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MEASURING THE BREAKAGE SUSCEPTIBILITY OF SOYBEANS

by

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SUMMARY:
Breakage susceptibilities of soybeans determined with a Stein breakage tester were correlated highly with those from a grain accelerator that simulates operation of a grain elevator. Breakage increased as temperature or moisture content decreased. Breakage susceptibility of 50% of 61 commercial soybean samples exceeded 12%. Breakage susceptibility of a mixture of soybeans can be calculated from the proportion and breakage susceptibilities of the components of the mixture.

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MEASURING THE BREAKAGE SUSCEPTIBILITY OF SOYBEANS[1]

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ABSTRACT

Breakage susceptibilities of soybeans determined with a Stein breakage tester were correlated highly with those from a grain accelerator that simulates operation of a grain elevator. A running time of 2 minutes will differentiate between sound and breakage-prone samples. Breakage increased as temperature or moisture content decreased. Breakage susceptibility of 50 percent of 61 commercial soybean samples exceeded 12 percent. Breakage susceptibility of a mixture of soybeans can be calculated from the proportion and breakage susceptibilities of the components of the mixture.

INTRODUCTION

The importance of soybeans in world trade in general and for U.S. balance of payments in particular is well know. Measuring and maintaining soybean quality, therefore, are of concern, and methods to measure the breakage susceptibility of soybeans during harvesting and handling should be evaluated.

Methods to measure breakage of soybeans can be classified into two groups: (a) chemical methods, which involve staining and visual inspection for seedcoat damage (Paulsen and Nave, 1977) and (b) mechanical methods, which involve impacting or grinding the grain and then measuring the cracked grain (McGinty, 1970, Cain and Holmes, 1977, and Newbery, Paulsen and Nave, 1978). The latter type of methods is preferred for its simplicity.

We undertook to determine the correlation of breakage obtained by the Stein breakage tester with that obtained by a grain accelerator (Miller et al. 1979a), a device that causes grain to be propelled against grain. A further objective was to survey the breakage susceptibility of random commercial samples that had been graded by the Federal Grain Inspection Service (FGIS).

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MATERIALS

Commercial soybeans from three sources were studied: (a) one set was from Farmland Industries, Kansas City, Mo., and Cargill, Minneapolis, Minn. (Table 1), and (b) one set of 47 inspection samples was obtained from the FGIS (Table 2).

The samples from Cargill and Farmland Industries were selected by them to cover a wide range of kernels ranging from sound to breakage-prone. Differences in breakage (Table 1) probably were due to effects of sample history, particularly drying. Differences in kernel size were not correlated with breakage, and grain is rarely segregated according to variety during commercial handling. Those factors, therefore, do not account for the differences in breakage.

METHODS

Samples were tested for breakage susceptibility in a Stein breakage tester according to the standard procedure for corn (except for sieve size) outlined by Miller et al. (1979b). After a soybean sample had been cleaned by the standard dockage procedure, a 100-g portion was run in a Stein breakage tester for 4 minutes and then sieved for 30 s on a Gamet shaker equipped with a 3.97 x 19.05 mm (10/64 x 3/4 in.) slotted, grain-dockage sieve (Grain Inspection Manual, 1978, and McGinty, 1970). The screen was oriented so that the slots were perpendicular to the sieving stroke. Percent breakage was calculated from the amount of sample passing through the sieve.

Samples were tested for breakage susceptibility in the grain accelerator (Miller et al. 1979a) after cleaning according to the procedure described above. A 200-g sample of cleaned soybeans was passed through the grain accelerator and allowed to impinge on 200 g of the same lot of cleaned kernels; sieving the resulting 400 g sample was as described in the procedure for the Stein breakage tester.

Tests with the Stein Breakage Tester

Tests were conducted to determine the effects of running time of the Stein breakage tester, soybean moisture content, and temperature on the breakage susceptibility of soybeans.

Equilibration of Soybean Samples to Given Moisture Contents

For tests to determine the effect of moisture on breakage susceptibility, soybean samples were equilibrated in enclosed containers at constant temperature over different mixtures of sulfuric acid and water according to Miller et al. (1979a). All other tests were run with samples on an "as is" moisture basis.

Determination of Moisture

Moisture in whole soybeans was determined from their weights before and after heating at 105° C for 24 hours (Newbery, Paulsen, and Nave, 1978).

RESULTS AND DISCUSSION

Breakage Results Obtained by the Grain Accelerator and a Stein Breakage Tester Compared

The breakage susceptibility of the commercial samples in Table 1 and seven composite samples with comparable breakage susceptibility were studied. The composites were prepared from several samples shown in Table 2. The results obtained with the grain accelerator correlated highly (r=0.93, 16 d.f.) with those obtained with a CK2 Stein breakage tester, which was run for 4 min (Fig. 1). All results represent the average of triplicate analyses. The Stein breakage tester caused about twice the breakage the grain accelerator did, and thereby accentuated differences among samples.

Effects of Running Time

The effects of Stein breakage tester running time are shown in Figure 2 for sound and breakage-prone soybeans. Although all other results we report are for a 4-minute running time, a running time of 2 minutes did differentiate between sound and breakage-prone samples.

Effects of Moisture Content

The effects of moisture content on sound and breakage-prone soybeans (Fig. 3) are similar to those for sound and breakage-prone corn (Miller et al. 1979b). Breakage increased as moisture decreased. The results corroborate those of McGinty (1970) and Foster and Holman (1973).

If moisture effects are to be eliminated, all samples must be equilibrated to a common moisture content, but that requires a long time with soybeans. We believe that breakage susceptibility of soybeans in commercial channels should be measured at their moisture content at the time of sampling, because susceptibility to breakage with actual moisture is much more important than susceptibility at an arbitrarily selected moisture. If information on the inherent genetic differences in susceptibility to breakage is desired, for example by plant breeders, the effects of various moisture contents would have to be considered and comparisons made for samples at the same moisture.

Effects of Temperature

The effects of temperature on breakage of sound and breakage-prone soybeans (Fig. 4) were similar to those reported for corn but were less pronounced (Miller et al. 1979b). Breakage increased as temperature decreased. The results corroborate those of Foster and Holman (1973).

Breakage of Mixtures of Sound and Breakage-Prone Soybeans

The data in Figure 5 show the breakage of mixtures of two soybean samples differing widely in susceptibility to breakage. The breakages of the mixtures could be calculated from both the proportion and breakage susceptibilities of the components in the mixtures. An analysis of variance (table 3) was run for the data in Figure 5. There was a highly significant linear relationship ($p<0.0001$) for the data and no evidence of lack of fit.

Reproducibility of Results

Ten replicate subsamples of sound and breakage-prone soybeans from samples 1 and 8 (table 1) were analyzed in one working day; and the data (table 4) showed good reproducibility. The standard deviation was 0.38 for sound sample and 2.1 for the breakage-prone sample. The standard deviation gradually increased as breakage increased from 4 to 20% (data not shown).

Breakage and Grading of Commercial Soybean Samples

Grade data and breakage percentages for 47 soybean samples obtained from the FGIS during their normal work are recorded in Table 2. The distribution according to breakage of those 47 samples and 14 other samples received from Farmland Industries and Cargill is shown in Figure 6. Breakage in 50 percent of the samples exceeded 12 percent.

Official grading (table 2) does not indicate susceptibility to breakage; it only indicates the amount of breakage already present in the sample. If susceptibility to breakage is important to a purchaser of soybeans, an objective method to measure the susceptibility to breakage would be useful.

ACKNOWLEDGMENTS

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LIST OF FIGURES

Table 1. Summary of grading, kernel weight, and Stein breakage tester data for commercial soybean samples from Farmland Industries and Cargill

Sample No.	Moisture percent	Splits* percent	Damaged kernels Total percent	Damaged kernels Heat percent	Foreign material percent	US† grade number	1000 kernel weight g	Breakage percent
1	10.9	7.0			0.4	1	---	2.3
2	10.7	2.0	3.0	0.1	0.4	2	178	17.7
3	11.2	3.0	3.2		0.9	3	152	17.7
4	10.4	10.0			1.0	1	175	18.9
5	10.6	3.0	2.6		0.6	2	150	19.3
6	9.2	19.0			20.4	SG[ϕ]	171	25.0
7	11.6	11.0	0.1		2.5	3	148	27.7
8	11.2	11.0	0.4	0.1	2.8	3	166	31.7
9	10.2	15.0	0.4		2.9	3	146	37.9

*Halves of soybeans not damaged.
†Official United States Standards for Grain (1978).
ϕSample grade.

Table 2. Summary of grading data supplied for 47 soybean inspection samples obtained from the Federal Grain Inspection Service and breakage measured with a Model CK2 Stein breakage tester

Moisture	Splits*	Damaged kernels		Foreign material	US† Grade	Breakage	Moisture	Splits*	Damaged kernels		Foreign material	US† Grade	Breakage
		Total	Heat						Total	Heat			
Percent	Percent	Percent	Percent	Percent	Number	Percent	Percent	Percent	Percent	Percent	Percent	Number	Percent
10.3	3.0	0.1		1.5	2	2.5	12.2	11.0	0.6			2	11.1
11.8	8.0	0.7		5.9	SG	3.5	9.1	8.0	0.8			2	11.5
9.3	8.3	0.5			1	4.4	11.0	9.0			0.5	1	11.5
12.2	7.0	0.2		4.6	4	4.5	11.2	6.0	2.1	0.7	0.6	3	11.6
10.1	7.0	0.8			2	5.1	11.9	11.5	0.6		2.8	3	11.7
9.6	7.0	0.8			2	5.6	11.0	10.0	0.5			1	11.8
9.4	4.0	2.1			2	5.6	12.4	11.0	1.6	0.4	2.9	2	12.1
10.6	8.0	0.8			2	5.8	10.6	12.0	0.1		5.0	4	12.4
9.2	6.0	0.7			2	6.0	12.0	11.0	0.6			2	12.6
11.3	9.0	<1.0		2.5	3	6.1	11.6	6.3	2.3	0.6	1.0	3	13.0
11.7	6.0	1.4		5.2	SG	6.1	11.1	9.0	0.7			3	13.1
9.4	7.0	0.9			2	6.4	12.1	11.0	0.9			2	14.1
13.5		1.2		1.2	3	6.7	12.3	13.0	0.3			2	14.8
11.3	6.6	1.7		4.3	4	7.0	12.3	9.0	0.8			1	15.2
9.7	7.0	0.9			1	8.4	11.5	6.0	0.5	0.1		2	15.4
8.6	6.0	2.0	0.07	1.4	2	8.5	9.8	15.0	0.9	2.0		2	16.1
10.7	9.0	0.4			2	8.8	11.1	16.0	0.6		0.5	2	16.8
12.5	10.0	0.5			2	9.1	12.1	12.0	0.6			2	17.1
9.8	9.0	0.9			1	9.2	10.8	13.0	0.3		3.6	4	18.0
12.6	4.0	0.1		0.7	1	9.9	10.0	6.0			13.2	2	18.5
12.2	10.0	0.5		2.6	3	10.1	12.5	15.0	0.2		1.8	2	19.2
11.2	8.0	0.4		1.3	2	10.5	11.8	13.0	0.9	1.2		2	19.7
12.2	8.0	2.0	0.8		SG	10.5	10.5	19.0	0.2		0.4	2	36.5
10.0	10.0	0.6		1.2	2	10.9							

*Halves of soybeans not damaged.
†Official United States Standards for Grain (1978).

Table 3. Analysis of variance of the data in Figure 5

Source of variation	Degrees of freedom	Mean squares	F values
Linear	1	773.18	95.73*
Lack of fit	3	3.56	0.44
Residual	10	8.08	
Total	14		

*p<0.0001

Table 4. Breakage of two soybean samples measured with a Model CK2 Stein breakage tester by one operator

	Breakage	
	Sound sample	Breakage-prone sample
	Percent	Percent
	2.9	30.6
	2.8	28.4
	2.0	29.3
	2.6	33.6
	1.8	30.9
	2.3	35.3
	2.2	30.4
	2.0	32.4
	1.9	32.7
	2.1	32.0
Mean	2.3	31.6
Standard deviation	0.4	2.1

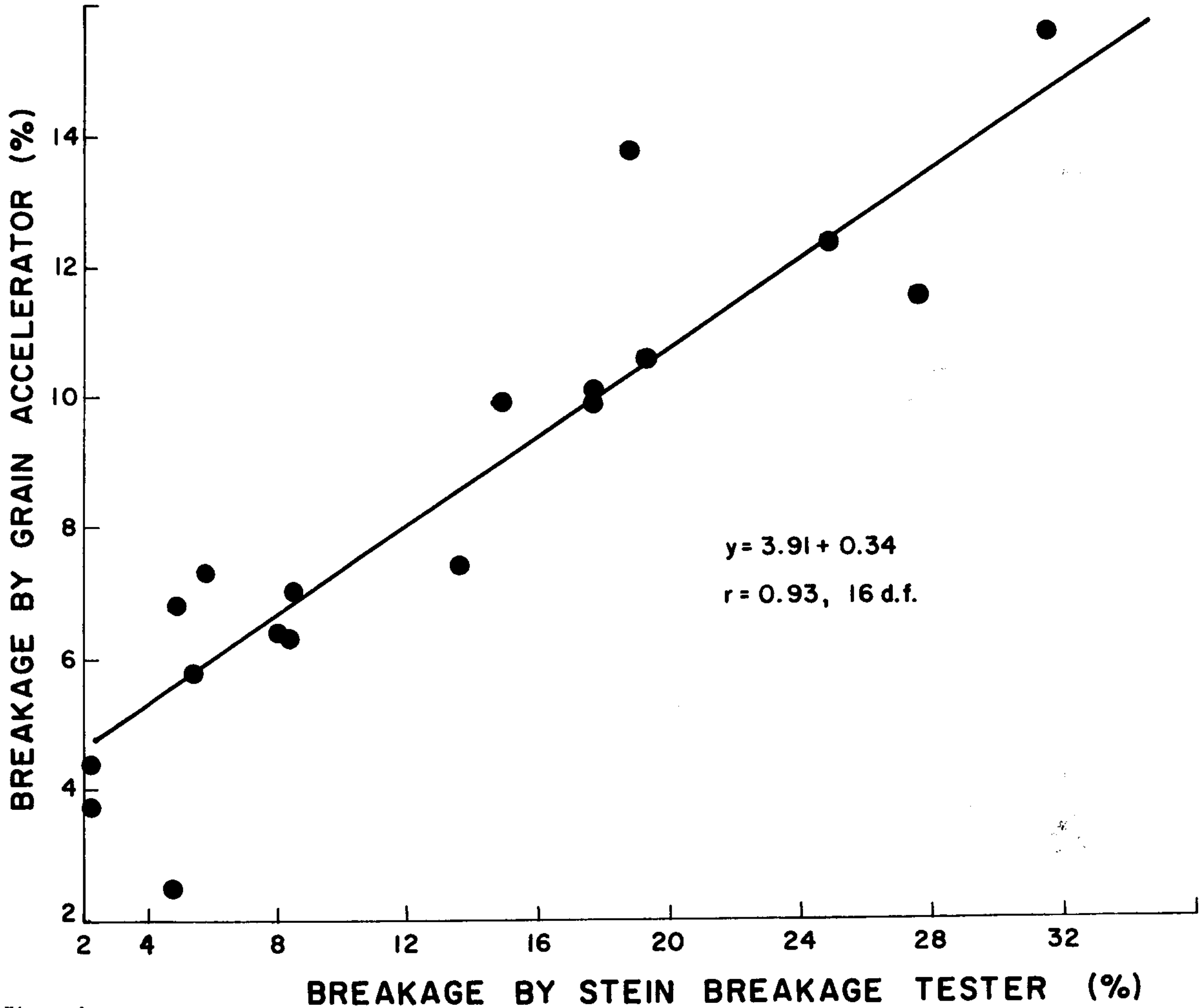
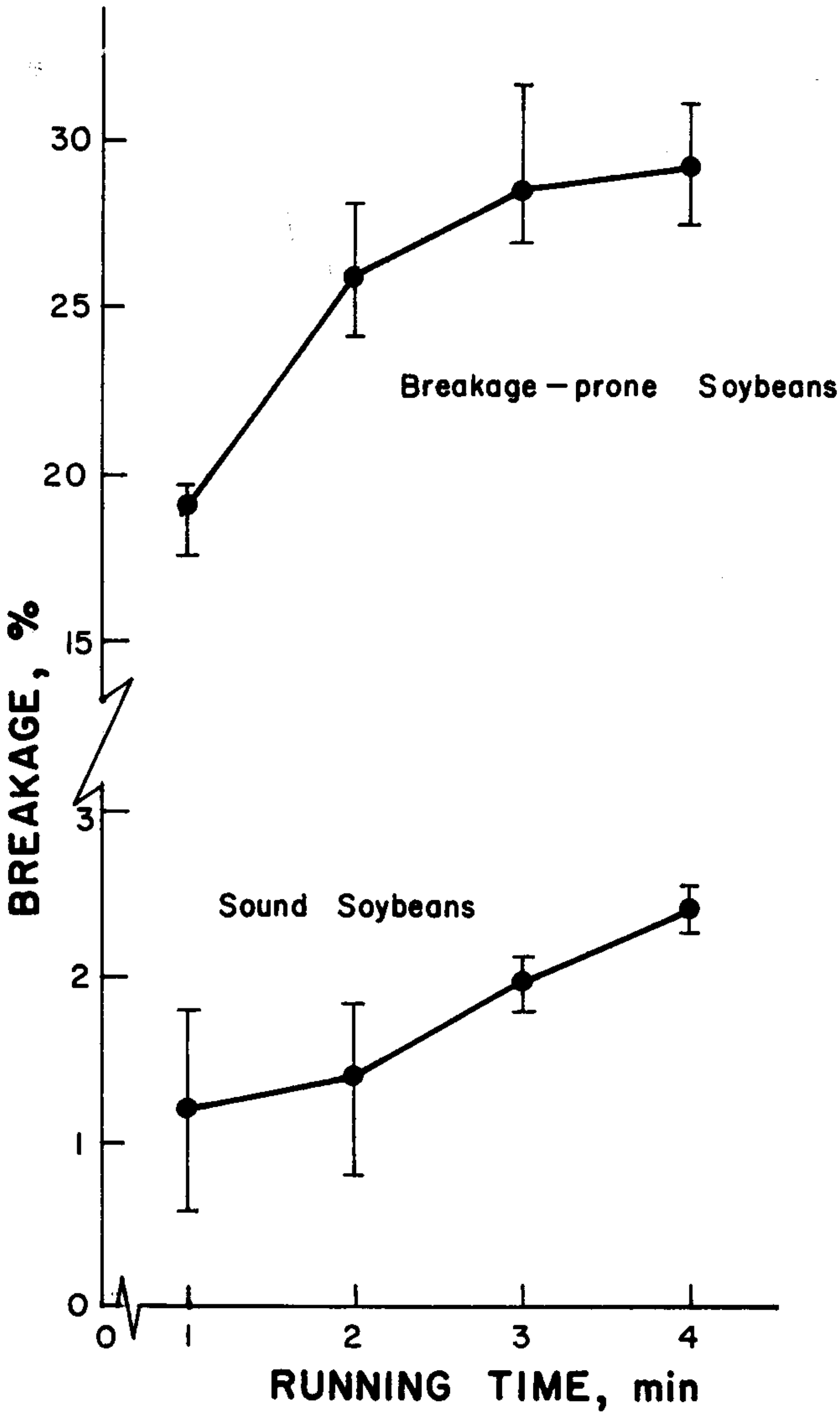

BREAKAGE BY GRAIN ACCELERATOR (%)
2
4
6
8
10
12
14
2
4
8
12
16
20
24
28
32
BREAKAGE BY STEIN BREAKAGE TESTER (%)
y = 3.91 + 0.34
r = 0.93, 16 d.f.

Figure 1



30
25
20
15
3
2
1
0
Breakage — prone Soybeans
Sound Soybeans
BREAKAGE, %
0
1
2
3
4
RUNNING TIME, min

FIGURE 2

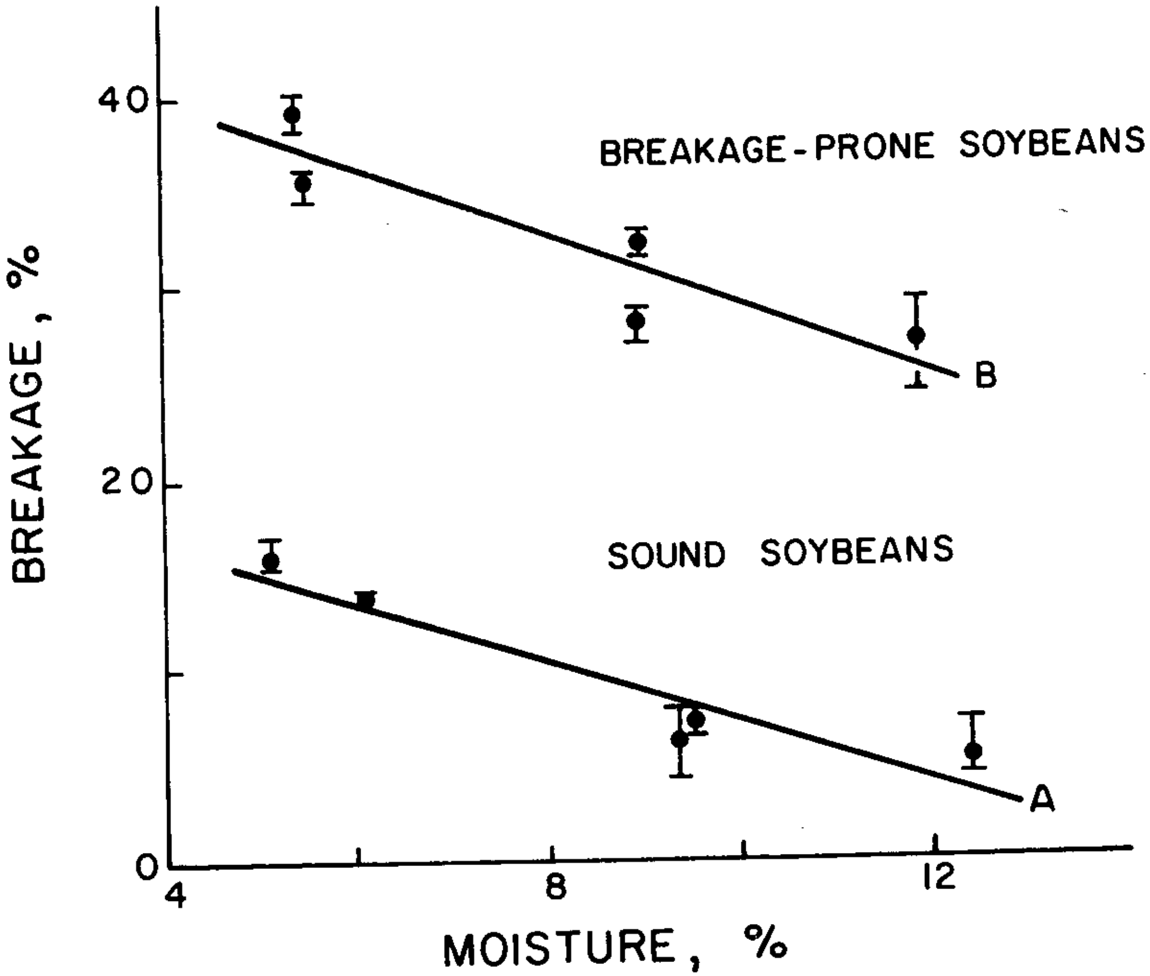
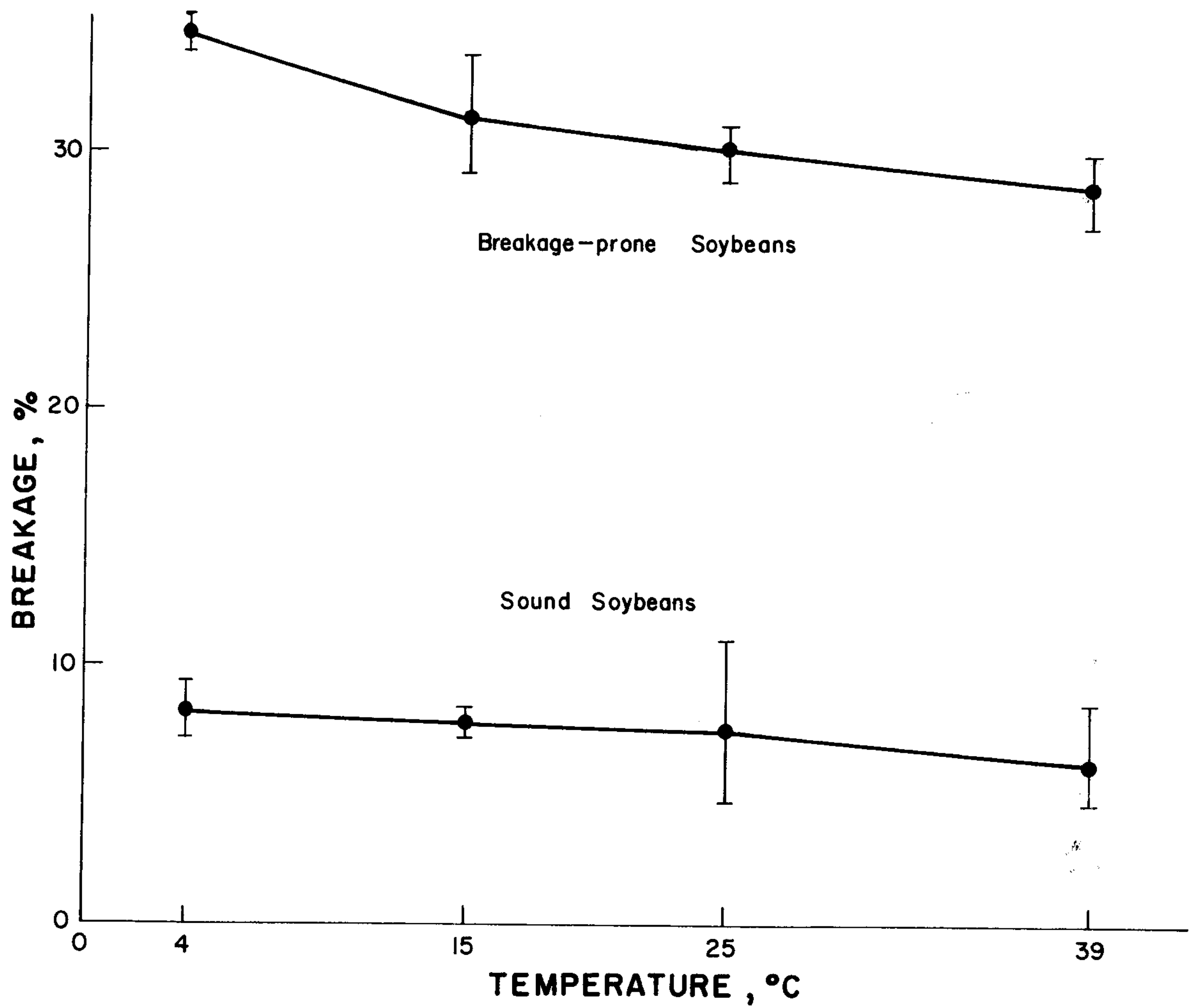
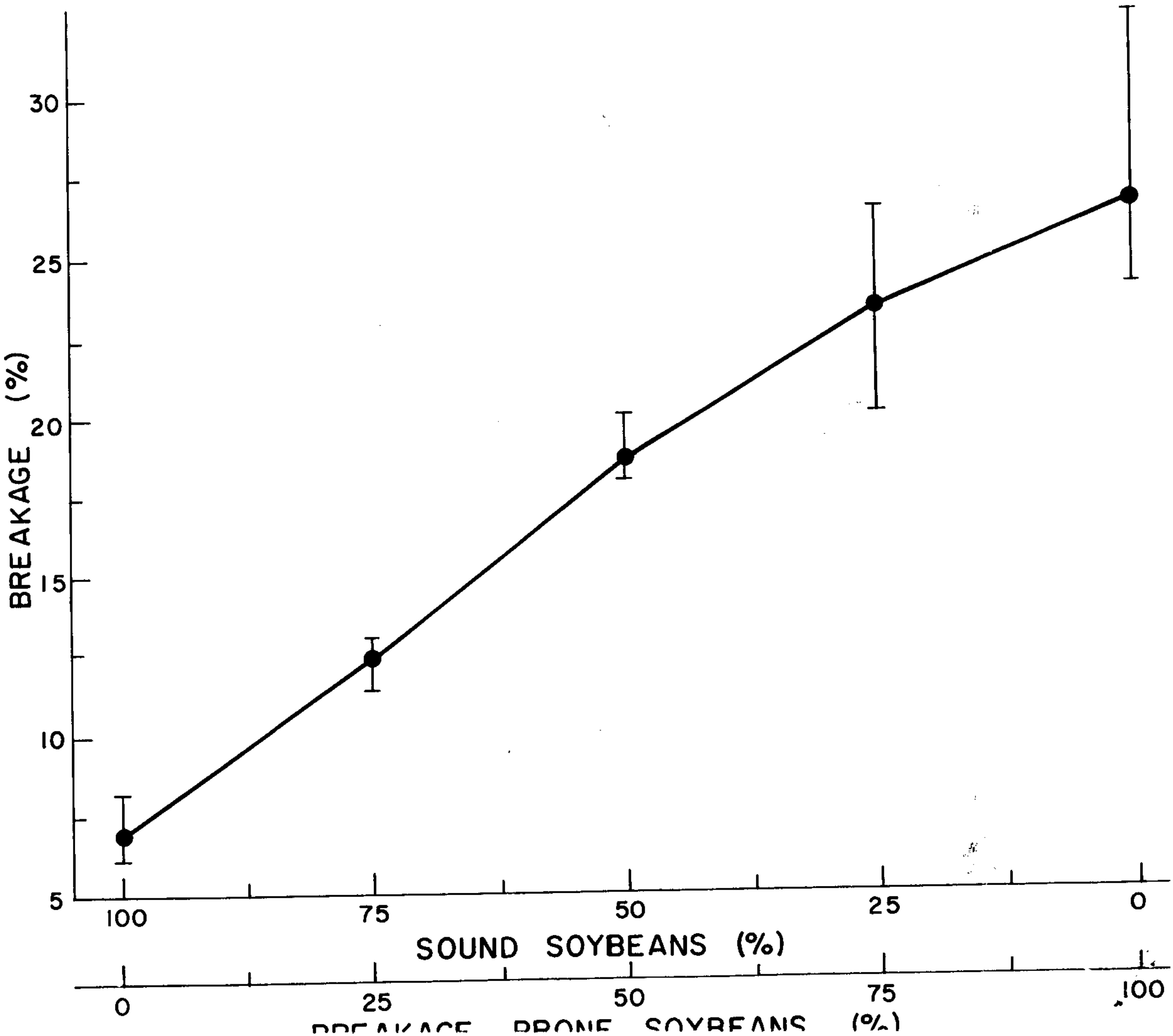

BREAKAGE-PRONE SOYBEANS
SOUND SOYBEANS
B
A
40
20
0
4
8
12
BREAKAGE, %
MOISTURE, %

Figure 3


Breakage-prone Soybeans
Sound Soybeans
BREAKAGE, %
30
20
10
0
0
4
15
25
39
TEMPERATURE, °C


BREAKAGE (%)
30
25
20
15
10
5
100
75
50
25
0
SOUND SOYBEANS (%)
0
25
50
75
100