A STUDY OF COMBINE DAMAGE AND PROPERTIES OF YELLOW CORN AS RELATED TO DIFFERENT VARIETIES AND MOISTURE LEVELS

by 500

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INTRODUCTION

The harvesting process is, indeed, a complex process in which the quality of the grain depends upon the many factors involved. The final quality depends on factors like moisture content at the time of the operation, variety, type of machine and machine adjustment, presence or absence of weeds, operator skill, etc. (1, 7, 12). The congregation of all these variables together contribute to the final quality of the grain. It can easily be seen that the knowledge of how these factors vary and how much they affect the operation, would provide basic information toward improving the harvesting operation. It also could help in planning of planting dates and selecting and scheduling machine operations for corn production.

Moisture content, for example, is an important factor in harvesting. But moisture content, due to many circumstances can not be controlled very effectively during harvesting. Factors such as zone climate during the harvesting period, size of machinery and crop field, storage and drying facilities, are of great influence in determining when harvest should take place.

Knowledge of the variety performance as related to moisture content and field location conditions can give an estimation of what harvesting results will be under certain existing farm conditions.

PURPOSE OF STUDY

The purposes of this work are to study the field combine behavior on corn damage and physical properties of some yellow corn varieties at various moisture contents, compared with hand shelled corn as "control".

REVIEW OF LITERATURE

Corn damage could be evaluated by different methods. These methods go from the simple evaluation of the quantity of chips from the kernels to damage in future germination, checked by means of detecting certain enzymes, supposedly present in the live embryos.

Kaminski (8) reported that the methods for evaluating grain damage could be classified in two categories: methods that evaluate the external or visible grain damage and methods that evaluate the internal or invisible grain damage. He includes in the first group the mechanical particle sizing, generally based on use of USDA grain sieves, or visual inspection that offers better information but is time consuming. The visual inspection could be a simple visual observation or observation after the use of a fast green dye indicator or optical scanners. He also cited the corn breakage tester as a device capable of revealing the susceptibility of damage to the kernels. For invisible or internal grain damage he cited the standard germination test, acid germination and staining reaction methods.

In his work he concluded that a poor correlation existed between the results obtained with different methods and that a need existed for standardization of the tests for both visible and invisible grain damage.

Bailey (2) reported that the principal losses in corn quality, now, is from broken kernels; he cited that around three cents per bushel is lost this way in all corn sold by farmers and that the amount sieved out before the corn gets to the consumer is over three percent.

Johnson and Lamp (7) suggested two procedures for crackage or physical damage evaluation in kernels: separation of whole kernels from chips or kernels from which chips have been broken, and screening with a 12/64" round hole screen. In both cases the damage should be referred to as a percent of total sample weight. They reported that in the first case damage up to 30 percent could be found, and in the second case the percentage is normally lower.

Marcus (10) describes different methods of evaluation of grain damage and refers to the applicability of some methods for corn. He cited for physical damage evaluation in corn: transmitted light as a method for evaluating endosperm cracks, a green dye test for evaluating seed coat cracks, and a breakage test for evaluating the breakage tendency of the kernels.

Forth (4) analyzed the problem of grain damage from the point of view of viability and the real necessity of determining grade of corn for marketing. He concludes that there is a need for standardization in methods for damage evaluation that permit communication from farmers to buyers. He also cited that standard methods would help in comparing or evaluating harvesting machinery performance.

Morrison (11), while testing attachments for combining corn in the range of 13 to 26 percent moisture, found that damage was a minimum at around 15 percent moisture content, increasing above and below this level. He cited 3.5 to 13 percent damage in the range studied.

Agnes (1) studying shellability of hybrid varieties found that physical properties showed large differences between varieties. He found also that physical dimensions and moisture content varied more from ear to ear within a variety than between varieties. By using high speed movies he found differences in shelling action between varieities but also that different planting dates induced more variation in physical properties and shelling action than different varieties. He also found that kernel damage was proportional to the moisture content at time of harvest.

Waelti (12) studying physical properties of cob and kernels, and damage in different varieities of corn, cited that significant differences were obtained among varieties for many properties. He cited also that some of the physical properties are related to moisture content. He found that generally high correlations existed between kernel moisture and damage and stated the mathematical relationship as

$$Y = .882 \times X^{1.039}$$

where

Y = grain damage percentage

X = kernel's moisture percentage

He also found that kernel compressive strength and moisture content are related and so is variety, and cited that yield point strength showed a decrease with an increase in moisture content.

Hall (5) studying mechanical shelling reported an increase in tips broken at high levels of moisture content (around 32 percent). Working with a moisture range from around 10 to 38 percent he found that the quantity of particles passing through a 12/64" screen decrease as moisture increases from around 10 to 22 percent and increased above this level of moisture. He also reported variation in damage at the same moisture levels from year to year.

Johnson and Lamp (7) cited that the visual cracking percent decreases from 11 to around 16 percent moisture and increases above that level. They also reported kernels tips retained in the cobs at high moisture levels. They further cited that crackage is closely related to moisture content or the degree of maturity when corn is subjected to mechanical action. They also reported a decrease in the weight per bushel with an increase in moisture content.

Johnson et al. (6) studying corn harvesting performance at different dates cited that several factors should be integrated to determine optimum time for harvesting. Some of these factors are inherent in farm programs and are difficult or even impossible to characterize. He cited that corn grain would not reach full maturity until an average of 26 percent water content is reached.

Bilanski (3) studying grain resistance to damage at three levels of moisture content: 1, 8, and 17 percent moisture reported that force applied to initiate fracture in grains, for gradually applied load, increased from 1 to 8 percent moisture and decreased for 17 percent. He also found that the resistance of kernels to low or high velocity impact increased with moisture content. He concluded in his work that size, moisture content and position of the grain, all influence damage resistance.

MacMasters (9) describes the structure and composition of kernels and the physical properties of corn. He put emphasis on the importance of structure and components in the kernel behavior.

EXPERIMENTAL METHODS AND MATERIALS

In order to fulfill the purpose of this project, corn samples of the 1968 crop were obtained from a farm where several varieties were planted and treated under practically the same conditions. This farm was a private farm located southeast of Manhattan, Kansas, owned by Warren Roepke. The harvesting was done by a 1962 two-row John Deere combine, Model 45, equipped with a Model 210 cornhead.

There were six varieties, planted in different plots, and in some cases there was more than one plot available for the same variety. These varieties are commercial varieties and were planted during the period April 30 to June 18. Table 1 shows the varieties studied and also the coded label used.

The corn culture on this farm was good; the corn was healthy, and practically no weeds were present at the time of the harvesting.

Table 1.--Codes for varieties and their history

Method of harvesting	Code	Variety	Lot No.	Approximate moisture content range (%wb)
Combined	A1 - M	Pioneer 3306	8	24
	A2 - M	Pioneer 3306	4	14
	B1 - M	Pioneer 3307	2	15
	B2 - M	Pioneer 3307	9	22
	C1 - M	B14 x B57	5	17
	C2 - M	B14 x B57	10	20
	C3 - M	B14 x B57	11	21
	C4 - M	B14 x B57	15	16
	D1 - M	N28 x N31 x O43	3	15
	D2 - M	N28 x N31 x O43	12	16
	E1 - M	Funks 5757	1	16
	E2 - M	Funks 5757	13	17
	F1 - M	Funks 4697	14	15
	F2 - M	Funks 4697	6	15
Hand shelled	A1 - H	Pioneer 3306	8	22-29
	B1 - H	Pioneer 3307	2	17
	B2 - H	Pioneer 3307	9	26
	C1 - H	B14 x B57	5	17-18
	C2 - H	B14 x B57	10	24-25
	C3 - H	B14 x B57	11	25-31
	D1 - H	N28 x N31 x O43	3	16
	E1 - H	Funks 5757	1	14-21
	F1 - H	Funks 4697	14	15

The yields observed, according to the farmer's records were from 83 to 113 bushels per acre and the density of plants per acre were from 18,000 to 23,000.

Sampling Procedure

Samples were taken every time a different variety of corn in the plots was harvested. Combine shelled corn was sampled during the combine unloading operation at the combine bin unloader, and more than one discharge operation was used to collect a single sample. Samples were collected in tin containers with tight lids to eliminate possible moisture content change during transportation. The samples were transferred to plastic bags at the laboratory and were kept under refrigeration until time of analysis. The analyses were done as soon as possible to ensure the same conditions of the corn samples as at the field. It was observed that in samples treated this way, the change in moisture is kept to a minimum.

Since this work was to obtain information on corn damage during normal harvesting, the decisions for machine adjustment, speed, etc. were made by the farmer, based on the field conditions, the product coming from the combine, and his own experience. Changes in operational conditions of the combine were made during or in between harvesting time as necessary. Because the farmer who operated the combine was a person with a great deal of machinery experience, we are assuming that the way that the combine harvesting was done could be considered as a typical or representative way of field corn harvesting.

Some samples for hand shelling corn were taken at the time of combine harvesting, and also a few more samples were taken at different times, according to convenience and time available for the analysis. The ears of corn were taken randomly at the field and kept in plastic bags under refrigeration.

The ears were shelled by hand before analysis, and the portion not used in the test was put back at the same storage conditions for future checking or analysis at a different moisture content level.

The samples were labeled according to variety, field plot origin, treatment, and sampling date.

RESULTS

The total field sample was passed through a Boerner Sample Divider and approximately 2000 grams were separated for evaluating damage and other properties.

The first step was to evaluate the dockage by a Carter dockage tester. The dockage was calculated as a percentage of the total sample on the weight basis.

The results of dockage tests for field-combined corn and for hand-shelled corn are given in Table 2.

The dockage found in hand-shelled corn was almost negligible.

Moisture contents of samples were determined by using an air circulating oven. Three sub-samples of approximately 100g were taken and placed in an oven for 72 hours at 104 degrees centigrade. The average moisture content (percent weight basis) of three

Table 2.--Test weight and dockage of combined corn and hand shelled corn samples

Method	Variety code	Moisture content (wb)	Test weight	Dockage
		%	lb/bu.	%
Combined	A2 - M	13.74	58.32	0.51
	F2 - M	14.54	58.49	0.05
	D1 - M	14.76	58.36	0.47
	B1 - M	15.04	56.42	0.89
	F1 - M	15.30	57.68	0.76
	E1 - M	15.46	57.82	1.33
	C4 - M	15.65	56.75	0.50
	D2 - M	16.02	56.76	0.64
	E2 - M	16.82	58.66	0.76
	C2 - M	19.66	53.40	0.89
	C3 - M	20.56	51.79	0.44
	B2 - M	22.26	52.23	1.01
	A1 - M	24.28	51.93	0.77
Hand shelled	E1 - H	13.64	61.33	----
	F1 - H	15.34	59.91	0.05
	D1 - H	15.72	58.58	0.08
	C1 - H	17.10	57.53	0.06
	E1 - H	17.17	59.60	0.15
	C1 - H	17.45	57.41	0.06
	B1 - H	17.47	55.77	0.12
	E1 - H	20.75	56.34	0.13
	A1 - H	22.17	55.77	0.03
	A1 - H	23.42	51.80	0.09
	A1 - H	23.83	52.49	0.13
	C2 - H	24.47	51.11	0.02
	C3 - H	25.08	52.43	0.02
	C2 - H	25.25	52.03	0.05
	B2 - H	25.83	52.76	0.05
	C3 - H	27.18	51.38	0.08
	A1 - H	28.74	51.61	0.09
	C3 - H	30.49	51.40	0.25

sub-samples for the different varieties harvested are tabulated in Table 2.

The weight per bushel test of the sample was determined by a Boerner tester. Three duplicates for a given sample were made and the average values are shown in Table 2.

In order to evaluate the damage in the corn samples, three sub-samples of 100g each were taken and examined visually under the light. The kernels were classified into the following categories:

A. Sound: Kernels with no visual external or internal crack or part missing. (Kernels with a small portion of the tip missing were considered as sound kernels.)

B. Broken: Kernels with visible external cracks and/or having a part missing.

C. Cracked: Kernels with no visible external cracks but small or large internal cracks, visible under light transmittance conditions.

D. Foreign material: Any material other than kernels present in the sample.

Every sample was examined twice. The results of damage evaluation for combined corn and hand-shelled corn given as a percentage of sample weight are tabulated in Tables 3 and 4, respectively.

Three sub-samples of 100g each consisting of only sound kernels were prepared for the breakage test. The breakage test was performed by a corn breakage tester, shown in Figure 1. This machine gives uniform treatment to the kernels in a cylinder with a diameter of 3-5/8 inches and depth of 3-1/3 inches by revolving

Table 3.--Observed damage on field combined corn

Variety code	Moisture content (wb) %	Broken %	Cracked %	Foreign material %	Total damage %
A2 - M	13.74	2.8	3.5	1.1	6.9
F2 - M	14.54	4.3	3.6	0.1	7.9
D1 - M	14.76	3.8	2.8	1.1	6.6
B1 - M	15.04	5.0	3.0	2.4	8.0
F1 - M	15.30	4.9	4.0	1.4	8.9
E1 - M	15.46	5.1	3.4	1.7	8.5
C4 - M	15.65	6.9	4.9	0.6	11.8
D2 - M	16.02	7.4	5.0	1.7	12.4
E2 - M	16.82	4.4	2.5	1.5	6.9
C2 - M	19.66	11.5	8.6	1.3	20.1
C3 - M	20.56	10.3	0.6	2.1	10.9
B2 - M	22.26	8.8	2.1	0.6	10.9
A1 - M	24.28	7.6	1.7	1.1	9.3

Table 4.--Observed damage on hand shelled corn

Variety code	Moisture content (wb)	Broken	Cracked	Foreign material	Total damage
	%	%	%	%	%
E1 - H	13.64	---	---	0.2	---
F1 - H	15.34	---	0.4	0.2	0.4
D1 - H	15.72	0.1	0.8	0.4	0.9
C1 - H	17.10	---	---	0.2	---
E1 - H	17.17	---	0.5	1.7	0.5
C1 - H	17.45	---	---	---	---
B1 - H	17.47	---	---	0.2	---
E1 - H	20.75	0.2	---	0.8	0.2
A1 - H	22.17	---	---	0.3	---
A1 - H	23.42	---	---	0.3	---
A1 - H	23.83	---	0.1	0.3	0.1
C2 - H	24.47	---	---	0.1	---
C3 - H	25.08	---	---	0.2	---
C2 - H	25.25	---	0.2	---	0.2
B2 - H	25.83	---	---	0.1	---
C3 - H	27.18	---	---	0.1	---
A1 - H	28.74	0.1	---	0.1	0.1
C3 - H	30.49	0.1	---	1.3	0.1

Fig. 1

Stein breakage tester used in the analysis.

Fig.1

the grains with an impeller that rotated at approximately 1765 rpm for two minutes. The time elapse was automatically controlled by the machine.

After this treatment, the kernels were poured into a 12/64" sieve of a standard shaking sieve machine and shaken 30 times. The fractions separated by the screen were recorded and are shown in Tables 5 and 6. The portion that stayed in the sieve were again examined under light and classified according to three categories: sound, broken, and cracked kernels. The same criteria for separation, as cited before, were followed. The average values of each damage category, as a percentage of the total sample weight, are shown in Tables 5 and 6.

The next step was to classify the corn according to size and shape in order to examine the size distribution for a given variety of corn. This was achieved by passing a sample through a grader machine. The machine consisted of two superimposed sets of rotating cylindrical sieves. The top set had round holes for width sizing while the bottom one had rectangular slotted perforations for thickness sizing. Eight kernel sizes were separated by the grader. The schematic flow and sieve hole sizes of the grader are given in Figure 2. The results of size classification for combined corn and hand-shelled corn are given in Tables 7 and 8, respectively.

The fraction calles "fines" consisted of small pieces of broken or ground kernels, foreign materials, and small kernels. Large pieces of foreign materials, generally cob pieces, were included in the fraction labeled "extra large". The extra large

Table 5.--The results of breakage test for field combined corn

Variety code	Moisture content (wb)	Shaking sieve method	Light transmittance method		
		Through sieve	Broken	Cracked	Total damage
	%	%	%	%	%
A2 - M	13.74	0.47	2.79	0.73	3.52
F2 - M	14.54	0.30	2.68	1.23	3.91
D1 - M	14.76	0.40	2.14	0.63	2.77
B1 - M	15.04	0.30	2.66	0.65	3.31
F1 - M	15.30	0.43	3.62	1.11	4.73
E1 - M	15.46	0.27	1.68	1.70	3.38
C4 - M	15.65	0.33	4.22	2.11	6.33
D2 - M	16.02	0.40	3.49	1.31	4.80
E2 - M	16.82	0.27	2.74	1.61	4.35
C2 - M	19.66	0.33	4.02	8.65	12.67
C3 - M	20.56	0.53	4.13	0.98	5.11
B2 - M	22.26	0.65	2.31	----	2.31
A1 - M	24.28	1.40	3.46	2.08	5.54

Table 6.--The results of breakage test for hand shelled corn

Variety code	Moisture content (wb) %	Shaking sieve method: Through sieve %	Light transmittance method: Broken %	Cracked %	Total damage %
E1 - H	13.64	0.17	0.27	0.10	0.37
F1 - H	15.34	0.10	0.10	0.67	0.77
D1 - H	15.72	0.10	0.43	0.23	0.66
C1 - H	17.10	0.06	0.23	0.23	0.46
E1 - H	17.17	0.07	0.10	0.10	0.20
C1 - H	17.45	0.10	0.37	0.63	1.00
B1 - H	17.47	0.10	0.23	----	0.23
E1 - H	20.75	0.40	2.52	0.47	2.99
A1 - H	22.17	0.17	1.74	0.77	2.51
A1 - H	23.42	0.17	3.88	2.04	5.92
A1 - H	23.83	0.17	3.29	1.38	4.67
C2 - H	24.47	0.20	7.11	6.61	13.72
C3 - H	25.08	0.20	5.63	4.12	9.74
C2 - H	25.25	0.40	14.05	7.13	21.18
B2 - H	25.83	0.17	3.55	----	3.55
C3 - H	27.18	0.17	3.59	2.74	6.33
A1 - H	28.74	1.13	3.84	----	3.84
C3 - H	30.49	1.50	7.94	0.74	8.68

Fig. 2

Schematic flow in the cylinder grader sizing machine.

Fractions

1- Small- medium flats

2- Small- small flats

3- Large rounds

4- Large- large flats

5- Large- medium flats

6- Small rounds

7- Extra- larges

8- Fines

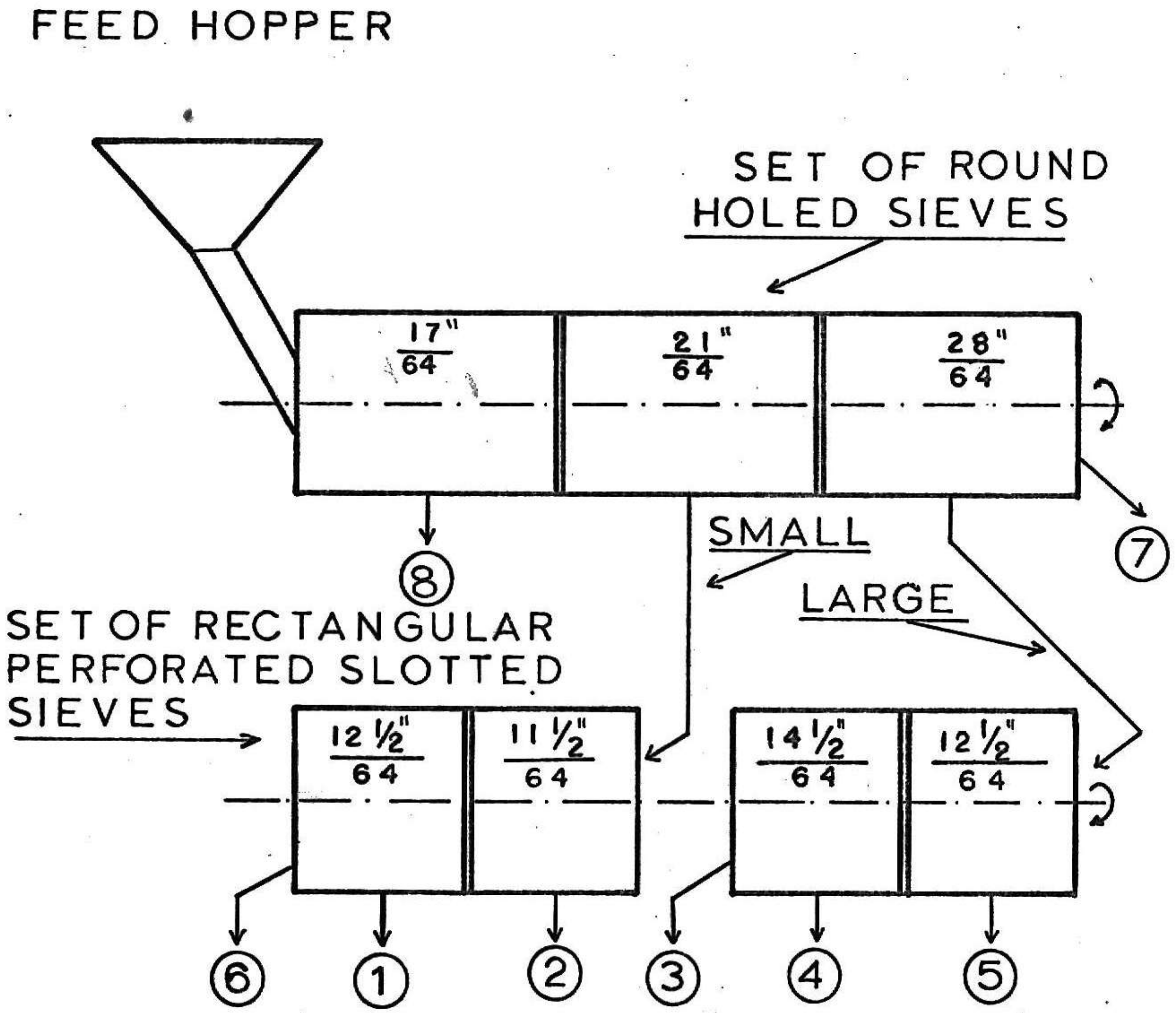

FEED HOPPER
SET OF ROUND HOLED SIEVES
17"/64
21"/64
28"/64
SMALL
LARGE
SET OF RECTANGULAR PERFORATED SLOTTED SIEVES
12 1/2"/64
11 1/2"/64
14 1/2"/64
12 1/2"/64
8
7
6
1
2
3
4
5

Fig. 2

Table 7.--The size distribution of field combined corn

Variety code	Moisture content (wb)	Flat				Round		A = width, B = thickness	
		Small 17/64"<A<21/64"		Large 21/64"<A<28/64"					
		Small	Medium	Medium	Large	Small	Large	Extra large	Fines
	%	%	%	%	%	%	%	%	%
		B<11½/64"	B<12½/64"	B<12½/64"	B<14½/64"	17/64<A <21/64"	21/64<A <28/64"	A>28/64"	A<17/64"
A1 - M	24.28	9.10	3.87	60.41	11.03	4.41	7.95	0.21	3.04
B2 - M	22.26	21.06	7.57	45.57	9.88	7.44	5.68	0.11	2.70
C3 - M	20.56	7.83	8.36	39.12	20.33	9.49	12.64	0.41	1.80
C2 - M	19.66	4.33	6.02	37.17	27.57	9.05	12.80	0.58	2.34
E2 - M	16.82	11.97	4.07	55.28	11.05	6.08	9.10	0.54	1.90
D2 - M	16.02	17.88	7.53	37.76	11.99	11.47	10.52	0.16	2.69
C4 - M	15.65	12.76	9.71	42.64	13.99	10.02	8.85	0.13	1.88
E1 - M	15.46	13.98	6.48	44.27	11.44	9.23	10.64	0.29	3.67
F1 - M	15.30	24.60	7.72	38.00	9.53	10.10	7.07	0.12	2.84
B1 - M	15.04	14.98	27.20	9.72	8.02	30.12	4.49	-----	5.45
D1 - M	14.76	19.04	9.15	34.77	12.93	11.32	10.49	0.14	2.16
F2 - M	14.54	6.85	6.30	48.33	10.74	7.83	18.66	0.29	0.98
A2 - M	13.74	18.06	4.93	56.06	7.80	6.93	3.87	0.09	2.27

Table 8.--The size distribution of hand shelled corn

Variety code	Moisture content (wb)	Flat: Small 17/64<A<21/64"		Flat: Large 21/64<A<28/64"		Round		A = width, B = thickness	
		Small	Medium	Medium	Large	Small	Large	Extra large	Fines
	%	%	%	%	%	%	%	%	%
		B<11½/64"	B<12½/64"	B<12½/64"	B<14½/64"	17/64<A<21/64"	21/64<A<28/64"	A>28/64"	A<17/64"
C3 - H	30.49	0.67	2.60	26.01	42.97	6.28	19.55	1.64	0.26
A1 - H	28.74	7.05	4.32	55.80	16.07	5.63	10.52	0.81	0.41
C3 - H	27.18	1.38	2.49	39.01	32.77	4.92	17.35	1.95	0.11
B2 - H	25.83	18.70	9.61	31.62	12.62	8.59	14.59	3.40	0.51
C2 - H	25.25	0.61	1.77	39.42	36.27	4.57	17.00	0.33	0.02
C3 - H	25.08	1.61	2.93	42.18	32.38	4.67	14.94	1.23	0.07
C2 - H	24.47	0.57	1.80	41.21	35.73	5.31	14.77	0.57	0.04
A1 - H	23.83	11.98	3.91	63.36	10.11	5.20	4.88	0.06	0.50
A1 - H	23.42	11.56	5.09	57.98	10.38	6.65	7.63	0.23	0.47
A1 - H	22.17	15.39	6.45	53.79	9.24	6.63	7.91	----	0.58
E1 - H	20.75	5.77	4.53	43.73	20.51	9.89	14.84	0.21	0.51
B1 - H	17.47	12.13	31.10	10.73	10.40	28.38	3.17	----	4.06
C1 - H	17.45	8.09	12.42	29.42	23.77	14.22	11.24	0.33	0.50
C1 - H	17.10	7.94	12.32	28.23	24.57	14.57	11.73	0.21	0.42
D1 - H	15.72	17.49	9.68	33.92	14.46	14.87	9.07	0.07	0.43
F1 - H	15.34	24.09	6.34	43.01	9.81	7.56	8.39	0.09	0.70
E1 - H	13.64	16.34	5.09	47.56	12.35	7.45	10.36	0.21	0.63

pieces of foreign material were discarded; consequently, the values found in the tables represent the net weight of the kernels in the fraction.

The strengths of kernels under static loading were tested by a compression tester. In these tests, twenty kernels from the "large-medium" fraction of each sample were examined. Only the "large-medium" fraction was tested due to the fact that it was, in the majority of the cases, the biggest fraction and it was impractical to run the test with all fractions from all samples.

The kernel size in this fraction was:

Width: more than 21/64 inch and less than 28/64 inch

Thickness: less than 12½/64 inch.

The kernels were placed in a flat position while the load was gradually applied until the kernel reached the cracking point. The cracking point was determined by the typical cracking sound detected at the time of the cracking.

The cracking load in pounds and the number of loading turns required to reach the cracking point were recorded. The deformation displaced by the kernels until the cracking point was calculated from the number of turns. The data obtained in this test are shown in Table 9.

DISCUSSION

Due to the nature of the work done, replications of the treatments could not be obtained. This needs to be done in the future so that meaningful statistical analysis can be performed.

Table 9.--The cracking strengths and deformation at cracking point of "large-medium flat" kernels under the static loading[1/]

Method	Variety code	Moisture content (wb)	Cracking strength	Deformation
		Percent	Pounds	Inches
Combined	A2 - M	13.74	78.7*	0.0174
	F2 - M	14.54	88.3*	0.0180
	D1 - M	14.76	87.9*	0.0197
	B1 - M	15.04	90.4*	0.0229
	F1 - M	15.30	86.5*	0.0212
	E1 - M	15.46	98.0*	0.0169
	C4 - M	15.65	108.7*	0.0257
	D2 - M	16.02	87.9*	0.0210
	E2 - M	16.82	85.3*	0.0185
	C2 - M	19.66	130.2+	0.0431
	C3 - M	20.56	170.4+	0.0607
	B2 - M	22.26	144.3+	0.0571
	A1 - M	24.28	148.5+	0.0623
Hand shelled	E1 - H	13.64	82.7*	0.0108
	F1 - H	15.34	80.9*	0.0184
	D1 - H	15.72	93.6*	0.0228
	C1 - H	17.10	101.1*	0.0200
	C1 - H	17.45	100.5*	0.0261
	B1 - H	17.47	111.7*	0.0413
	E1 - H	20.75	147.6+	0.0538
	A1 - H	22.17	120.1*	0.0348
	A1 - H	23.42	160.1+	0.0573
	A1 - H	23.83	80.7*	0.0153
	C2 - H	24.47	154.7+	0.0629
	C3 - H	25.08	177.8+	0.0636
	C2 - H	25.25	144.4+	0.0613
	B2 - H	25.83	134.2+	0.0645
	C3 - H	27.18	157.9+	0.0653
	A1 - H	28.74	125.0+	0.0662
	C3 - H	30.49	114.5+	0.0633

[1/] The average values of twenty kernels tested for each sample.

* Strength of cracking point.

\+ Strength of collapsing point (cracking point not detected).

As stated at the beginning, these results constitute only one year's observation. The author assumes that, in the future, when more tests are made and more information is put together, some of the trends shown now might be different.

The literature already referred to states that combined corn damage depends on variety and moisture content at the time of combining. The variety effect could not be rigorously examined with the type of data available in this investigation. However, if the variety effect were disregarded, the effect of moisture content on corn damage and physical properties can be examined. Damage evaluation results for the field shelled corn show that damage increased as moisture content increased until around 20 percent moisture (wb), then started decreasing. Figure 3 shows this general trend.

In all observed ranges of moisture content, the percentage of cracked damage was lower above 20 percent moisture level than at lower levels. The cracked damage represented, as cited before, the visual cracks in the kernels observed under light transmittance conditions. These were small or large cracks inside the kernels, showed by the light as a dark plane inside the kernel. If the kernels had been examined by a dye test, the damage evaluation result would have been different from that by the light transmittance method. The dye test would indicate clearly all defects present in the skin coat of kernels. The visual observation method using the light transmittance method is not as thorough as the dye test. However, the visual observation method was used since the sound kernel fraction had to be separated in

Fig. 3

Broken and total damage observed in field shelled corn in relation to the moisture content of corn.

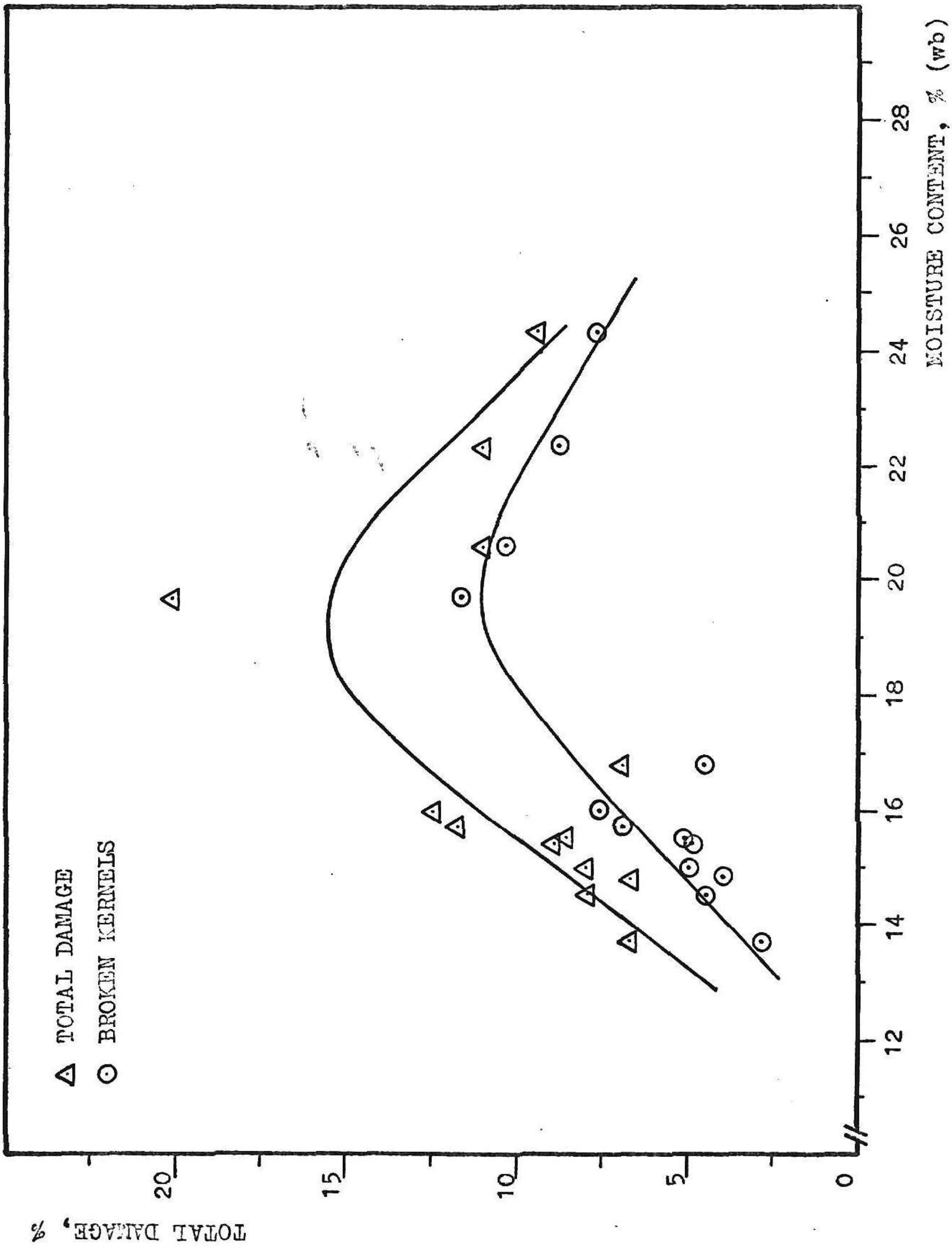

TOTAL DAMAGE
BROKEN KERNELS
MOISTURE CONTENT, % (wb)
12
14
16
18
20
22
24
26
28
TOTAL DAMAGE, %
0
5
10
15
20

Fig. 3

order to evaluate the sample's susceptibility to damage. Separation would not be possible after using a dye indicator because of the destructive nature of the test.

A comparison between the kernel damage evaluation using the dye treatment and the procedure used in this work showed a big difference in samples from the same machine and field. A further test was made to examine this difference. The results are shown in Table 10. It shows that the differences in total damage characterized by the two methods are quite different. The major difference between the two methods was the light damage characterization. This kind of damage amounted to nearly 16.5 and 11.5 percent, respectively in the retro examples. So, conclusions given in terms of total damage have to be carefully examined when comparisons with other types of grain damage evaluation is desired. Wrong conclusions could be induced by the simple matching of total damage figures.

The results of the susceptibility to breakage, tested by means of the breakage tester showed that shelled corn harvested by a combine had a higher susceptibility to damage then hand-shelled corn at the lower range of moisture content.

In the range of 13 to 19 percent moisture, the difference in total damage ranged from 2 to 6 percent as shown in Figures 4 and 5.

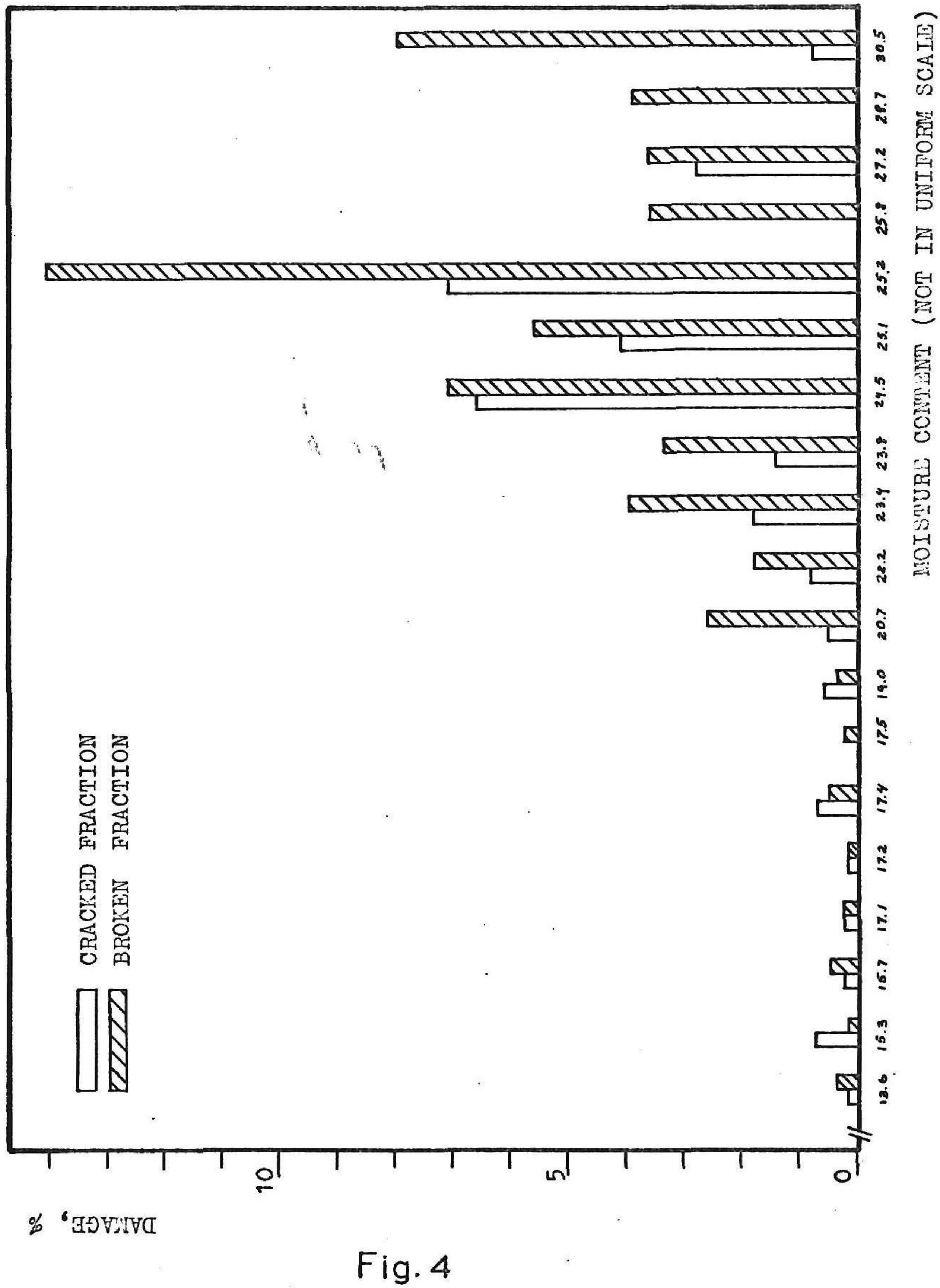
The samples shelled by hand, with above 20 percent moisture level, showed considerable increase in broken kernels and total breakage. Some variety effects on the breakage were probably present. Further investigation on the effects are needed for

Table 10.--Comparison of damage evaluation between light transmittance and dye methods

Variety	Treatment	Total damage: Light Transmittance	Total damage: Dye
A2 - M	Combined	8.26	26.64
D1 - M	Combined	7.17	21.26

Fig. 4

Cracked and broken damage by the breakage tester for various varieties of hand-shelled corn in relation to the moisture content.



CRACKED FRACTION
BROKEN FRACTION
DAMAGE, %
0
5
10
13.6
15.3
15.7
17.1
17.2
17.4
17.5
19.0
20.7
22.2
23.4
23.8
24.5
25.1
25.3
25.9
27.2
28.7
30.5
MOISTURE CONTENT (NOT IN UNIFORM SCALE)

Fig. 4

Fig. 5

Cracked and broken damage by the breakage tester for various varieties of combine-shelled corn in relation to the moisture content.

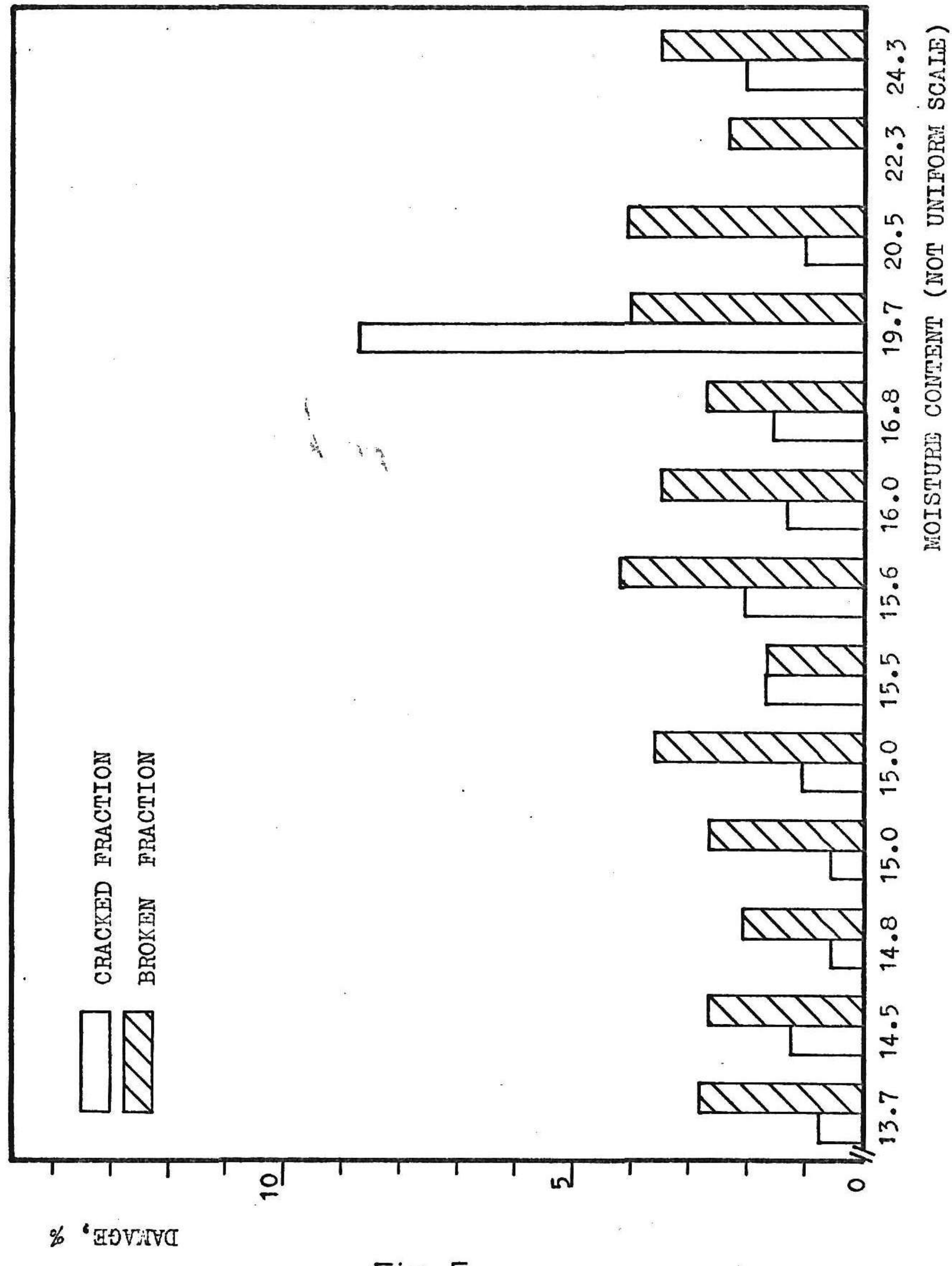

CRACKED FRACTION
BROKEN FRACTION
DAMAGE, %
0
5
10
13.7
14.5
14.8
15.0
15.0
15.5
15.6
16.0
16.8
19.7
20.5
22.3
24.3
MOISTURE CONTENT (NOT UNIFORM SCALE)

Fig. 5

verifying the present results. The results of breakage tests for shelled corn samples by a combine show almost the same broken damage level regardless of moisture content and variety. Only one to two percent variation among samples tested can be seen in Figure 5.

These results provide some information on the susceptibility to corn damage in future handling and for improving combine shelling techniques to preserve higher quality of corn.

It was found that tha total damage observed by the breakage tester could be correlated with the total damage observed in the field combine, for the approximate range of 14 to 24 percent moisture content. Figure 6 shows a linear relationship between total damage by the breakage tester and by the field combined corn in which the correlation coefficient r was .87. The regression line in Figure 6 evaluated by the least square method was:

$$Y = 4.04 + 1.21 X$$

where

Y = total damage by field combine, percent

X = total damage by the breakage tester, percent.

The results indicated that shelled corn with a high percent of damage which resulted from field combining would be more susceptible to damage in future handling and also damage from field combining for shelled corn might be estimated by the breakage tester. The flat kernels, classified as large medium, were loaded until the cracking point was reached, by the compression tester. The results are shown in Figure 7. The general tendency was that

Fig. 6

Total damage observed in field combined corn in relation to the total damage observed in the breakage tester.

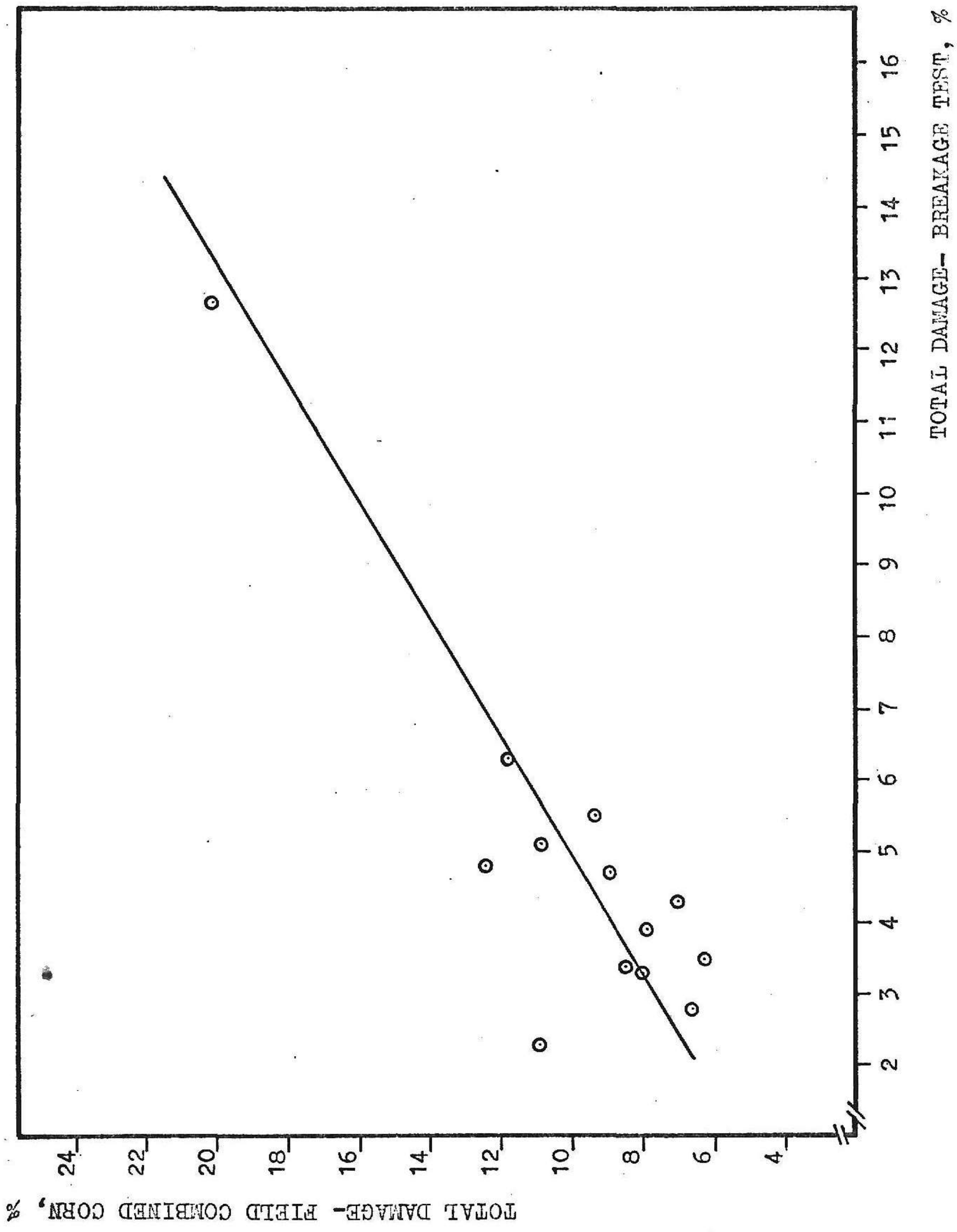

TOTAL DAMAGE- BREAKAGE TEST, %
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
TOTAL DAMAGE- FIELD COMBINED CORN, %
4
6
8
10
12
14
16
18
20
22
24

Fig. 6

Fig. 7

Cracking strengths of hand and combine shelled corn in relation to the moisture content.

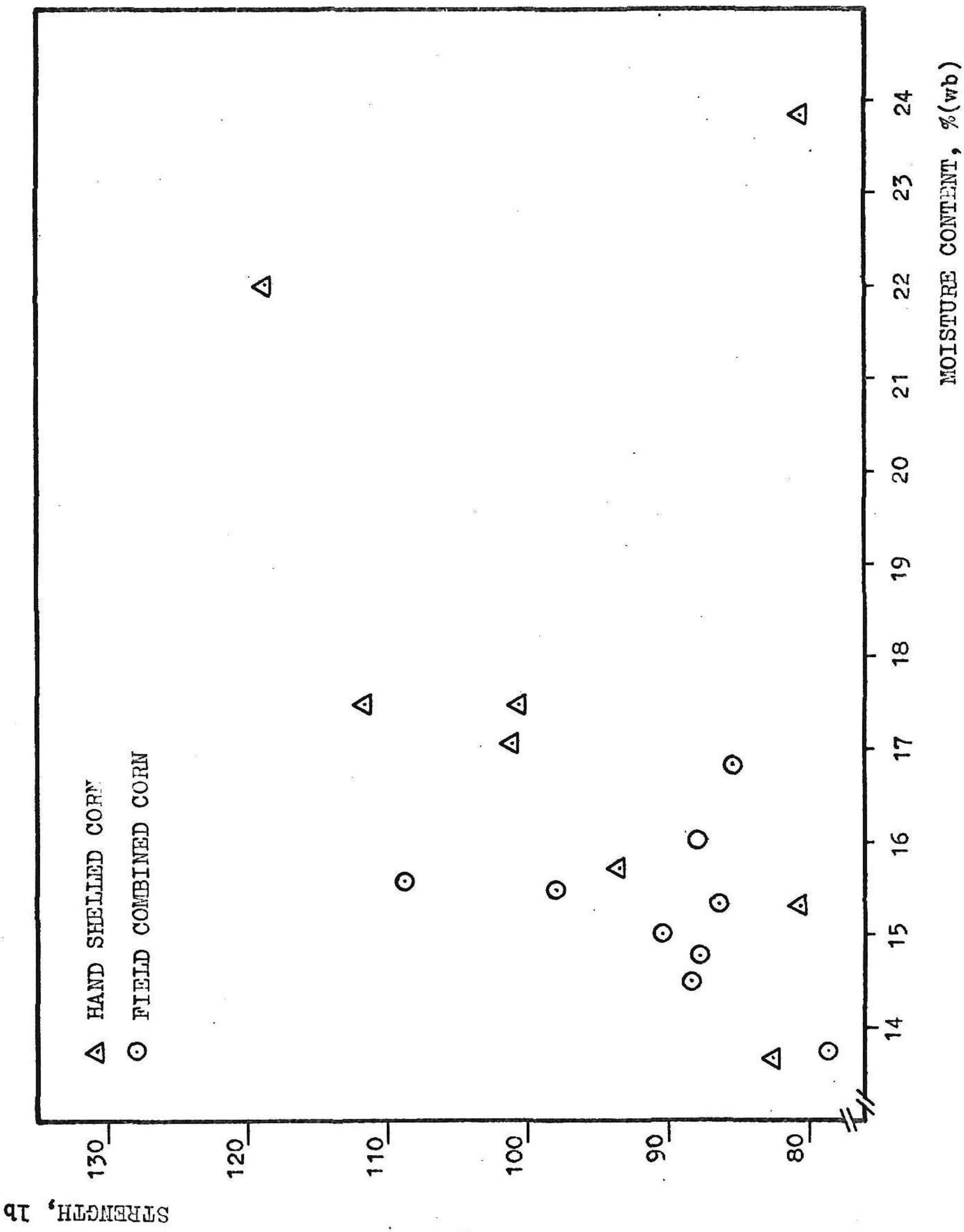

HAND SHELLED CORN
FIELD COMBINED CORN
MOISTURE CONTENT, %(wb)
14
15
16
17
18
19
20
21
22
23
24
STRENGTH, lb
80
90
100
110
120
130

Fig.7

the strength of a kernel increased with increasing moisture content. Comparison between samples of the combined and the hand-shelled corn with small moisture content variation, showed a wide variation in load acceptance, indicating variety difference or sampling error (Figure 8).

The deformation displaced by the kernels at the cracking point during the loading test is shown in Figure 8. The values in Figure 9 show no difference in deformation between hand and combine-shelled kernels.

It was found that the deformation presented by the kernels at the cracking point could be correlated with applied static load. The effect of applied load in deformation can be seen in Figure 10. The relationship between these variables were found to be:

$$Y = 61.13 + 1344.85\ X$$

where

Y = applied load at cracking point, pounds

X = deformation at cracking point, inches.

The correlation coefficient between Y and X was 0.81.

The cracking point is the point where the kernels start indicating the first sign of failure to the applied load. This failure was shown by small or large cracks in the kernels and produced a typical sound when it happened. After that point, another zone of resistance to load is observed until total collapsing of the kernel. The cracking failure is some times easy to detect, but in some cases very difficult because of the machine characteristics and location of the kernel in relation to the plates of the loader. Indication of the crack in this work was detected by the

Fig. 8

Cracking strengths of three varieties of hand and combine shelled corn.

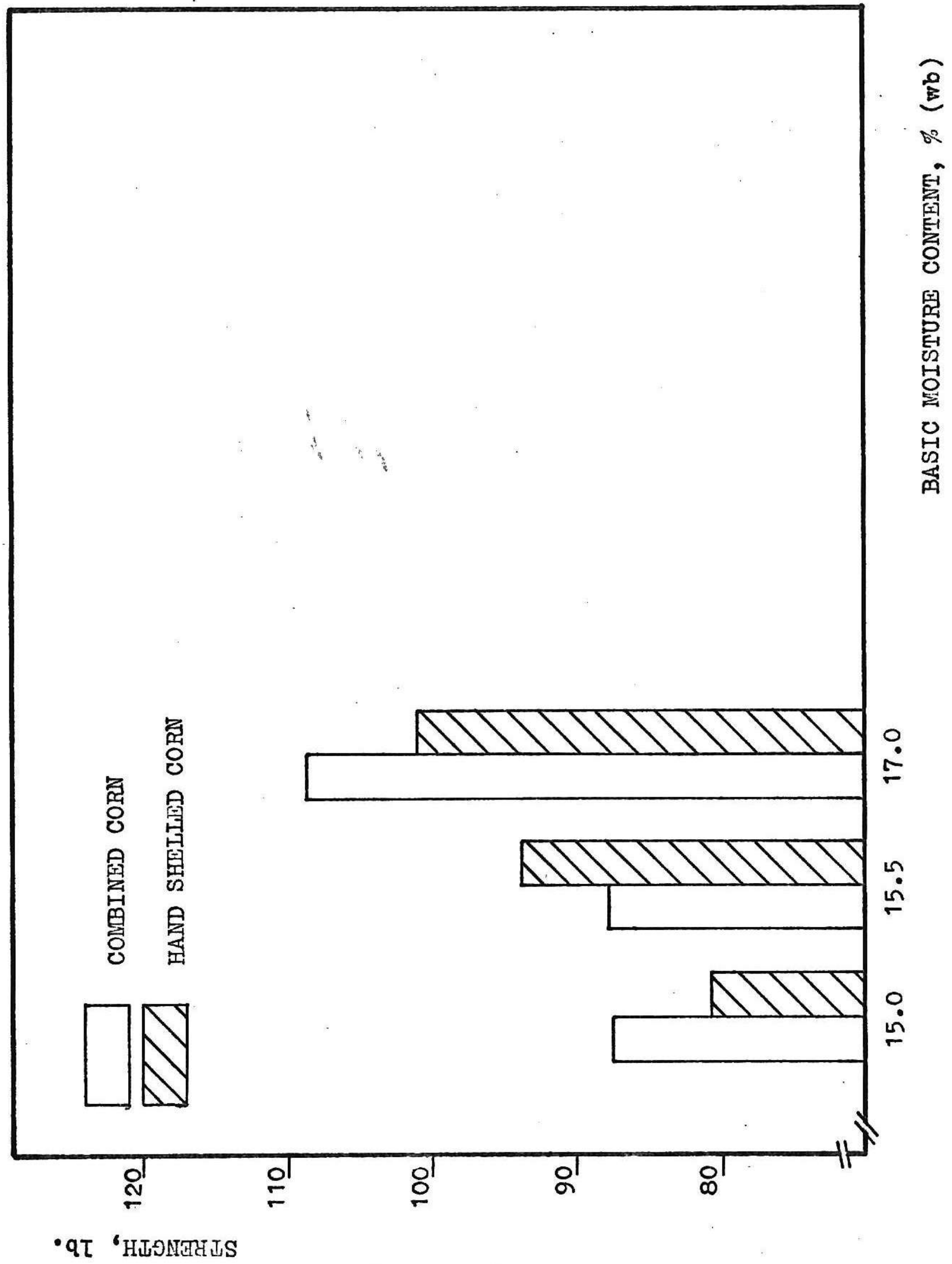

COMBINED CORN
HAND SHELLED CORN
120
110
100
90
80
15.0
15.5
17.0
STRENGTH, lb.
BASIC MOISTURE CONTENT, % (wb)

Fig.8

Fig. 9

Deformation of corn kernels at the cracking point, under static load.

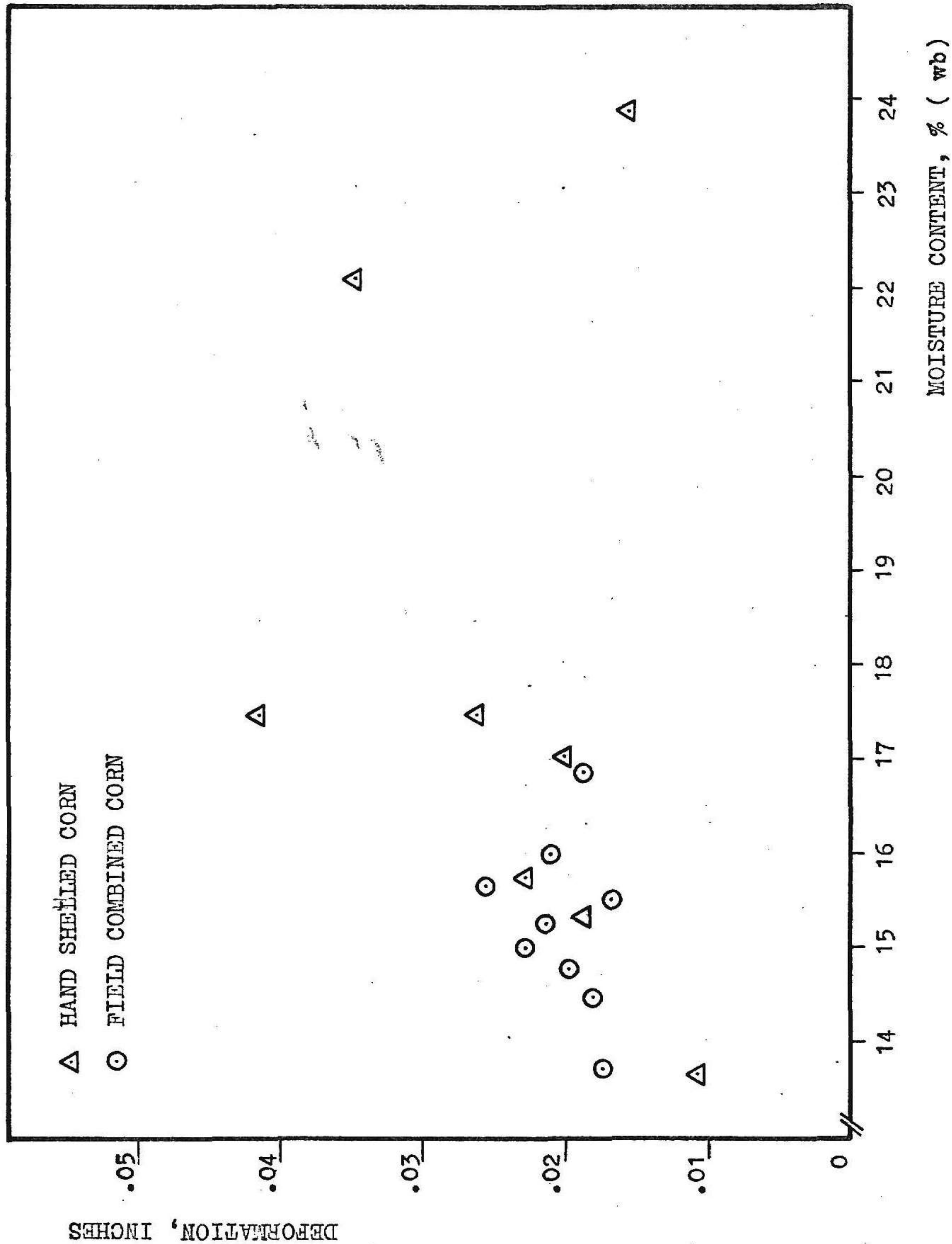

HAND SHELLED CORN
FIELD COMBINED CORN
MOISTURE CONTENT, % (wb)
14 15 16 17 18 19 20 21 22 23 24
DEFORMATION, INCHES
0 .01 .02 .03 .04 .05

Fig. 9

Fig. 10

Applied load on hand and combine shelled corn in relation to deformation, under static load.

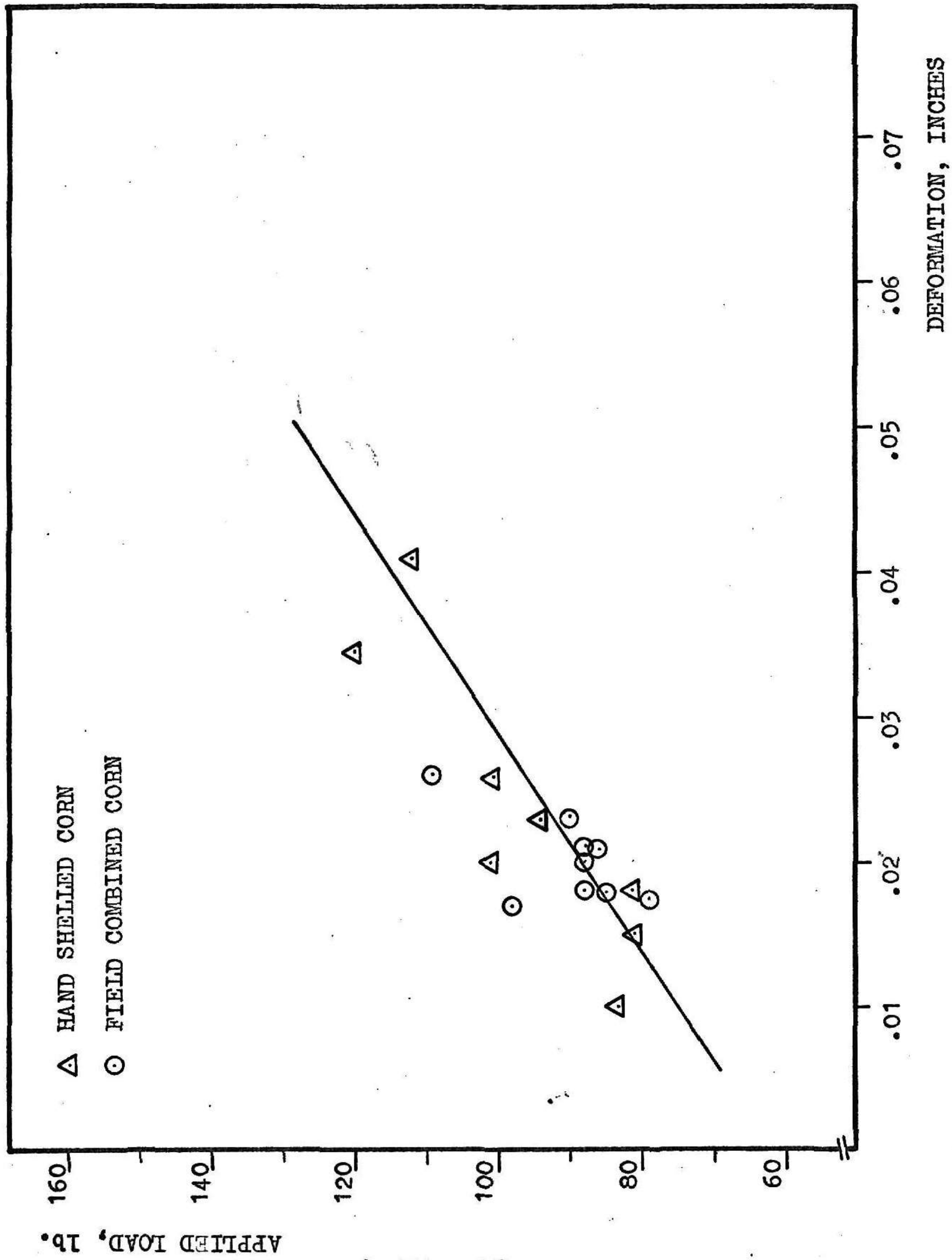

HAND SHELLED CORN
FIELD COMBINED CORN
160
140
120
100
80
60
APPLIED LOAD, lb.
.01
.02
.03
.04
.05
.06
.07
DEFORMATION, INCHES

Fig. 10

typical sound at the moment of crack. At the moisture content of nearly 22 percent or above, it was difficult or even impossible to detect the cracking point by the cited procedure. In the majority of cases, the collapsing point was reached without noticing the cracking point that should come before. The cracking sound became weak as the moisture content increased.

The use of some device for increasing the hearing capacity of the operator or electronic force deformation sensing device and recorder would make possible the detection of the cracking point at such high levels, and also increase the accuracy of the determination.

The weight per bushel test showed that test weight decreases with an increase in moisture content, and field combined corn had a lower test weight, compared with hand-shelled corn of the same moisture level. Figure 11 shows the effect of moisture content on test weight for combine shelled and hand-shelled corn for both treatments.

The increase in weight per bushel with the decrease in moisture could be explained by the change in kernel size and shape due to the loss of moisture resulting in a higher packing factor. The decrease in test weight due to combining could be explained by the increase in voids due to the broken kernels and also the increase in roughness of the kernel's cuticle that would affect the packing chracteristics of the corn.

The size distributions of the samples analyzed showed fairly uniform distribution for both combined corn and for hand-shelled corn. The general trend of this size distribution could be seen

Fig. 11

Weight per bushel of hand and combine shelled corn in relation to the moisture content.

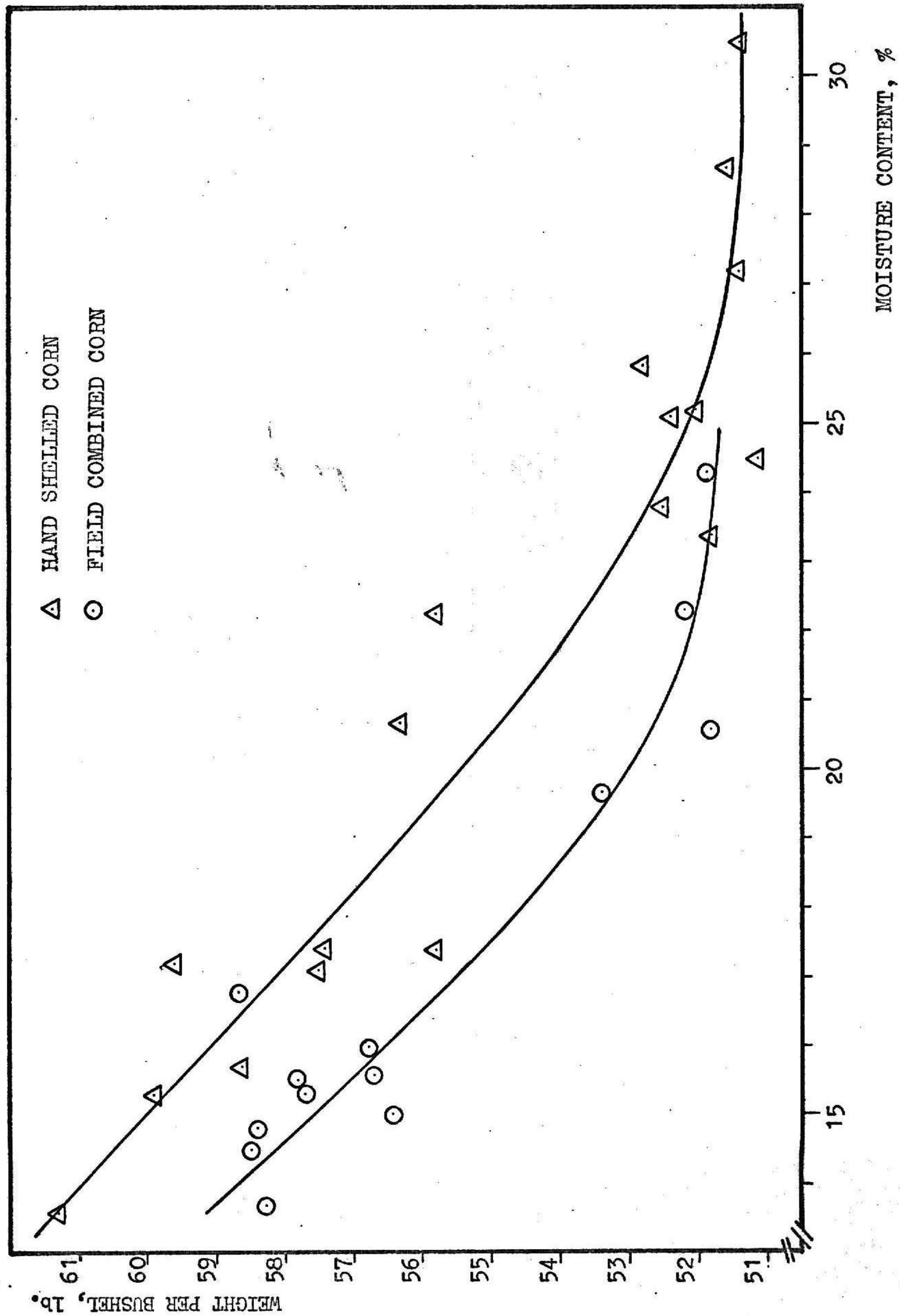

HAND SHELLED CORN
FIELD COMBINED CORN
MOISTURE CONTENT, %
15
20
25
30
WEIGHT PER BUSHEL, lb.
51
52
53
54
55
56
57
58
59
60
61

Fig. 11

in Figure 12, where the cumulative percent weight is plotted against volume of kernels according to the size classification. In this figure, seven varieties, with approximately the same level of moisture content are plotted; only one variety did not follow the general pattern. It should be mentioned that the same variety planted in a different plot had a different size distribution and followed the general trend shown. Thus, it appears that an effect of plot is more pronounced than variety difference.

Fig. 12

Cumulative size distribution for seven varieties of corn, at approximately the same level of moisture content (15 percent water content)

Fractions	Volume in cubic centimeters*
Small-small flats	0.207
Small-medium flats	0.228
Small rounds	0.229
Large-medium flats	0.261
Large-large flats	0.288
Large rounds	0.311
Extra larges	> 0.311
Fines	< 0.207

*(13)

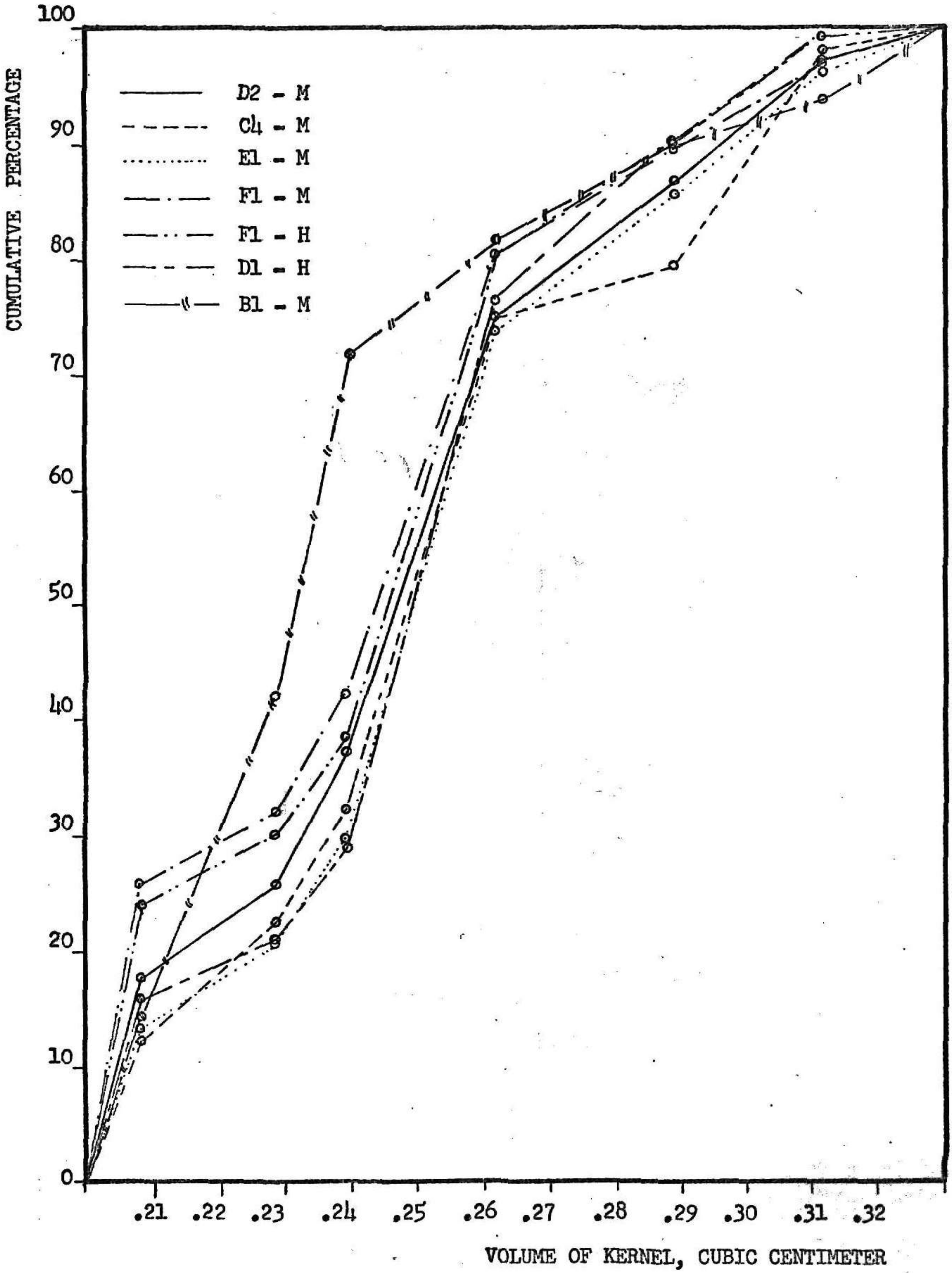

CUMULATIVE PERCENTAGE
100
90
80
70
60
50
40
30
20
10
0
D2 - M
C4 - M
E1 - M
F1 - M
F1 - H
D1 - H
B1 - M
.21
.22
.23
.24
.25
.26
.27
.28
.29
.30
.31
.32
VOLUME OF KERNEL, CUBIC CENTIMETER

Fig. 12

CONCLUSIONS

Damage in the field combined corn is dependent on moisture content, and maximum level of damage was observed at around 20 percent moisture content.

It was not possible to indicate light damage in the samples by the visual damage evaluation method. Lower values were found with a dye indicator test method.

The combined corn showed a higher susceptibility to total damage at lower moisture content than hand-shelled corn, but the broken damage level showed a small variation among samples, regardless of moisture content.

The total damage observed by the breakage test correlated with the total damage observed in the field combined corn, indicating that combine shelled corn with a high percentage of damage would be more susceptible to damage in future handling. The breakage test could also give an estimate of field damage from field combined shelled corn.

The static load test showed that the cracking strength of kernels increased with increasing moisture content, and also that deformation of the kernels at the cracking point could be correlated with applied static load.

The characterization of the cracking point by visual process or by hearing the cracking sound, proved to be not reliable for samples with moisture content of around 22 percent or above. The use of some device for increasing the hearing capability of the operator or an electronic sensing device and recorder would probably make possible the detection of the cracking point at high levels of moisture content; it also would increase the accuracy of the determination.

The weight per bushel of the corn decreased with increasing moisture content and also, field combined corn, showed a lower weight per bushel as compared with hand-shelled corn of the same moisture level.

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A STUDY OF COMBINE DAMAGE AND PROPERTIES OF YELLOW CORN AS RELATED TO DIFFERENT VARIETIES AND MOISTURE LEVELS

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AN ABSTRACT OF A MASTER'S REPORT

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requirements for the degree

MASTER OF SCIENCE

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Department of Agricultural Engineering

KANSAS STATE UNIVERSITY

Manhattan, Kansas

1969

Samples of different varieties of corn with different moisture contents were obtained from a combine and by hand harvesting from a farm near Manhattan, Kansas, during the period October 12 till November 27, 1968. Analysis of physical properties and damage was made on samples collected.

In combined corn, the damage increased as moisture content in kernels increased to around 20 percent then tended to decrease. The method used to evaluate the total damage of grains was inaccurate in evaluating minor damage in kernels when compared with the dye test; lower values for the part called "cracked fraction" were found.

The results of the susceptibility to breakage, tested by means of the breakage tester, showed that shelled corn harvested by combine had a higher susceptibility to damage than hand-shelled corn at the lower range of moisture content; the broken damage fraction in the breakage test for combined corn indicated a small variation between samples regardless of moisture content and variety.

Total damage by the breakage test showed correlation with total damage in the field-combined corn in the 14 to 24 percent moisture content range. The deformation of the kernels at the cracking point also was correlated with applied static load.

Weight per bushel decreased when moisture content increased. The size and shape distribution of kernels, tested for different varieties at approximately 15 percent moisture content, were nearly the same for the great majority of the cases.

The static load test, with flat kernels of the biggest size fraction, showed an increase in load acceptance with an increase in moisture content. The method and procedure used in the static load test were not reliable for corn at high moisture content levels.