripping, leaf shredding, and stalk bruising was inflicted during the tasseling period.

The same type of study was conducted by Kiesselbach (36) and Lyness in Nebraska. Their results were similar to the ones obtained by Eldredge.

In a defoliation experiment with koaliang, Li and Liu (40) removed all leaves at various stages of growth and also obtained the greatest reduction in seed yield during the blooming period. Complete defoliations when the kernels were in the dough stage caused insignificant decreases in yield.

Dungan (10, 11, 12, 13, 14, 15) did some of the earliest work on hail damage to corn, his work was conducted at Ohio State College. He found that hail damaged corn worse when it occurred between tasseling and the fresh milk stage. His results indicated that blade injuries reduced the yield roughly in proportion to the per cent of leaf area removed. In stages of growth, the damage had considerably less effect in reduction of yields. He found that test weight was reduced as well as the quality of the grain. Dungan concluded that splitting the leaves did not reduce the yield any significant amount.

In more recent years a number of studies have been made on hail damage to soybeans. One of the first to start this study was Dungan (16). He measured the effect of removing all leaves from spaced soybean plants cut off one foot above the ground at several different times during the period of pod formation and bean development. When compared with undamaged plants, this type of injury caused an average loss in yield of more than 95 per cent. In the same test when approximately 50 per cent of the leaves were removed, an average loss of 22 per cent in yield was found.

Fuelleman (23) in a study of simulated hail damage with soybeans removed 3 different percentages of leaves (30, 50, and 75 per cent) and repeated the experiment at each of 7 dates throughout the growing seasons. The heaviest treatment included bruising and breaking of the stems. The 30 and 50 per cent defoliation treatments before blooming reduced the yield only little, whereas 75 per cent defoliation materially reduced the yield. All rates when inflicted at the period of pod and seed formation, brought about severe reductions in yield.

Gibson (26) in North Carolina working with soybeans, obtained about the same results as Fuelleman. However, he observed differences in the way a specific treatment affected the different varieties.

One of the most recent investigations on simulated hail damage was conducted by Kalton, Weber and Eldredge (33) in Iowa, with soybeans.

They found little difference in the reduction of yield whether the treatment was administered by beating or by clipping. Their results showed the yields were reduced most when damage was inflicted about the time seed began to develop. They concluded that injuries sustained before and during blooming delayed maturity 3 days for medium damage and 8 days for heavy damage. Other results indicated that the protein quality of the seed was not changed but the per cent of oil was decreased.

Garner (25) noted that other agronomic characters might be affected by hail damage. They studied the effects of hail on plant height, seed size, oil content, and seed yield.

In all treatments, plant height was reduced, as was the total amount of the seed. Oil percentage on the other hand, was increased by the injury.

White (44) in an experiment designed to measure the effects of grasshopper damage, completely defoliated wheat plants at a number of stages of plant development. He found that yields were reduced most when all the leaves were removed between heading and soft dough stage. Complete defoliation during the 2 weeks just prior to maturity did not affect yields. Plant height and bushel weight were reduced most by defoliation when heads were emerging.

Thatcher (42) of Ohio found that when wheat was clipped, the yield of grain as well as straw was reduced in every case.

The Hays Branch Experiment Station (1) obtained results that indicated by clipping wheat on fallow land, the yield was increased considerably. This was explained by the fact that wheat has too much vegetative growth when grown on fallow land and lodges badly during the time of harvest. Evidently the clipping reduced this growth and decreased lodging to some extent.

Eldredge (20) made a study of hail damage to oats, wheat, and barley based on simulated methods. He administered 3 types of injury at weekly intervals from May 11 to July 1. He found damage inflicted during the vegetative stages resulted in less reduction in yield than damage at heading time, with the reductions being progressively more as heading time approached.

Knowles (37) made a study of the effects of hail injury on wheat and other grain crops. He approached the problem by 2 methods: first, by studying the effects of natural hail injuries and second, by studying effects of artificial injuries in imitations of hail. He found that results of barley and oats were similar to wheat. Head bruises may result in greater loss than stem bruises. He concluded that the loss was not only in yield but also in quality of the kernels. The recovery of the wheat after a whipping treatment was fairly good at the 3 leaf stage, but decreased rapidly towards heading time. Breaking stems over a lath at low level proved to reduce the yield more than when the injury was applied higher up on the stem.

He felt that the studies made under the natural conditions of hail were more satisfactory than the artificial methods of study.

MATERIALS AND METHODS

Preparation, Planting Procedure, and Crop Condition

The area for this experimental work was located in field H at the Agronomy farm. The preceding crop was oats which had followed sweet clover.

Tillage operations began in July of 1948 and at the time of planting, the seed bed was in excellent condition. The variety of wheat selected was Kanred and was seeded under optimum conditions on September 30, 1948.

The crop was planted in rows 16 inches apart at the rate of 45 pounds per acre. The chief reasons for spacing of rows at this wide width was for better observations and to keep down excessive injury to the wheat plants by trampling when the various types of treatments were administered.

A good even stand was obtained and the young plants made moderate growth during the fall. The plants went into the winter dormancy in an average condition. The crop survived the winter in an excellent condition and the spring growth was quite vigorous. There was plenty of moisture all season.

Experimental Design

In this investigation, the principal factors to be considered were the type and degree of damage and the stage of growth at the time the injury was inflicted.

With this in mind, each date or time that the damage was inflicted was considered a separate unit or experiment. The total number of experiments amounted to 7. The dates for inflicting injury ranged from May 5, which was 18 days before heading, to June 16, which was 10 days before the crop had reached maturity.

Three general types of injury were inflicted. The first type was inflicted by whipping the plants with an osage orange switch, which was 3 1/2 feet long. The second type was by bending the stems at various heights, and the last treatment was by removing spikelets from the inflorescence of the plant. Experiments 1, 2, 3, and 4 consisted of the first type of damage, 5 and 6 received the second type of injury, and number 7 had the spikelets removed.

The total area or field for these experiments was 150 feet long and 70 feet wide. An individual plot was 10 feet long and 4 drill rows wide (16 x 4 = 64 inches).

In order to obtain more accurate data, each experiment was repeated or replicated 4 times. The wheat was drilled from east to west, and plots were numbered consecutively from north to south, beginning from the northwest corner with plot 1 and ending at the southeast corner with plot 144. Thus, the total area or field was 12 plots long and 12 plots wide. Twelve plots crosswise constituted a tier; 3 such tiers composed a block of which 1 replication of the treatments appeared.

Methods and Techniques of Harvesting

The crop on the undamaged plots ripened June 26 and harvest began at this time. However, on the plots that were damaged, the ripening was delayed a few days depending upon the degree of damage it had received. The harvesting of the plots was completed by July 10. All harvesting was done by hand with a cycle and only the 2 inside rows were harvested out of each plot in Experiments 1, 2, 3, and 4. This was to eliminate any influence of outside factors, such as that which outside rows of the adjacent plots might exert due to their having had a different type of treatment. Sample heads were harvested from plots in Experiments 5, 6, and 7. In order to obtain a representative sample, the heads were harvested by taking a section of the row and gathering all of the heads, rather than sampling at random.

In Experiments 1, 2, 3, and 4 the wheat was cut approximately 3 to 6 inches above the ground, wrapped and tied in bundles. All of the heads were harvested even though they may have been on or near the ground. The bundles of wheat were labeled and placed in the Agronomy barn for storage. Approximately 1 month later the bundles were opened and the heads were counted. The heads were then threshed and the total grain from each plot was placed in paper bags, labeled and stored in barrels in the plant research laboratory.

The head samples harvested from plots in Experiments 5, 6, and 7 were placed in large manila envelopes, labeled, and stored in barrels at the plant research laboratory.

Methods and Techniques of Computing the Data

As the data were computed for each experiment, they were recorded directly on tables already prepared. The data included yield (g total grain per plot), size of heads (expressed in g), size of kernels (expressed in mg), number of kernels per head, and test weight (lbs. per bushel). The averages were computed for the 4 replications for each experiment and tabulated on a second group of tables. The last group of tables represented the per cent of decrease or increase of the data as compared to the undamaged wheat.

Most of the data were quite simple to compute and needs no explanation. However, it would be well to point out techniques in obtaining data for the test weight and weight of kernels.

The test weight data were obtained by a means devised by the Kansas State Experiment Station here at Manhattan in conjunction with the annual pre-harvest wheat survey. This method has been used when samples being tested were too small to be weighed by the standard method. In this method, a small 16 cc macrocontainer was used for the measurement of the samples. The sample was then weighed on a small torsion-balance scale. Using the factor 0.20704 which had been worked out beforehand. The test weight was then computed by dividing the weight of the sample by the factor. In obtaining the final test weight for the individual plots, 3 samples were measured and weighed, the average obtained, and then computed by using the above-mentioned factor.

In obtaining the data for the size of the kernels, 3 samples consisting of 500 kernels each were weighed and the average computed. The figure was then doubled and this represented the weight of 1000 kernels and the data were tabulated on the tables as size of kernels in mg.

EXPERIMENTAL RESULTS

These investigations were divided into three general phases, the results of which are presented in the following sections: (1) Effect of whipping plants at various stages of growth, (2) Effect of bending different proportions of the stems at different heights, and (3) Effect of removal of different proportions of spikelets from the head.

Effect of Whipping Plants at Various Stages of Growth

In this series, 4 experiments were conducted and were designated numerically in the order of their occurrence. This group of experiments was designed, primarily to study and observe the recovery of the plants and the reduction of the crop, when whipping types of damage were inflicted to varying degrees and at different stages of growth.

Experiments 1, 2, 3, and 4 received injuries on May 5, 12, 23, and June 4 respectively. At the time damage was inflicted to the plants in Experiment 1, which was approximately 18 days before "heading",[1] the wheat was vigorous, growing rapidly, and was well tillered. The plants were 14 to 16 inches high with heads 4 to 5 inches above the ground and the heads were 1/4 to 3/8 of an inch long.

In Experiment 2, the damage was inflicted 11 days before heading and the plants had increased to 20 inches in height. The position of the heads ranged from 6 to 12 inches above the ground with the heads about 3/8 to 1/2 inch long.

The damage was inflicted to the plants in Experiment 3 at the "heading" stage of growth. At the time of the damage, the plants were in excellent condition. This was approximately 34 days before the plants were mature.

Experiment 4 received treatment 10 days after the heading date and 22 days before maturity. The plants had attained their maximum growth as far as height and foliage were concerned.

In each experiment there was a gradient of 4 degrees of damage and Experiment 1 included: (1) Undamaged wheat, (2) light, (3) moderate, and (4) heavy damage. The gradients of damage in Experiments 2 and 3 were identical to Experiment 1 except that a treatment of slight damage was included and the "heavy damage" was omitted.

The damage in Experiment 4 was inflicted at different heights on the plants and to varying degrees. The treatments included:

---

[1] "Heading" as used here refers to heading of wheat when about 10 per cent of the heads were showing.

(1) Undamaged wheat, (2) light damage, inflicted at mid-point between the heads and the ground, (3) moderate damage, inflicted in the same region as indicated in number 2, and (4) moderate damage, inflicted several inches below the heads but above the flag leaf.

The degrees of damage listed are briefly described in the following paragraphs.[2]

Heavy treatment consisted of whipping the plants until all vegetation had been practically obliterated. Only a few stems remained upright and they were approximately 4 to 6 inches high. This simulated hail damage was quite severe and a hailstorm no matter how severe, could have caused only little if any more injury to the plants.

Moderate damage was inflicted to the extent that about 4/5 of the leaves of the plants were beaten off and the stems were badly bruised. Nearly all of the stems were standing and were approximately 6 to 8 inches in height.

In the light damage, approximately 1/5 of the leaves were knocked off and these were chiefly the upper ones. The upper portions of the plants were bruised considerably but practically all stems remained upright and ranged from 10 to 12 inches in height.

Slight damage was inflicted to the extent that only a few of the upper leaves were destroyed. The top portion of the stems received minor injury but very few of the plants were broken over.

---

[2] If further information is desired pertaining to the degree of damage and stages of growth, kodachrome slides are available at the Agronomy department.

Light damage mid-high on the plants was to the same degree as mentioned earlier, but was inflicted at the designated height. About 1/5 of the stems were broken over and many others were bruised.

The "moderate damage mid-high", inflicted only in Experiment 4, was to the extent that about 1/2 to 2/3 of the stems were broken over. Most of the other stems were badly bruised.

The "moderate damage high" at the "neck" or area just below the head, was to the same degree as moderate treatment at the mid-point. Very few of these heads fell off after receiving the treatment.

The reader should keep in mind that the stage of maturity is much more important than the actual date of damage when studying the data for these experiments. There is considerable difference in the degree of maturity on the same date in different seasons.

Experiment 1. Results revealed that in plots that received heavy damage, no recovery was made. Without exception every plot was a total loss. In a few of the plots as many as 6 heads appeared but did not reach maturity. In every instance the plots receiving heavy damage were completely dominated by foxtail grass.

A study of the data in Table 2 revealed that the heavier the damage, the greater the reduction of the yield of the crop. Table 2 shows the average data for the 4 replications. The yield for undamaged wheat was 433.8 g per plot as compared to 139.7 g for light and 35.7 g for moderate damaged wheat. Table 1 points out rather emphatically that in every case, the heavier the treat-

Table 1. Data obtained in Experiment 1 where wheat was damaged by whipping on May 5.

Plot No.	Degree of damage	Heads below 7 inches (%)	No. of heads	Yield of grain per plot (g)	Size of head (g)	Size of kernel (mg)	No. of kernels per head	Test weight lbs. per bu.
3	Undamaged	1	1007	500.9	0.497	20.90	23.77	56.5
2	Light damage	8	506	156.4	0.309	16.22	19.07	53.0
1	Moderate damage	20	139	29.9	0.215	15.85	13.52	50.0
4	Heavy damage	100	-	-	-	-	-	-
57	Undamaged	2	830	407.4	0.491	21.30	23.05	54.5
60	Light damage	12	425	107.6	0.253	16.46	15.98	51.0
58	Moderate damage	28	227	51.5	0.227	14.22	15.33	45.5
59	Heavy damage	100	-	-	-	-	-	-
98	Undamaged	0	833	425.1	0.510	24.16	26.29	58.0
100	Light damage	9	478	153.2	0.376	17.08	21.46	52.0
99	Moderate damage	30	105	39.5	0.367	14.30	21.07	46.5
97	Heavy damage	100	-	-	-	-	-	-
128	Undamaged	1	836	399.7	0.478	22.34	21.34	56.5
126	Light damage	10	454	141.6	0.312	17.66	17.62	51.0
125	Moderate damage	34	121	21.9	0.181	12.48	14.48	43.0
127	Heavy damage	100	-	-	-	-	-	-

Table 2. Average of 4 replications of each treatment in Experiment 1.

Data	Types of treatment		
	Undamaged	Light	Moderate
Yield g per plot	433.8	139.7	35.7
Number of heads per plot	876.5	465.7	148.0
Heads below 7 inches (per cent)	1.0	9.7	28.0
Size of heads; g grain per head	0.494	0.310	0.250
Size of kernels, mg	22.18	16.86	14.22
Number of kernels per head	22.31	18.37	17.57
Test weight	56.3	51.7	46.2

Table 3. Per cent of decrease below undamaged wheat (100 per cent).

Data	Types of treatment		
	Undamaged	Light	Moderate
Yield	0	67.8	91.8
Number of heads	0	46.8	83.1
Heads below 7 inches	0	8.7	27.0
Size of heads; g	0	37.2	49.4
Size of kernels, mg	0	24.0	35.9
Number of kernels per head	0	17.7	21.2
Test weight	0	8.2	18.0

ment, the greater the reduction in yield of the crop. Light damaged and moderate damaged wheat when compared to the undamaged, disclosed that the yield was reduced 67.8 and 91.8 per cent, respectively. This is indicated in Table 3.

Table 3 also revealed the per cent reduction of yield and number of heads were much greater than for the other data obtained. Number of heads were reduced in light and moderate treatments by 46.8 and 83.1 per cent whereas test weight for the same treatments were reduced by 8.2 and 18.0 per cent, respectively.

The size of the heads and the size of kernels were reduced in every case as shown in Table 1. Table 2 shows the average size of grain in undamaged wheat to be 0.494 g compared to 0.310 g for the light, and 0.250 g for the moderate damage to wheat. Table 3 indicates that the size of the heads was reduced somewhat more than the size of the kernels. In the light and the moderate damage, the heads were reduced by 37.2 and 49.4 per cent while the kernels were reduced in size by 24.0 and 35.9 per cent, respectively. The reductions in size of the heads are illustrated by Figs. 1, 2, and 3 on Plate I. Figures 1, 3, and 5 of Plate II show the relative size of the kernels.

Experiment 2. In this experiment the results disclosed the same general trends as in Experiment 1. Table 4 reveals that in every case, the heavier the damage, the greater the reduction of the crop. The averages in Table 5 show the yield of undamaged wheat to be 441.2 g as compared to 314.6 g for slight, 207.9 g for light, and 22.2 g for moderate degree of damaged wheat.

Table 6 indicates that the per cent reduction in yield and number of heads was much greater than for the other data obtained in the experiment. The per cent reduction of yield for slight, light, and moderate degrees of damage were 28.7, 52.9, and 95.0 per cent, respectively. The reduction of the number of the heads showed the same trend but to a slightly less extent. Slight, light, and moderate damage reduced the number of heads by 22.7, 43.9, and 87.4 per cent respectively. Test weight for the same

EXPLANATION OF PLATE I

Fig. 1. Heads from the undamaged plots in Experiments 1, 2, 3, and 4.

Fig. 2. Undamaged heads from plots that were damaged in Experiments 1, 2, 3, and 4.

Fig. 3. Damaged heads from damaged plots in Experiments 1, 2, 3, and 4.

PLATE I

Table 4. Data obtained in Experiment 2 where wheat was damaged by whipping on May 12.

Plot No.	Degree of damage	Heads below 7 inches (%)	No. of heads	Yield of grain per plot (g)	Size of head (g)	Size of kernel (mg)	No. of kernels per head	Test weight lbs. per bu.
7	Undamaged	0	1039	478.5	0.474	22.52	20.48	56.0
6	Slight damage	8	686	325.4	0.461	20.08	21.44	54.5
5	Light damage	10	617	193.7	0.314	22.06	15.70	51.5
8	Moderate damage	35	114	27.4	0.240	18.42	13.04	49.5
50	Undamaged	2	603	318.8	0.529	20.28	26.05	55.5
51	Slight damage	12	571	266.4	0.467	20.14	23.23	51.0
52	Light damage	16	386	167.0	0.433	16.64	26.08	47.5
49	Moderate damage	21	135	21.4	0.159	12.86	12.32	41.5
107	Undamaged	1	876	467.7	0.578	21.92	24.38	55.5
105	Slight damage	10	718	344.5	0.534	20.64	23.30	55.0
106	Light damage	14	439	253.6	0.480	19.08	30.26	53.0
108	Moderate damage	33	89	22.9	0.257	14.90	17.24	46.5
121	Undamaged	1	906	499.9	0.552	23.06	23.89	57.5
122	Slight damage	6	671	322.0	0.480	20.18	23.76	54.5
124	Light damage	12	480	217.4	0.453	20.80	21.77	52.5
123	Moderate	38	93	17.0	0.183	15.00	12.20	46.0

Table 5. Average of 4 replications of each treatment in Experiment 2.

Types of data	Types of treatment			
	Un-damaged	Slight	Light	Moderate
Yield, g per plot	441.2	314.6	207.9	22.2
Number of heads per plot	856.0	661.5	480.5	107.8
Heads below 7 inches (per cent)	1	9	13	31.75
Size of heads; g grain per head	.519	.475	.445	.210
Size of kernels, mg	21.94	20.75	19.15	15.29
Number of kernels per head	23.70	22.93	23.45	13.70
Test weight	56.12	53.75	51.12	45.87

Table 6. Per cent of decrease below undamaged wheat (100 per cent).

Types of data	Types of treatment			
	Un-damaged	Slight	Light	Moderate
Yield	0	28.7	52.9	95.0
Number of heads	0	22.7	43.9	87.4
Heads below 7 inches	0	8.0	12.0	30.7
Size of heads; g	0	8.5	14.3	59.5
Size of kernels, mg	0	5.4	12.7	30.3
Number of kernels per head	0	3.2	1.1	42.2
Test weight	0	4.2	8.9	18.3

treatments decreased only 4.2, 8.9, and 18.3 per cent.

As was the case in Experiment 1, the heads and the kernels were reduced in size. Table 4 shows the average size of heads in undamaged wheat to be 0.519 g as compared to 0.475 for slight, 0.445 for light, and 0.210 for moderate degree of damage. Compared to the undamaged wheat, these would represent decreases of 8.5 per cent for slight damage, 14.3 per cent for light, and 59.5 per cent for moderate damage.

In comparison, the size of the kernels was not reduced as much as was the size of heads. Table 6 indicates that slight, light, and moderate damage reduced the size of the kernels by 5.4, 12.7, and 30.3 per cent, respectively. Figures 2, 4, and 6 of Plate II illustrate these kernels' differences while Figs. 1, 2, and 3 of Plate I represent the difference in size of the heads.

Table 4 reflects the data as being relatively consistent, thus indicating the treatments were rather uniform within the experiment.

The competition from foxtail grass did not seem to be so pronounced as in Experiment 1. The plots receiving moderate damage were dominated somewhat by the grass.

Experiment 3. The data in this experiment revealed the same results as those obtained in Experiments 1 and 2 in which the wheat was damaged 18 days earlier and in Experiment 2 where the damage was inflicted 11 days earlier. In every case in Experiment 3, the heavier the damage, the greater the reduction of the crop. Table 7 disclosed that in all cases the reductions were progressively more as the damage became heavier. Results in Table 8 show the average yield of undamaged wheat to be 415.6 g as compared to 321.0 g for slight, 260.7 g for light, and 132.8 g for moderate degree of damage. The per cent reduction of yield for these same treatments as shown in Table 9, were 22.8, 37.3, and 68.0.

The size of the heads and kernels were reduced to a considerable extent. Table 7 shows this to be true in every case, while

EXPLANATION OF PLATE II

Fig. 1. Kernels from heads on plots that were undamaged (Experiment 1).

Fig. 3. Kernels from heads on plots that received light damage on May 5 (Experiment 1).

Fig. 5. Kernels from heads on plots that received moderate damage on May 5 (Experiment 1).

Fig. 2. Kernels from heads on plots that received slight damage on May 12 (Experiment 2).

Fig. 4. Kernels from heads on plots that received light damage on May 12 (Experiment 2).

Fig. 6. Kernels from heads on plots that received moderate damage on May 12 (Experiment 2).

PLATE II

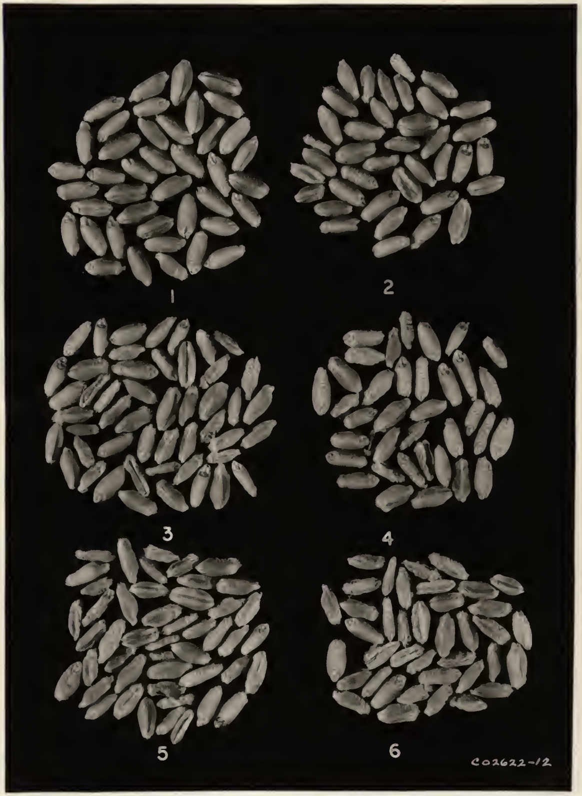


Table 7. Data obtained in Experiment 3 where wheat was damaged by whipping on May 23.

Plot No.	Degree of damage	Heads below 7 inches (%)	No. of heads	Yield of grain per plot (g)	Size of head (g)	Size of kernel (mg)	No. of kernels per head	Test weight lbs. per bu.
9	Undamaged	4	973	396.2	0.407	21.16	19.19	55.5
10	Slight damage	10	811	299.7	0.370	18.32	20.21	54.5
11	Light damage	12	793	267.2	0.337	17.84	18.93	55.0
12	Moderate damage	25	753	126.5	0.168	16.70	10.05	47.5
43	Undamaged	1	958	447.5	0.467	20.06	23.35	55.0
41	Slight damage	8	875	356.9	0.408	19.08	20.60	54.5
42	Light damage	10	768	291.2	0.379	18.64	20.37	53.5
44	Moderate damage	20	616	122.3	0.199	15.46	12.83	48.0
87	Undamaged	2	789	386.3	0.490	21.50	22.02	56.0
86	Slight damage	10	739	302.0	0.409	19.70	20.76	54.0
85	Light damage	12	735	263.7	0.359	19.72	18.22	51.5
88	Moderate damage	40	426	121.3	0.285	15.36	18.50	46.5
143	Undamaged	5	830	432.1	0.521	22.72	22.95	56.0
144	Slight damage	10	814	325.5	0.400	21.03	19.04	56.0
142	Light damage	20	743	220.7	0.297	19.06	15.54	55.0
141	Moderate damage	39	666	161.0	0.242	18.96	12.73	51.0

Table 8. Average of 4 replications of each treatment in Experiment 3.

Types of data	Types of treatment			
	Un-damaged	Slight	Light	Moderate
Yield, g per plot	415.6	321.0	260.7	132.8
Number of heads per plot	887.5	809.8	759.3	615.3
Heads below 7 inches (per cent)	3.0	9.5	13.5	31.0
Size of heads; g grain per head	0.471	0.397	0.343	0.224
Size of kernels, mg	21.38	19.72	18.82	16.62
Number of kernels per head	21.88	20.15	18.27	13.53
Test weight	55.6	54.7	53.7	48.2

Table 9. Per cent of decrease below undamaged wheat (100 per cent).

Types of data	Types of treatment			
	Un-damaged	Slight	Light	Moderate
Yield	0	22.8	37.3	68.0
Number of heads	0	8.8	14.4	30.7
Heads below 7 inches	0	6.5	10.5	28.0
Size of heads; g	0	15.7	27.2	52.4
Size of kernels, mg	0	7.8	12.0	22.3
Number of kernels per head	0	7.9	16.5	38.2
Test weight	0	1.6	3.4	13.3

Table 8 revealed the average for the size of heads to be 0.471 g, 0.397 g, 0.343 g, and 0.224 g for the undamaged, slight, light, and moderate damage.

The reduction of the size of kernels reflected the same trends but to a lesser extent. Table 9 shows for slight, light, and moderate damage, the heads were reduced by 15.7, 27.2, and 52.4 per cent, respectively, whereas the kernels were reduced only

7.8, 12.0, and 22.3 per cent for the same treatments. Figures 1, 3, and 5 of Plate III illustrate the relative size of the kernels.

Table 7 indicates that the treatments were relatively uniform from one replication to another.

<u>Experiment 4</u>. The study of the data resulted in somewhat different trends than were found in the preceding experiments. Table 10 revealed that the heavier damage did not always result in a greater reduction of the crop.

Yields as shown in Table 11 disclosed that undamaged wheat produced 358.7 g; light damage, mid-high 234.7 g; moderate damage, mid-high 228.5 g; and moderate damage, high 277.0 g. Wheat damaged light mid-high when compared to undamaged was reduced 34.6 per cent in yield of grain whereas moderate damage high on the stem reduced the yield 22.8 per cent, and moderate damage mid-high reduced it 36.3 per cent. These data in Table 12 would indicate that the lower the damage is inflicted, the greater will be the reduction of the crop. In this case, light damage at mid-height reduced the crop more than moderate damage high on the stems.

This trend was true for the size of the heads and kernels and test weight. This is shown in Tables 10 and 11. Table 12 indicated that these data were reduced but to a lesser degree. Figures 2, 4, and 6 of Plate III reflect the relative difference in size of the kernels, while Figs. 1, 2, and 3 of Plate I illustrate the difference in the size of heads.

Table 10. Data obtained in Experiment 4 where wheat was damaged by whipping on June 4.

Plot No.	Degree of damage	Heads below 7 inches (%)	No. of heads	Yield of grain per plot (g)	Size of head (g)	Size of kernel (mg)	No. of kernels per head	Test weight lbs. per bu.
24	Undamaged	4	842	281.8	0.335	18.02	18.61	54.5
22	Light (Mid-high)	10	703	222.4	0.316	17.90	17.65	52.5
21	Moderate (High)	10	778	247.1	0.318	16.94	18.81	52.5
23	Moderate (Mid-high)	20	819	184.2	0.225	14.22	15.84	51.0
38	Undamaged	2	775	301.2	0.389	17.30	22.48	54.0
39	Light (Mid-high)	19	791	281.2	0.355	17.50	20.28	52.5
40	Moderate (High)	15	812	328.5	0.402	17.32	23.23	52.5
37	Moderate (Mid-high)	24	817	276.4	0.340	16.42	20.73	52.0
82	Undamaged	8	716	395.1	0.552	20.84	26.53	57.0
81	Light (Mid-high)	30	425	221.9	0.522	18.70	27.91	52.0
83	Moderate (High)	17	625	258.6	0.414	18.54	22.37	54.0
84	Moderate (Mid-high)	45	565	226.1	0.400	18.06	22.09	50.0
140	Undamaged	2	967	456.7	0.472	20.74	22.80	55.0
137	Light (Mid-high)	17	630	213.4	0.339	17.48	19.37	51.0
138	Moderate (High)	28	809	273.7	0.338	17.10	19.76	52.5
139	Moderate (Mid-high)	32	654	227.2	0.347	14.22	24.43	49.5

Table 11. Average of 4 replications of each treatment in Experiment 4.

Types of data	Types of treatment: Un-damaged	Light Mid-High	Moderate High	Moderate Mid-High
Yield, g per plot	358.7	234.7	277.0	228.5
Number of heads per plot	825.0	637.3	757.3	712.5
Heads below 7 inches (per cent)	4.0	19.0	17.5	30.25
Size of heads; g grain per head	0.437	0.383	0.368	0.328
Size of kernels, mg	19.22	17.89	17.47	15.73
Number of kernels per head	22.61	21.30	21.04	20.77
Test weight	55.12	52.00	52.87	50.62

Table 12. Per cent of decrease below undamaged wheat (100 per cent).

Types of data	Types of treatment: Un-damaged	Light Mid-high	Moderate high	Moderate Mid-high
Yield	0	34.6	22.8	36.3
Number of heads	0	22.8	8.2	13.6
Heads below 7 inches	0	15.0	13.5	26.2
Size of heads; g	0	12.4	15.8	24.9
Size of kernels, mg	0	6.9	9.1	18.2
Number of kernels per head	0	5.8	6.9	8.1
Test weight	0	5.7	4.1	8.2

The experimental evidence obtained in these studies compared favorably with results obtained by other workers (38, 20, 37). Those workers found that as plants approached heading, the damage inflicted reduced the crop more than at earlier stages of growth. As could be expected, there were certain results obtained by these workers that the studies here did not confirm.

EXPLANATION OF PLATE III

Fig. 1. Kernels from heads on plots that received slight damage on May 23 (Experiment 3).

Fig. 3. Kernels from heads on plots that received light damage on May 23 (Experiment 3).

Fig. 5. Kernels from heads on plots that received moderate damage on May 23 (Experiment 3).

Fig. 2. Kernels from heads on plots that received light damage high on the stems (Experiment 4).

Fig. 4. Kernels from heads on plots that received moderate damage mid-high on the stems (Experiment 4).

Fig. 6. Kernels from heads on plots that received moderate damage high on the stems. (Experiment 4).

PLATE III

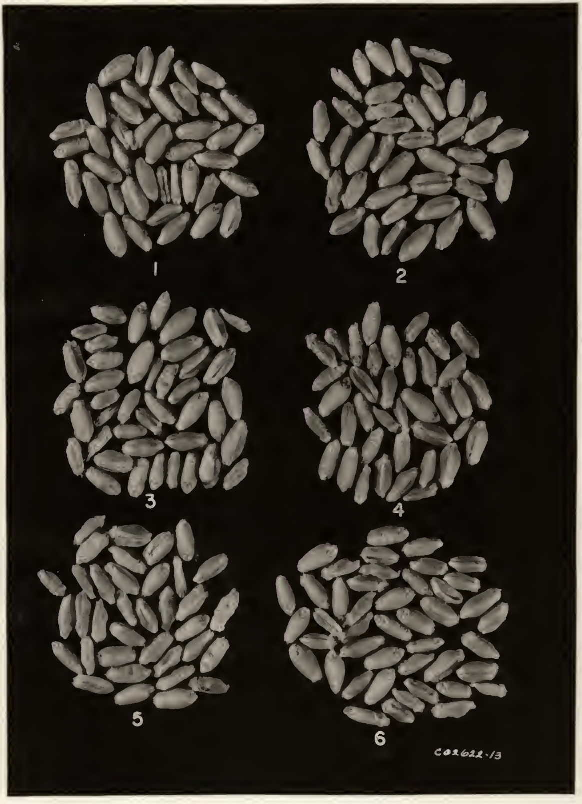


Table 13 indicates that when light damage was inflicted to plants on May 5, 12, 23, and June 4, the damage reduced the yield of grain less as the plants reached maturity.

Table 13. Light damage showing percentage decrease below undamaged wheat at 100 per cent for Experiments 1, 2, and 3.

Data	May 5	May 12	May 23	June 4
Yield	67.8	52.9	37.3	34.6
Number of heads	46.8	43.9	14.4	22.8
Test weight	8.2	8.9	3.4	5.7

The slight damage was inflicted on 2 dates only, May 12 and May 23. It indicated the same trend as the light treatment, the yield was reduced by 28.7 per cent on May 12 and 22.8 per cent on May 23. The moderate damaged wheat showed little trend either way. When damaged on May 5, the yield was reduced by 91.8 per cent as compared to 95.0 and 68.0 per cent on May 12 and 23.

A possible explanation for the difference found in these studies was that the number of experiments were limited; the same treatments did not appear in all of the experiments and as indicated earlier, the severity of the treatments may have varied from one experiment to the next. These facts coupled with the fact that the moderate damage trend was not the same would tend to show that this data could not be considered indicative.

Effect of Bending Different Proportions
of the Stems at Different Heights

The purpose of this study was to investigate and evaluate the influence that might be exerted on the heads when the stems were bent over at various heights, at the time the kernels were filling.

Two experiments were set up in this study and were designated as numbers 5 and 6. They were identical in their design; the only difference being that injuries were inflicted on June 9 in Experiment 5 and June 16 in Experiment 6. The damage, in both cases, was inflicted when the crop was in good condition and after the plants had reached their maximum height and completed foliage growth.

A plot consisted of 2 rows instead of the usual 4 and therefore, letters were used to designate the particular rows involved in each case.

The treatments included: (1) undamaged wheat, (2) all (100 per cent) stems bent about 6 inches above the ground, (3) all (100 per cent) stems bent about mid-way between the head and the ground, (4) all 100 per cent stems bent several inches below the heads but above the flag leaf, (5) alternate (50 per cent) stems bent midway up the stem, and (7) alternate (50 per cent) stems bent several inches below the heads but above the flag leaf.

The stems were bent by breaking sharply over a lath. This was accomplished by using 2 laths about 4 feet long fastened together at both ends with heavy rubber bands. A lath was placed at the desired height on either side of the row of plants and the stems were bent over.

Experiment 5. The study of the data in Table 15 revealed that when stems were bent, the heads were reduced in size. The average size of heads from undamaged wheat was 0.6188 g compared to 0.5130 g for heads from stems bent high, 0.4464 g for heads from stems bent mid-high, and 0.4433 g for heads from stems bent low. Table 14 also indicates that in every case this was true. The study of these data not only discloses that the heads were reduced in size when the stems were bent but that the lower on the stem the damage occurred, the greater the reduction. Table 16 shows that when compared to undamaged wheat, the heads on stems damaged high, mid-high, and low were reduced 17.1, 27.9, and 28.4 per cent, respectively. For these same treatments, test weights were reduced by 7.5, 14.3, and 14.5 per cent.

Table 14 shows that in every case the size of the kernels was reduced, while Table 15 disclosed the average size of kernels from undamaged heads was 23.5 mg as compared to 19.5 mg, 18.3 mg, and 16.8 mg, respectively. Table 16 revealed that the per cent of reduction of kernels was nearly the same as the reduction in the size of the heads. When compared to kernels from undamaged wheat, the per cent reduction was 16.8 for kernels from heads on stem bent high, 23.0 for kernels from heads on stems bent mid-high, and 28.7 for kernels from heads on stems bent low.

Figures 1, 2, 3, and 4 of Plate IV illustrate the relative size of the heads while Figs. 1, 2, 3, and 4 of Plate V indicate the relative size of the kernels.

Table 14. Data obtained in Experiment 5 where wheat was damaged by bending stems on June 9.

Plot No. & row letter	Degree & height of damage*	No. of heads		g grain per sample		Size of head g		Size of kernels mg		No. of kernels per head		Test wt. # per bu.	
		Bent	Not bent	Bent	Not bent	Bent	Not bent	Bent	Not bent	Bent	Not bent	Bent	Not bent
45B & C	50% L	119	107	46.40	74.87	.3899	.6997	15.90	25.02	24.5	28.0	47.7	54.1
45D & 46A	100% L	197		76.36		.3876		15.24		25.5		47.3	
46B & C	50% MH	112	108	47.49	71.02	.4240	.6576	17.74	25.16	24.0	26.1	51.4	55.7
46D & 47A	100% MH	197		78.38		.3979		16.32		24.4		44.1	
47B & C	Undamage		170		112.48		.6616		24.46		27.0		55.1
47D & 48A	50% H	131	120	61.21	78.26	.4673	.6522	18.46	25.06	25.3	26.1	48.6	56.6
48B & C	100% H	177		86.82		.4905		19.26		25.4		54.7	
65B & C	100% MH	173		67.43		.3898		16.72		23.3		42.7	
65D & 66A	50% MH	112	109	50.51	75.87	.4510	.6961	17.28	23.84	26.1	29.2	47.4	57.1
66B & C	50% H	116	94	60.32	58.44	.5200	.6217	20.12	23.78	25.9	26.1	55.5	57.0
66D & 67A	100% H	197		96.02		.4874		19.30		25.3		48.3	
67B & C	100% L	177		74.77		.4224		16.78		25.1		49.7	
67D & 68A	50% L	93	112	39.33	65.57	.4229	.5854	18.34	22.76	23.1	25.7	46.2	56.1
68B & C	Undamage		177		104.12		.5882		22.28		26.4		56.8
101B & C	50% L	95	113	48.51	70.49	.5106	.6238	19.16		26.6	26.2	47.0	54.8
101D & 102A	100% L	172		85.42		.4966		18.24		27.3		44.1	
102B & C	100% H	177		97.24		.5494		20.22		27.2		50.4	
102D & 103A	50% H	122	103	61.39	63.28	.5032	.6144	18.92	23.06	26.6	26.6	51.5	55.2
103B & C	Undamage		179		108.31		.6051		22.92		26.4		55.0
103D & 104A	100% MH	177		89.36		.5049		19.10		26.4		52.4	
104B & C	50% MH	120	119	57.73	85.61	.4811	.7194	19.38	24.24	24.8	29.7	51.3	55.7
133B & C	Undamage		214		132.71		.6201		25.14		24.7		56.1
133D & 134A	100% MH	222		109.40		.4928		20.86		23.6		51.8	
134B & C	50% MH	107	105	52.01	72.07	.4861	.6864	20.78	25.48	23.4	26.9	53.3	56.6
134D & 135A	50% H	113	104	59.81	70.13	.5293	.6743	19.72	24.60	26.9	27.4	53.1	54.1
135B & C	100% H	213		111.73		.5248		20.12		26.1		53.0	
135D & 136A	50% L	107	108	65.06	72.41	.6080	.6705	21.30	24.90	28.5	26.9	48.3	56.4
136B & C	100% L	218		101.71		.4666		17.30		27.0		49.8	

* 50% - alternate stems being bent; 100% - stems were bent; L - damage inflicted about 6" above ground; MH - damage mid-high; H - damage in neck but above flag leaf.

Table 15. Average of 4 replications of each treatment in Experiment 5.

Types of data	Un-damaged	100% H	100% MH	100% L	50% H Bent	50% H Not bent	50% MH Bent	50% MH Not bent	50% L Bent	50% L Not bent
Size of head, g	0.6188	0.5130	0.4464	0.4433	0.5050	0.6407	0.4605	0.6899	0.4829	0.6449
Size of kernel, mg	23.5	19.5	18.3	16.8	19.3	24.8	18.8	24.5	18.5	24.3
No.of kernels/head	26.1	26.0	24.4	26.2	26.2	26.6	24.6	28.0	25.7	26.7
Test weight	55.8	51.6	47.8	47.7	47.7	55.7	50.9	56.3	47.3	55.4

Types of treatment*

Table 16. Per cent of decrease from undamaged wheat (100 per cent).

Types of data	Un-damaged	100% H	100% MH	100% L	50% H Bent	50% H Not bent	50% MH Bent	50% MH Not bent	50% L Bent	50% L Not bent
Size of head, g	0	17.1	27.9	28.4	18.4	-3.5	25.6	-11.5	22.0	-4.2
Size of kernel,mg	0	16.8	23.0	28.7	18.6	-1.8	20.7	- 4.1	21.2	-1.8
No.of kernels/head	0	0.4	6.5	0.4	0.4	-1.9	5.7	- 7.3	1.5	-2.3
Test weight	0	7.5	14.3	14.5	6.5	0.2	8.8	- 0.9	15.2	0.7
Per cent reduction Bent to Not bent:										
Size of head					21.2	0	33.3	0	25.1	0
Size of kernel					21.3	0	23.2	0	23.9	0
No. of kernels					1.5	0	12.0	0	3.7	0
Test weight					6.3	0	9.6	0	14.6	0

Types of treatment*

* 50% - alternate stems being bent; 100% - stems were bent; L - damage inflicted about 6" above ground; MH - damage mid-high; H - damage in neck but above flag leaf.

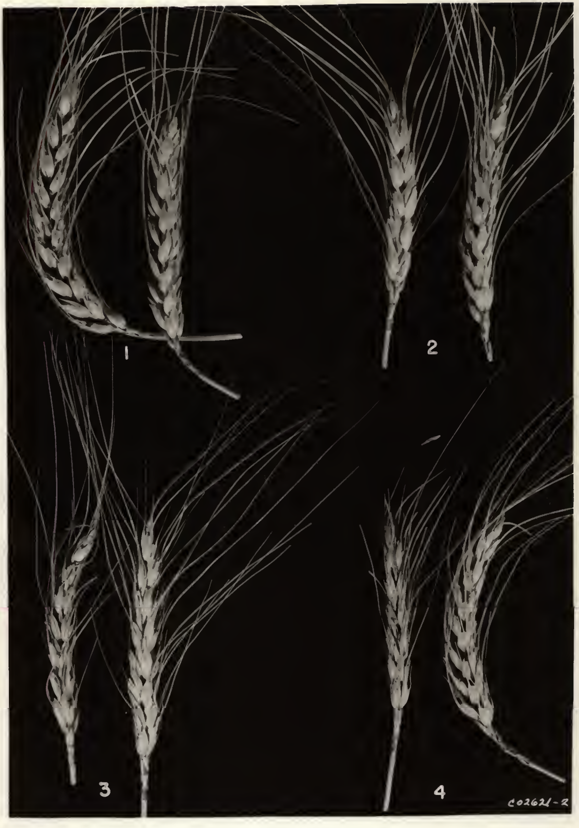
EXPLANATION OF PLATE IV

Fig. 1. Undamaged heads.

Fig. 2. Heads from plants that had stems bent on June 9 (Experiment 5).

Fig. 3. Heads from plants that had stems bent at mid-height on June 9 (Experiment 5).

Fig. 4. Heads from plants that had stems bent at low level on June 9 (Experiment 5).


1
2
3
4
C02621-2

EXPLANATION OF PLATE V

Fig. 1. Kernels from heads that were undamaged.

Fig. 2. Kernels from heads on plots that received damage by bending the stems at high areas on the stems on June 9 (Experiment 5).

Fig. 3. Kernels from heads on plots that were damaged by bending the stems at mid-height on June 9 (Experiment 5).

Fig. 4. Kernels from heads on plots that were damaged by bending at low level on the stems on June 9 (Experiment 5).

PLATE V

Where alternate stems were bent, the heads from the bent stems were reduced in size whereas the heads from the stems that were not bent benefitted considerably. Table 14 indicated that in all cases, the heads of stems bent were reduced in size and the heads of the stems not bent increased in size. The average size of heads where no damage was inflicted was 0.6188 g whereas the average size of heads alternating with those on bent stems was 0.6583 g. The heads on the bent stems produced 0.5050 g, 0.4605 g, and 0.4829 g where the stems were damaged high, mid-high, and low, respectively. The average size of heads not bent from the same treatments were 0.6407 g, 0.6899 g, and 0.6449 g, respectively. These data are found in Table 15.

Table 16 shows the per cent decrease in size of heads from stems bent high, mid-high, and low to be 18.4, 25.6, and 22.0 per cent, respectively. The alternate heads from the stems not bent were increased in size by 3.5, 11.5, and 4.2 per cent. Figures 1, 2, and 3 of Plate VI illustrate the relative size of the heads.

These data show less reduction in the size of the heads when stems were bent at the high positions than either the mid-high or low position. However, the mid-high damage reduced the size of the heads slightly more than the low treatment. It is also indicated that the increases in the size of the heads not bent were in the same relation--that is, heads adjacent to stems bent high increased less than where adjacent to either of the other treatments. The mid-high treatment increased the size of the kernels from heads not bent,a little more than the other treatments.

The heads on undamaged stems that were adjacent to damaged stems showed a percentage increase in size of 21.2 for the high treatment, 33.3 for mid-high treatment, and 25.1 for the low damage.

Tables 14, 15, and 16 indicated that the same general trends prevailed with respect to kernel size. The kernels were decreased in size by 18.6 per cent when stems were bent at a high point, whereas the same treatment at mid-high reduced the size of the kernels by 20.7 per cent, and at low level the kernels were decreased some 21.2 per cent.

Where alternate stems were bent, the kernels on the undamaged stems increased in size by 1.8, 4.1, and 1.8 per cent for the high, mid-high, and low damage treatments, respectively. Figures 1, 2, 3, 4, 5, and 6 of Plate VII show the relative size of the kernels.

EXPLANATION OF PLATE VI

Heads on this plate were obtained from plots in Experiment 5. In these plots, alternate stems were bent at various heights. The heads on the left of the figures represent heads from stems that were not bent while the heads to the right represent heads from stems that were bent.

Fig. 1. Head not bent.
Head from stem that was bent at a high level on June 9.

Fig. 2. Head not bent.
Head from stem that was bent at mid-height on June 9.

Fig. 3. Head not bent.
Head from stem that was bent at low level on June 9.

PLATE IV

EXPLANATION OF PLATE VII

These kernel samples correspond to heads on Plate VI. These are from plots where alternate stems were bent on June 9, in Experiment 5. Figures 1 and 2; 3 and 4; and 5 and 6 represent kernels from heads where alternate stems were bent high, mid-high, and low.

Fig. 1. Kernels from heads on stems that were not bent.

Fig. 2. Kernels from heads on stems that were bent on June 9, at high points on the stems.

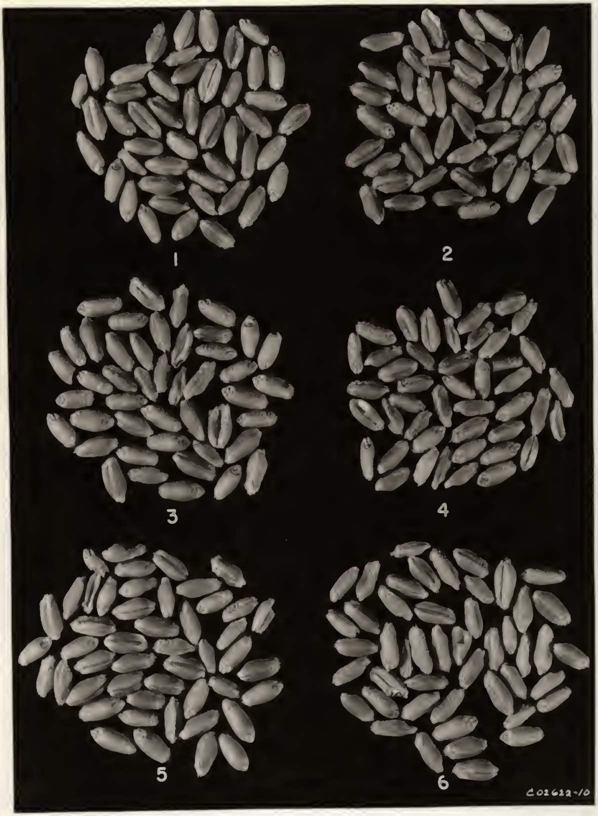
Fig. 3. Kernels from heads on stems that were not bent.

Fig. 4. Kernels from heads on stems that were bent on June 9, at mid-height.

Fig. 5. Kernels from heads on stems that were not bent.

Fig. 6. Kernels from heads on stems that were bent on June 9, at low level.

PLATE VII



<u>Experiment 6</u>. Data in Table 17 reveals when stems were bent on June 23, the heads were reduced in size and that the lower on the stem the damage occurred, the greater was the reduction. This trend prevailed in each of the 4 replications.

Table 18 shows the average size of the heads from undamaged wheat was 0.6246 g as compared to 0.5465 g for heads from stems bent high, 0.5254 g for heads from stems bent mid-high, and 0.5128 g for heads from stems bent low. When compared to undamaged wheat, the heads from stems damaged high, mid-high, and low were reduced 12.5, 15.9, and 17.9 per cent, respectively. The test weight for these same treatments were reduced 3.4, 6.4, and 8.7 per cent. Figures 1, 2, 3, and 4 of Plate VIII illustrate the relative size of heads.

Table 19 revealed that the per cent of reduction in size of kernels was nearly the same as the reduction in the size of the heads. Figures 1, 2, 3, and 4 of Plate IX show the relative size of the kernels.

The data obtained from plots which had alternate stems bent, indicated the heads from the bent stems were reduced in size considerably. The heads from the stems that were not bent, were larger than those from the adjacent damaged stems bent at mid-high and low levels and nearly the same size as those bent high.

Table 18 shows the average size of heads in the undamaged plots to be 0.6246 g as compared to 0.5763 g, 0.5278 g, and 0.5214 g for heads from damaged stems where 50 per cent were bent at high, mid-high, and low levels. The average size of undamaged heads adjacent

Table 17. Data obtained in Experiment 6 where wheat was damaged by bending stems on June 16.

Plot No. & row letter	Degree & height of damage*	No. of heads: Bent	No. of heads: Not bent	g grain per sample: Bent	g grain per sample: Not bent	Size of head g: Bent	Size of head g: Not bent	Size of kernels mg: Bent	Size of kernels mg: Not bent	No. of kernels per head: Bent	No. of kernels per head: Not bent	Test wt. # per bu.: Bent	Test wt. # per bu.: Not bent
16B & C	50% H	99	89	51.94	43.54	.5245	.4892	20.64	21.30	25.5	23.0	54.3	54.2
16D & 17A	100% H	169		81.97		.4850		20.36		23.8		54.7	
11B & C	100% MH	169		73.52		.4350		19.48		22.3		52.4	
17D & 18A	50% MH	119	120	60.89	65.89	.5112	.5491	19.90	21.14	25.7	26.0	53.6	55.6
18B & C	Undamage		167		102.97		.6166		23.20		26.6		55.8
18D & 19A	100% L	234		105.11		.4492		19.54		23.0		51.1	
19B & C	50% L	132	121	55.77	70.81	.4225	.5852	17.56	21.38	24.0	27.3	51.7	54.7
69B & C	Undamage		222		137.81		.6208		23.80		26.1		56.8
69D & 70A	100% L	217		118.31		.5452		20.82		26.2		53.4	
70B & C	50% L	123	113	71.06	75.49	.5777	.6681	22.38	24.52	25.2	27.3	53.2	56.5
70D & 71A	100% H	224		138.31		.6175		22.28		27.7		56.0	
71B & C	50% H	123	112	73.32	61.81	.5961	.5519	22.48	23.16	26.5	23.8	56.1	56.0
71D & 72A	100% MH	227		125.83		.5543		20.94		26.5		54.1	
72B & C	50% MH	110	107	61.00	60.69	.5545	.5672	22.30	22.80	24.9	24.9	54.7	56.3
77B & C	50% L	112	107	59.14	64.54	.5280	.6032	22.32	20.98	23.7	27.4	53.7	51.8
77D & 78A	100% L	222		118.40		.5333		20.60		25.9		53.4	
78B & C	50% MH	107	99	59.19	61.90	.5532	.6253	20.82	23.30	26.6	26.8	53.7	54.7
78D & 79A	100% MH	153		82.34		.5382		21.34		25.3		52.9	
79B & C	Undamage		169		104.59		.6189		22.84		27.1		57.5
79D & 80A	50% H	102	102	60.89	61.27	.5970	.6007	22.96	22.90	26.0	26.2	55.0	55.1
80B & C	100% H	130		83.19		.6399		24.42		26.2		54.7	
117B & C	100% H	75		33.28		.4437		22.38		19.8		51.4	
117D & 118A	50% H	120	107	70.51	66.43	.5876	.6208	23.66	24.10	24.8	25.8	53.3	53.4
118B & C	100% L	216		113.04		.5233		22.38		23.4		46.9	
118D & 119A	50% L	101	107	56.31	68.16	.5575	.6370	24.62	24.32	22.7	25.2	51.5	54.0
119B & C	Undamage		143		91.84		.6422		24.94		25.8		54.1
119D & 120A	100% MH	175		100.43		.5739		23.54		24.4		50.7	
120B & C	50% MH	112	105	55.12	63.03	.4931	.6003	22.36	24.92	22.0	24.1	52.9	53.6

* 50% - alternate stems being bent; 100 - stems were bent; L - damage inflicted about 6" above ground; MH - damage mid-high; H - damage in neck but above flag leaf.

Table 18. Average of 4 replications of each treatment in Experiment 6.

Types of data	Undamaged	100% H	100% MH	100% L	50% H Bent	50% H Not bent	50% MH Bent	50% MH Not bent	50% L Bent	50% L Not bent
Size of head, g	0.6246	0.5465	0.5254	0.5128	0.5763	0.5657	0.5278	0.5855	0.5214	0.6234
Size of kernel, mg	23.7	22.4	21.3	20.8	20.5	22.9	21.4	23.0	21.9	23.3
No.of kernels/head	26.4	24.4	24.6	24.6	25.7	24.7	24.8	25.5	23.9	26.8
Test weight	56.1	54.2	52.5	51.2	54.7	54.7	55.7	55.1	52.5	54.3

Table 19. Per cent decrease from undamaged wheat (100 per cent).

Types of data	Undamaged	100% H	100% MH	100% L	50% H Bent	50% H Not bent	50% MH Bent	50% MH Not bent	50% L Bent	50% L Not bent
Size of head, g	0	12.5	15.9	17.9	7.7	9.4	15.5	6.3	16.5	0.2
Size of kernel, mg	0	5.7	10.0	12.1	5.3	3.5	10.0	2.8	7.8	1.7
No.of kernels/head	0	7.6	6.8	6.8	2.7	6.4	6.1	3.4	9.5	-1.5
Test weight	0	3.4	6.4	8.7	2.5	2.5	4.3	1.8	6.4	3.2
Per cent reduction Bent to Not bent:										
Size of head					-1.9	0	9.9	0	16.4	0
Size of kernel					10.5	0	6.9	0	6.0	0
No. of kernels					-4.0	0	2.7	0	10.8	0
Test weight					0	0	2.5	0	3.3	0

* 50% - alternate stems being bent; 100% - stems were bent; L - damage inflicted about 6" above ground; MH - damage mid-high; H - damage in neck but above flag leaf.

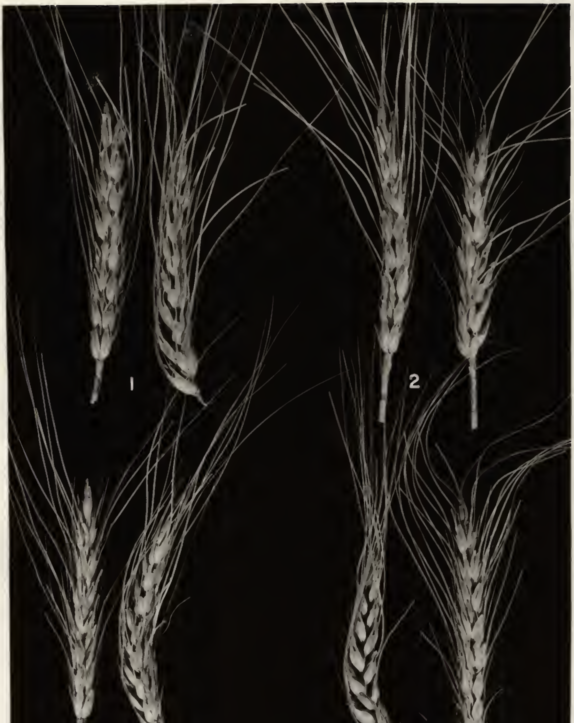
EXPLANATION OF PLATE VIII

Fig. 1. Heads from plots that were undamaged (Experiment 6).

Fig. 2. Heads from plots that were damaged by bending all of the stems at high points on June 16 (Experiment 6).

Fig. 3. Heads from plots that were damaged by bending all of the stems mid-high on June 16 (Experiment 6).

Fig. 4. Heads from plots that were damaged by bending all of the stems at low areas on June 16 (Experiment 6).


1
2
3
4
C02621-4

EXPLANATION OF PLATE IX

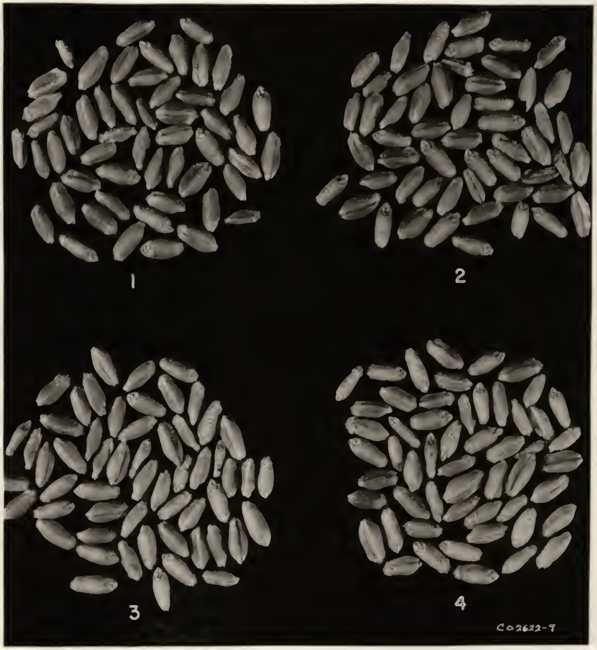
Fig. 1. Kernels from heads on plots that were not damaged.

Fig. 2. Kernels from heads on plots that were damaged by bending all of the stems at mid-height on June 16 (Experiment 6).

Fig. 3. Kernels from heads on plots that were damaged by bending all of the stems at mid-height on June 16 (Experiment 6).

Fig. 4. Kernels from heads on plots that were damaged by bending all of the stems at low level on June 16 (Experiment 6).

PLATE IX



to damaged stems was 0.5657 g, 0.5855 g, and 0.6234 g, respectively, as shown in Table 18. Table 19 shows the per cent decrease in size of heads from stems bent at high, mid-high, and low to be 7.7, 15.5, and 16.5 per cent, respectively. The heads from the stems not bent were decreased in size by 9.4, 6.3, and 0.2 per cent. Figures 1, 2, and 3 of Plate IX illustrate the size of the heads. Where alternate stems were bent at the high level, the heads were reduced in size compared to the heads from adjacent stems not bent. In these treatments, the stems that were bent were reduced in the same order as where all stems were bent--that is, the lower on the stems, the damage was inflicted, the greater the reduction in size of head.

Tables 17, 18, and 19 indicate that the same general trend prevailed with respect to kernel size. The size of the kernels was decreased 5.3 per cent when stems were bent at high level, whereas the same treatment at mid-high reduced the kernels 10.0 per cent, and in low areas the kernels were reduced in size by some 7.8 per cent. Where 50 per cent of the stems were bent, the kernels from undamaged stems were increased in size by 3.5, 2.8, and 1.7 per cent for the high, mid-high, and low damage treatment. Figures 1, 2, 3, 4, 5, and 6 of Plate X illustrate the size of the kernels.

In general, the results of Experiments 5 and 6 were comparable. When stems were bent high, mid-high, and low, the heads and kernels were reduced in size. The lower the damage occurred, the greater was this reduction. In Experiment 5 when alternate stems were bent, the heads from stems not bent increased in size

EXPLANATION OF PLATE X

Heads on this plate were obtained from plots in Experiment 6. In these plots, alternate stems were bent at various heights. The heads on the left of the figures represent heads from stems that were not bent while the heads to the right represent heads from stems that were bent.

Fig. 1. Head not bent.
Head from stem that was bent at a high level on June 16.

Fig. 2. Head not bent.
Head from stem that was bent at mid-height on June 16.

Fig. 3. Head not bent.
Head from stem that was bent at low level on June 16.

PLATE X

EXPLANATION OF PLATE XI

These kernel samples correspond to heads on Plate VI. These are from plots where alternate stems were bent on June 16, in Experiment 6. Figures 1 and 2; 3 and 4; and 5 and 6 represent kernels from heads where alternate stems were bent high, mid-high, and low.

Fig. 1. Kernels from heads on stems that were not bent.

Fig. 2. Kernels from heads on stems that were bent on June 9, at high points on the stems.

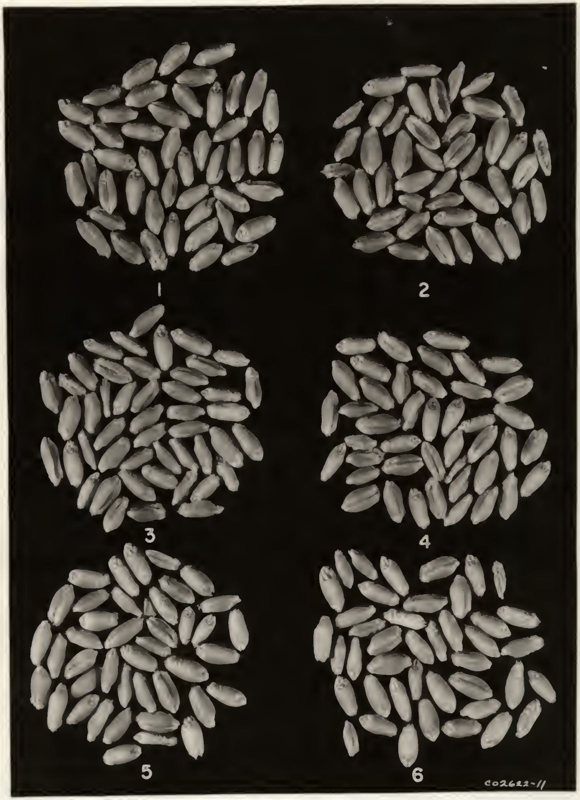
Fig. 3. Kernels from heads on stems that were not bent.

Fig. 4. Kernels from heads on stems that were bent on June 16, at mid-high.

Fig. 5. Kernels from heads on stems that were not bent.

Fig. 6. Kernels from heads on stems that were bent on June 16, at low level.

PLATE XI



thus showing that they were influenced by the damage inflicted to their neighbors.

However, when the same damage was inflicted 1 week later which was 10 days before maturity (Experiment 6), the heads on stems that were not bent were not influenced as much. Thus, indicating that this type of damage was more important when inflicted early in the period of kernel development.

Effect of Removal of Different Proportions of the Spikelets from the Head

The objective of this experiment was to evaluate the effect of removal of some of the spikelets from the head on the development of the grain in the remaining spikelets.

This study was made in Experiment 7 which included 3 comparisons namely; (1) Undamaged wheat, (2) 1/3 of the spikelets were removed from the head, and (3) 2/3 of the spikelets were removed from the head.

Each plot consisted of one row 3 feet long. The spikelets were removed on June 13, and at this time the plants had attained maximum height and foliage growth. These treatments were administered 21 days after heading and 13 days before maturity.

The 1/3 ratio was obtained by removing every third spikelet and the 2/3 ratio by removing the first and the third spikelets. The spikelets were removed from the heads with tweezers. Figures 1, 2, and 3 of Plate XII illustrate these types of treatment.

EXPLANATION OF PLATE XII

Fig. 1. Heads from undamaged plots in Experiment 7.

Fig. 2. Heads from plots in Experiment 7 in which 1/3 of the spikelets were removed from the head.

Fig. 3. Heads from plots of Experiment 7 in which 2/3 of the spikelets were removed from the head.

PLATE XII

Results indicated that when spikelets were removed from the head, the remaining ones benefitted considerably. Tables 19 and 20 show that in every case the remaining spikelets produced larger kernels than heads from which no spikelets were removed.[3]

The size of the kernels from the remaining spikelets increased significantly but such pronounced increases were not obtained in the test weight. This lesser difference can be explained in that test weight seems to be a measure of the plumpness or shape of the kernels rather than the size.

When 1/3 of the spikelets were removed from the head, the kernels from the remaining spikelets increased in size 9.29 per cent. In the removal of 2/3 of the spikelets, the per cent increase in the size of the remaining kernels was 19.91. However, the test weight increased only 2.2 per cent in the 1/3 removal of the spikelets and 4.6 per cent in the removal of 2/3 of the spikelets. These per cent increases are shown in Table 21. Figures 1, 2, and 3 of Plate XIII show the relative kernel size for these treatments.

[3] Table 19 does not show test weight for the individual plots for the 2/3 removal of spikelets. Samples were so small that a measure could not be obtained. However, it was obtained from a composite sample of the 4 replications and is shown in Table 20.

Table 20. Data obtained in Experiment 7 where spikelets were removed from the heads on June 13.

Plot No., row, and position of row sampled	No. of spikelets removed from the heads	No. of heads in the sample	Wt. of grain per sample, g	Size of head, mg	No. of kernels per sample	Size of kernel, mg	No. of kernels per head	Test wt. # per bu.
20 C 2	Undamaged	65	23.69	0.5183	1685	20.0	32.5	52.7
20 C 1	1/3 removed	51	21.11	0.4139	906	23.3	21.9	53.6
20 C 3	2/3 removed	44	8.21	0.1866	356	23.1	19.0	
54 D 1	Undamaged	60	33.39	0.5565	1462	22.8	26.3	52.7
54 D 2	1/3 removed	65	27.19	0.4183	1172	23.2	28.0	53.3
54 D 3	2/3 removed	34	8.30	0.2441	323	25.7	13.2	
73 A 3	Undamaged	68	36.50	0.5368	1592	22.9	29.7	55.7
73 A 1	1/3 removed	42	18.43	0.4388	690	26.7	15.7	56.8
73 A 2	2/3 removed	51	10.65	0.2088	368	28.9	17.6	
132 A 2	Undamaged	60	36.49	0.6082	1473	24.8	24.2	53.3
132 A 3	1/3 removed	45	20.19	0.4487	794	25.4	17.7	55.6
132 A 1	2/3 removed	39	10.66	0.2733	348	30.6	12.7	

Table 21. Average of 4 replications of each treatment in Experiment 7.

Types of data	Types of treatment		
	Un-damaged	1/3 spike-lets	2/3 spike-lets
No. of heads per sample	63.25	50.75	42.00
Wt. of grain per sample, g	35.02	21.73	9.46
No. of kernels per sample	1553	891	349
Wt. of grain per head, gm	.5550	.4299	.2282
Size of kernels, gm	22.6	24.7	27.1
Test wt., lbs. per bu.	53.3	54.5	55.8
No. of kernels per head	28.2	20.8	15.6

Table 22. Per cent increase above undamaged wheat (100 per cent).

Types of data	Types of treatment		
	Un-damaged	1/3 spike-lets	2/3 spike-lets
Size of kernel	0	9.29	19.91
Test weight	0	2.2	4.6

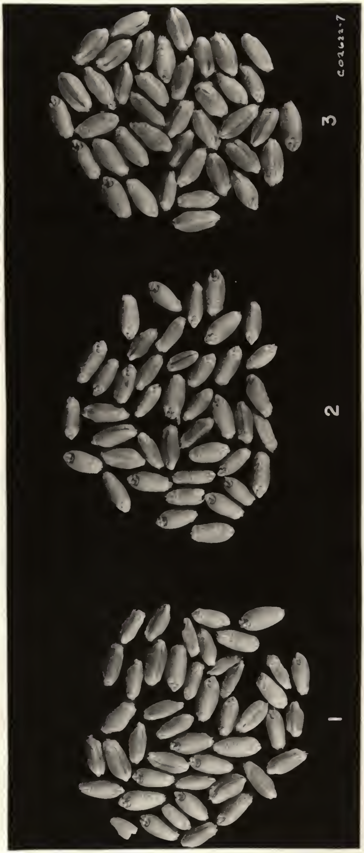
EXPLANATION OF PLATE XIII

Fig. 1. Kernels from undamaged heads in Experiment 7.

Fig. 2. Kernels from heads that had 1/3 of the spikelets removed (Experiment 7).

Fig. 3. Kernels from heads that had 2/3 of the spikelets removed (Experiment 7).

PLATE XIII



SUMMARY

In a study of this type it is recognized that data collected for a one-year period can by no means be considered conclusive, however, it can be indicative of certain general trends and of value in designing future experiments.

This simulated hail study included three general types of damage: (1) Whipping plants at various stages of growth; (2) By bending different proportions of the stems at different heights; (3) Removal of different proportions of the spikelets from the heads.

Four experiments were conducted by inflicting the first type of damage at four different stages of growth. Two experiments were conducted by inflicting the second type of damage of different heights and on different proportions of the stems. Only one experiment was conducted by removal of the spikelets.

Some of the general trends that were brought out in the study were:

1. The heavier the damage, the longer the delay in maturity of the crop.

2. In the heavier treatments, when injuries were inflicted at early stages of growth, considerable competition was obtained from weeds, especially foxtail grass.

3. The heavier the damage, the greater the reduction of the crop, except in Experiment 4 where whipping treatments at high level did not reduce the crop as much as treatments at mid-high,

even though the treatments were heavier.

4. When several types of injury were inflicted at intervals ranging from May 5 to June 4, the results indicated that reductions in yield of grain did not follow a consistent trend as the crop progressed toward heading.

5. When all stems were bent on June 9, at the time the heads were filling, a decrease in the size of the heads and kernels was noted.

6. When alternate stems were bent on June 9, the results showed the stems not bent benefited to the extent that in every case the heads and kernels were increased in size when compared to undamaged plants.

7. When all stems were bent on June 16, the heads and kernels were decreased in size, but the percentage decrease was less than when the damage was inflicted a week earlier.

8. When alternate stems were bent on June 16, the heads from the stems not bent were not influenced in size.

9. When all stems were bent on June 9, results indicated that the size of the heads was decreased least the higher on the stem the damage occurred.

10. When 1/3 of the spikelets were removed from the heads, the kernels in the remaining spikelets increased 10 per cent when compared to kernels from undamaged heads.

11. When 2/3 of the spikelets were removed from the heads, the kernels in the remaining spikelets increased 20 per cent in size when compared to kernels from undamaged heads.

ACKNOWLEDGMENT

The author wishes to express his appreciation to Dr. H. H. Laude, major instructor, for the personal interest and able direction given throughout the period of study.

Thanks should be extended to the Western Hail and Adjustment Association of Chicago, Illinois, which made this study possible by contributing financial support for a part of this work.

Appreciation is also expressed to the members of the Agronomy Department staff for their many helpful suggestions and excellent classroom instruction.

REFERENCES

(1) Anonymous.
Pasturing winter wheat. Kans. Branch Expt. Sta. (Hays). Mimeo. Rpt. 1929.

(2) Anonymous.
Removal of suckers on corn. Ark. Agr. Expt. Sta. Ann. Rpt. Bul. 231:11. 1928.

(3) Anonymous.
Removal of suckers on corn. Art. Agr. Expt. Sta. Ann. Rpt. Bul. 246:25. 1929.

(4) Anonymous.
Climaticological data. Kan. Sec. Weather Bureau. 1946-1949.

(5) Anonymous.
Average annual number of days with hail. Climate & Man. U.S.D.A. Yr. Bk. pp. 730. 1941.

(6) Bartel, A. T.
Changes in breaking strength of straw of wheat varieties from heading to maturity. Amer. Soc. Agron. Jour. 29:135-156. 1937.

(7) Cardwell, A. B., and S. D. Flora.
Kansas weather and climate. Kan. Agr. Expt. Sta. Bul. 302:11-18. 1942.

(8) Dungan, G. H.
Effects of hail injury on corn plant measured. Ill. Agr. Expt. Sta. Ann. Rpt. 41:51-54. 1928.

(9) Dungan, G. H.
Effects of hail injury on the development of the corn plant. Amer. Soc. Agron. Jour. 20:51-54. 1928.

(10) Dungan, G. H.
Artificial hailing shows damage to corn by storms. Ill. Agr. Expt. Sta. Ann. Rpt. 42:46-50. 1929.

(11) Dungan, G. H.
Hail injury to corn hurts both yield and quality. Ill. Agr. Expt. Sta. Ann. Rpt. 42:49-50. 1930.

(12) Dungan, G. H.
Relation of blade injury to the yielding ability of corn plants. Amer. Soc. Agron. Jour. 22:164-170. 1930.

(13) Dungan, G. H.
Hail damages corn worse when plants are tasseling. Ill. Agr. Expt. Sta. Ann. Rpt. 44:57-59. 1931.

(14) Dungan, G. H.
Corn grows some ever after hail destroys all blades. Ill. Agr. Expt. Sta. Ann. Rpt. 45:55-56. 1931.

(15) Dungan, G. H.
An indication that corn tillers may nourish the main stalk under some conditions. Amer. Soc. Agron. Jour. 22:662-670. 1931.

(16) Dungan, G. H.
Recovery of soybeans from hail injury is measured. Ill. Agr. Expt. Sta. Ann. Rpt. 51:77-78. 1942.

(17) Eldredge, J. C.
How hail damages corn. Wallace Farmer, 55:1296-97. Aug. 1930.

(18) Eldredge, J. C.
The effects of injury in imitations of hail damage on the development of the corn plant. Ia. Agr. Expt. Sta. Res. Bul. 185. 1935.

(19) Eldredge, J. C.
Hail damage to corn. Ia. Agr. Expt. Sta. Bul. 348. 1936.

(20) Eldredge, J. C.
The effects of injury in imitation of hail damage on the development of small grain. Ia. Agr. Expt. Sta. Res. Bul. 219. 1937.

(21) Flora, S. D.
Climate of Kansas. Rpt. Kans. State Board Agr. Vol. LXVII. Bul. 285:264-49. 1948.

(22) Fripp, E. F.
Hail in Canada's wheat fields. Blackwoods Mag. 235:809-822. Ia. 1934.

(23) Fuelleman, R. F.
Hail damage to soybeans. Rpt. 1943. Ill. Acad. Sci. Trans. 37:228-250. 1943.

(24) Garber, R. J., and M. M. Hoover.
Influence of corn smut and hail damage on the yield of certain first generation hybrids between synthetic varieties. Amer. Soc. Agron. Jour. 27:38-45. 1935.

(25) Garner, W. W.
Oil content of buds as affected by the nutrition of the plant. Amer. Soc. Agron. Jour. 27:38-45. 1935.

(26) Gibson, R. M.
Response of soybeans to experimental defoliation. Amer. Soc. Agron. Jour. 35:768-778. 1943.

(27) Haskell, R. J.
Breaking over wheat straw. U.S.D.A. Pl. Dis. Rpt. 14:157-58. 1930.

(28) Hawthorn, L. K.
Stimulated hail injury on yellow bermuda onions. Amer. Soc. Hort. Sci. 43:265-71. 1943.

(29) Hawthorn, L. K.
Defoliation studies as a basis for the estimation of hail losses on onions. Tex. Agr. Expt. Sta. Bul. 682. 1946.

(30) Hume, A. N., and Clifford Franzke.
The effect of certain injuries to leaves of corn plants upon weights of grain produced. Amer. Soc. Agron. Jour. 21:1156-64. 1929.

(31) Jenkins, M. T.
Influence of climate and weather on growth of corn. U.S.D.A. Yr. Bk. Climate & Man. pp. 314. 1941.

(32) Kalton, R. F., and J. C. Eldredge.
Can hail ruin soybeans. F.S. 172. 1947.

(33) Kalton, R. F., C. R. Weber, and J. C. Eldredge.
The effects of injury simulated hail damage to soybeans. Ia. Agr. Expt. Sta. Res. Bul. 359. 1949.

(34) Kiesselbach, T. A., and W. E. Lyness.
Simulated hail injury of corn. Nebr. Agr. Expt. Sta. Bul. 377. 1945.

(35) Kiesselbach, T. A., and W. E. Lyness.
Winter wheat investigations. Nebr. Agr. Expt. Sta. Res. Bul. 31:112-25. 1925.

(36) Klages, K. H. W.
The effects of simulated hail injuries on flax. Amer. Soc. Agron. Jour. 25:540-44. 1933.

(37) Knowles, D. B.
The effect of hail injury on wheat and other grain crops. U. of Sask. Agr. Res. Bul. 102. 1941.

(38) Leonard, W. H., and T. A. Kiesselbach.
The effect of the removal of tassels on the yield of corn. Amer. Soc. Agron. Jour. 24:514-18. 1932.

(39) Li, H. W., and T. N. Liu.
Defoliation experiments with Kioliang. Amer. Soc. Agron. Jour. 27:486-91. 1935.

(40) MacMillan, H. G.
An epidemic of corn smut following hail. Phytopath. 8:584-85. 1918.

(41) Paterson, D. D.
Statistical technique for agriculture research. McGraw-Hill Book Co. New York and London. 1938.

(42) Thatcher, L. E.
Wheat clipping test. Ohio Expt. Sta. 15th Ann. Rpt. Bul. 497. 1932.

(43) Wagner, K. A.
Asst. Sec. Square Deal Hail Ins. Ass'n. Unpub. Rpt. 1933.

(44) White, R. M.
Preliminary observations on some effects of artificial defoliation of wheat plants. Sci. Agr. 26:225-29. 1946.

SUMMARY

In a study of this type it is recognized that data collected for a one-year period can by no means be considered conclusive, however, it can be indicative of certain general trends and of value in designing future experiments.

This simulated hail study included three general types of damage: (1) Whipping plants at various stages of growth; (2) By bending different proportions of the stems at different heights; (3) Removal of different proportions of the spikelets from the heads.

Four experiments were conducted by inflicting the first type of damage at four different stages of growth. Two experiments were conducted by inflicting the second type of damage of different heights and on different proportions of the stems. Only one experiment was conducted by removal of the spikelets.

Some of the general trends that were brought out in the study were:

1. The heavier the damage, the longer the delay in maturity of the crop.

2. In the heavier treatments, when injuries were inflicted at early stages of growth, considerable competition was obtained from weeds, especially foxtail grass.

3. The heavier the damage, the greater the reduction of the crop, except in Experiment 4 where whipping treatments at high level did not reduce the crop as much as treatments at mid-high,

even though the treatments were heavier.

4. When several types of injury were inflicted at intervals ranging from May 5 to June 4, the results indicated that reductions in yield of grain did not follow a consistent trend as the crop progressed toward heading.

5. When all stems were bent on June 9, at the time the heads were filling, a decrease in the size of the heads and kernels was noted.

6. When alternate stems were bent on June 9, the results showed the stems not bent benefited to the extent that in every case the heads and kernels were increased in size when compared to undamaged plants.

7. When all stems were bent on June 16, the heads and kernels were decreased in size, but the percentage decrease was less than when the damage was inflicted a week earlier.

8. When alternate stems were bent on June 16, the heads from the stems not bent were not influenced in size.

9. When all stems were bent on June 9, results indicated that the size of the heads was decreased least the higher on the stem the damage occurred.

10. When 1/3 of the spikelets were removed from the heads, the kernels in the remaining spikelets increased 10 per cent when compared to kernels from undamaged heads.

11. When 2/3 of the spikelets were removed from the heads, the kernels in the remaining spikelets increased 20 per cent in size when compared to kernels from undamaged heads.

ACKNOWLEDGMENT

The author wishes to express his appreciation to Dr. H. H. Laude, major instructor, for the personal interest and able direction given throughout the period of study.

Thanks should be extended to the Western Hail and Adjustment Association of Chicago, Illinois, which made this study possible by contributing financial support for a part of this work.

Appreciation is also expressed to the members of the Agronomy Department staff for their many helpful suggestions and excellent classroom instruction.

REFERENCES

(1) Anonymous.
Pasturing winter wheat. Kans. Branch Expt. Sta. (Hays). Mimeo. Rpt. 1929.

(2) Anonymous.
Removal of suckers on corn. Ark. Agr. Expt. Sta. Ann. Rpt. Bul. 231:11. 1928.

(3) Anonymous.
Removal of suckers on corn. Art. Agr. Expt. Sta. Ann. Rpt. Bul. 246:25. 1929.

(4) Anonymous.
Climaticological data. Kan. Sec. Weather Bureau. 1946-1949.

(5) Anonymous.
Average annual number of days with hail. Climate & Man. U.S.D.A. Yr. Bk. pp. 730. 1941.

(6) Bartel, A. T.
Changes in breaking strength of straw of wheat varieties from heading to maturity. Amer. Soc. Agron. Jour. 29:135-156. 1937.

(7) Cardwell, A. B., and S. D. Flora.
Kansas weather and climate. Kan. Agr. Expt. Sta. Bul. 302:11-18. 1942.

(8) Dungan, G. H.
Effects of hail injury on corn plant measured. Ill. Agr. Expt. Sta. Ann. Rpt. 41:51-54. 1928.

(9) Dungan, G. H.
Effects of hail injury on the development of the corn plant. Amer. Soc. Agron. Jour. 20:51-54. 1928.

(10) Dungan, G. H.
Artificial hailing shows damage to corn by storms. Ill. Agr. Expt. Sta. Ann. Rpt. 42:46-50. 1929.

(11) Dungan, G. H.
Hail injury to corn hurts both yield and quality. Ill. Agr. Expt. Sta. Ann. Rpt. 42:49-50. 1930.

(12) Dungan, G. H.
Relation of blade injury to the yielding ability of corn plants. Amer. Soc. Agron. Jour. 22:164-170. 1930.

(13) Dungan, G. H.
Hail damages corn worse when plants are tasseling. Ill. Agr. Expt. Sta. Ann. Rpt. 44:57-59. 1931.

(14) Dungan, G. H.
Corn grows some ever after hail destroys all blades. Ill. Agr. Expt. Sta. Ann. Rpt. 45:55-56. 1931.

(15) Dungan, G. H.
An indication that corn tillers may nourish the main stalk under some conditions. Amer. Soc. Agron. Jour. 22:662-670. 1931.

(16) Dungan, G. H.
Recovery of soybeans from hail injury is measured. Ill. Agr. Expt. Sta. Ann. Rpt. 51:77-78. 1942.

(17) Eldredge, J. C.
How hail damages corn. Wallace Farmer, 55:1296-97. Aug. 1930.

(18) Eldredge, J. C.
The effects of injury in imitations of hail damage on the development of the corn plant. Ia. Agr. Expt. Sta. Res. Bul. 185. 1935.

(19) Eldredge, J. C.
Hail damage to corn. Ia. Agr. Expt. Sta. Bul. 348. 1936.

(20) Eldredge, J. C.
The effects of injury in imitation of hail damage on the development of small grain. Ia. Agr. Expt. Sta. Res. Bul. 219. 1937.

(21) Flora, S. D.
Climate of Kansas. Rpt. Kans. State Board Agr. Vol. LXVII. Bul. 285:264-49. 1948.

(22) Fripp, E. F.
Hail in Canada's wheat fields. Blackwoods Mag. 235:809-822. Ia. 1934.

(23) Fuelleman, R. F.
Hail damage to soybeans. Rpt. 1943. Ill. Acad. Sci. Trans. 37:228-250. 1943.

(24) Garber, R. J., and M. M. Hoover.
Influence of corn smut and hail damage on the yield of certain first generation hybrids between synthetic varieties. Amer. Soc. Agron. Jour. 27:38-45. 1935.

(25) Garner, W. W.
Oil content of buds as affected by the nutrition of the plant. Amer. Soc. Agron. Jour. 27:38-45. 1935.

(26) Gibson, R. M.
Response of soybeans to experimental defoliation. Amer. Soc. Agron. Jour. 35:768-778. 1943.

(27) Haskell, R. J.
Breaking over wheat straw. U.S.D.A. Pl. Dis. Rpt. 14:157-58. 1930.

(28) Hawthorn, L. K.
Stimulated hail injury on yellow bermuda onions. Amer. Soc. Hort. Sci. 43:265-71. 1943.

(29) Hawthorn, L. K.
Defoliation studies as a basis for the estimation of hail losses on onions. Tex. Agr. Expt. Sta. Bul. 682. 1946.

(30) Hume, A. N., and Clifford Fronzke.
The effect of certain injuries to leaves of corn plants upon weights of grain produced. Amer. Soc. Agron. Jour. 21:1156-64. 1929.

(31) Jenkins, M. T.
Influence of climate and weather on growth of corn. U.S.D.A. Yr. Bk. Climate & Man. pp. 314. 1941.

(32) Kalton, R. F., and J. C. Eldredge.
Can hail ruin soybeans. F.S. 172. 1947.

(33) Kalton, R. F., C. R. Weber, and J. C. Eldredge.
The effects of injury simulated hail damage to soybeans. Ia. Agr. Expt. Sta. Res. Bul. 359. 1949.

(34) Kiesselbach, T. A., and W. E. Lyness.
Simulated hail injury of corn. Nebr. Agr. Expt. Sta. Bul. 377. 1945.

(35) Kiesselbach, T. A., and W. E. Lyness.
Winter wheat investigations. Nebr. Agr. Expt. Sta. Res. Bul. 31:112-25. 1925.

(36) Klages, K. H. W.
The effects of simulated hail injuries on flax. Amer. Soc. Agron. Jour. 25:540-44. 1933.

(37) Knowles, D. B.
The effect of hail injury on wheat and other grain crops. U. of Sask. Agr. Res. Bul. 102. 1941.

(38) Leonard, W. H., and T. A. Kiesselbach.
The effect of the removal of tassels on the yield of corn. Amer. Soc. Agron. Jour. 24:514-18. 1932.

(39) Li, H. W., and T. N. Liu.
Defoliation experiments with Kioliang. Amer. Soc. Agron. Jour. 27:486-91. 1935.

(40) MacMillan, H. G.
An epidemic of corn smut following hail. Phytopath. 8:584-85. 1918.

(41) Paterson, D. D.
Statistical technique for agriculture research. McGraw-Hill Book Co. New York and London. 1938.

(42) Thatcher, L. E.
Wheat clipping test. Ohio Expt. Sta. 15th Ann. Rpt. Bul. 497. 1932.

(43) Wagner, K. A.
Asst. Sec. Square Deal Hail Ins. Ass'n. Unpub. Rpt. 1933.

(44) White, R. M.
Preliminary observations on some effects of artificial defoliation of wheat plants. Sci. Agr. 26:225-29. 1946.