PHYSICAL DAMAGE To SWEET CORN SEED

Caused by Mechanical Harvesting and Subsequent Processing

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Physical Damage to Sweet Corn Seed Caused by Mechanical Harvesting and Subsequent Processing

By W. A. Huelsen and W. N. Brown[a]

During the past few years seedsmen who produce peas, beans, and sweet corn have become increasingly concerned because of the wide discrepancy existing between laboratory germination tests and field stands. Some seedsmen have installed equipment for making "cold-test" germinations, which presumably give a more accurate index of field performance than standard laboratory germination tests. The low germination rating of their seed in cold tests has brought the more progressive seedsmen to the realization that remedial steps have to be taken.

The need for information regarding the damage caused by mechanical harvesting of sweet corn seed became particularly acute during the 1942-1945 war period. About 85 percent of the total sweet corn seed is produced in the Boise and Snake River Valleys of Idaho. Until 1942 labor was cheap and relatively plentiful in that area, and sweet corn was harvested by hand. Beginning in 1942 the mechanical corn picker came into use for harvesting midseason and late-maturing varieties. Combines were generally used to harvest the earlier maturing types. The choice of machines depended upon the moisture content of the corn at harvest, 25 percent being about the highest moisture content suitable for combining. The cold-test germinations of many mechanically harvested lots were unsatisfactory, and wide variations were noted in the yields secured from different seed lots of genetically identical hybrids. Only a superficial examination of the seed was needed to establish the fact that the low-yielding seed lots frequently were those that had been the most seriously damaged. Since all but the earliest maturing varieties are dried artificially either on the ear or as shelled corn, this phase of the problem was investigated first, especially as several Idaho driers were known to be inefficient. It was soon apparent that the question of physiological damage due to drying required separate investigation.

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The project for studying the effects of physical damage to sweet corn was first undertaken in 1946 and continued in 1947. Since the project would require the handling of large quantities of seed corn harvested and milled with standard machinery, a cooperative agreement was made with several seedsmen. Crookham Company, Caldwell, Idaho, made extensive samplings according to a plan outlined in advance, and the company contributed a total of 138 samples of seed along with pertinent information. A lesser amount of cooperative work was done with the California Packing Corporation, Rochelle, Illinois; Green Giant Company, Le Sueur, Minnesota; and F. H. Woodruff & Sons, Milford, Connecticut, which at the time operated a growing station in Clinton, Illinois.[a]

Relation Between Physical Seed Damage and Yields

The Illinois Station released the first sweet corn hybrids to the seed trade in 1935. Releases have always been made under cooperative agreements entailing a certain amount of supervision. Part of the cooperative program consists of testing the inbreds used for producing the commercial hybrids and subjecting the hybrids to replicated field trials. Wide yield variations between lots furnished by different seedsmen were noted each year. Since genetic differences were not involved, other factors must have been responsible.

No investigation of physical damage in relation to the productivity of sweet corn seed was undertaken until the start of the present project. Three lots of seed of Illinois hybrid 14 × 11 were submitted by three different seedsmen in 1946 and four lots in 1949. The field tests were conducted in 1947, a highly unfavorable season, and in 1950, a very favorable year. All seven lots were coated with a seed protectant before planting.

A close relation was found to exist between the field yields and the percent of seeds showing severe damage, but this relationship did not extend to the total damaged (Table 1). Under the unfavorable growing conditions in 1947 (a cold wet spring followed by intense heat and drouth), missing hills and yields varied in relation to the percentage of kernels severely damaged. The yield differences would

[a] The following companies cooperated in the work recorded in the following tables: Tables 2 through 11 and Table 16, Crookham Company, Caldwell, Idaho; Table 12, Green Giant Company, Le Sueur, Minnesota; Table 13, F. H. Woodruff & Sons, formerly of Clinton, Illinois; Table 15, California Packing Corporation, Rochelle, Illinois.

Table 1. — Relation Between Damage to Pericarp and Field Yields of Seven Lots of Seed of Illinois Hybrid 14 × 11 the Following Year

(Each value is an average of five replications. All yields are corrected to the basis of a full stand.)

Year seed was produced, and seedsman	External damage				Missing hills	Weight per prime husked ear	Yield of prime cut corn	
	None	Slight	Severe	Total damaged			Per acre	Percent of check[a]
1946	*perct.*	*perct.*	*perct.*	*perct.*	*perct.*	*lb.*	*tons*	
A	2	30	68	98	2	.606	1.7	116.2
B	7	8	85	93	10	.584	1.3	91.6
C	0	7	93	100	17	.548	1.0	76.1
1949								
A	7	31	62	93	2	.542	2.0	110.6
B (check)	2	32	66	98	0	.484	1.8	100.0
C	2	22	76	98	1	.484	1.7	96.5
D	0	2	98	100	1	.456	1.4	77.4

[a] Hybrid 14 × 13 (data not shown) was used as the check in 1946. In 1949, Hybrid 14 × 11 supplied by Seedsman B was used as the check.

be greatly increased by omitting the correction for missing hills. The formula used was as follows:

$$\frac{\text{Number of hills planted}}{\text{Number of hills surviving}} \times \text{Actual yield} = \text{Corrected yield}$$

In 1950, a favorable season, the stands of all lots were good in spite of a high percentage of severely damaged seeds, but the yields also varied in the same manner as in 1947.

Review of Literature

No information is available on the relation between pericarp damage, germination, yields, etc., in sweet corn, but a number of investigations have been made and published concerning the effect of various types of mutilations and injuries to field corn seed. Since sweet corn seed has a much more angular and irregular shape than field corn and the endosperm is far more brittle and fragile, it may be assumed that sweet corn is damaged much more easily than the various types of field corn.

Garner,[5] Culpepper and Magoon,[4] Bakke and Erwin,[2] and Sprague[12] noted that sweet corn seed has a much higher water-absorbing capacity than other types of corn owing to the composition of the endosperm. Halsted and Waksman[7] crossed popcorn and dent corn with sweet corn and separated the kernels of the F_2 generation into their respective starchy and sugary endosperm types. Each type was then further classified as to size of seed. The starchy-endosperm types germinated 30 percent better than the sugary types, and the seedlings were heavier and taller. The days to emergence were the same. From these investigations it may be concluded that while sweet corn seed takes up moisture more rapidly and in greater amount than corn with a starchy endosperm, seedling emergence is not more rapid, germination is poorer, and early growth weaker. Thus sweet corn is weaker than starchy corn, and it is reasonable to postulate that physical injuries to sweet corn seed will also have a more serious inhibitive effect on germination and seedling vigor.

Leaching of total soluble solids and colloidal materials from sweet corn seed physiologically but not physically injured was observed by Hottes and Huelsen.[9] Gopalkrishna[6] leached sweet corn seed in distilled water after injuring it physiologically with heat and physically by puncturing the pericarp. He found a close correlation between the quantity of reducing substances leached from the seed and the vigor of the seedlings grown in the greenhouse after being subjected to a cold test.

Considerable work has been done on artificial injuries to field corn seed, but in most cases the damage was different and more extensive than that which appears in commercial lots of seed. In one such experiment Myers[10] found that injuries to dent corn seed reduce the stand where the soil conditions are favorable for the growth of spores, and that an undamaged pericarp is valuable as a protection against molds.

Wortman and Rinke[15] compared two dent corn hybrids with respect to their susceptibility to pericarp injury during harvesting and processing. Although harvested and processed in substantially the same manner, one hybrid was damaged much more severely than the other during the initial machine picking, husking, and drying. Since the two hybrids differed materially in their kernel characters, Wortman and Rinke concluded that one was more susceptible to physical injury than the other, but assigned no reason.

Brown[3] observed that the seed samples showing the most severe damage frequently had blistered pericarps. He defined blisters as irregular areas of variable size where the pericarp had loosened, leaving an air pocket. Blisters were found both over the endosperm and over the scutellum. The blisters are extremely fragile and even gentle handling will shatter them, leaving areas of endosperm or scutellum exposed. The largest blisters were usually located on the abgerminal surface of the endosperm. In a given seed lot, kernels blistered on both germinal and abgerminal surfaces were usually large and plump, while those showing no blisters were much smaller. Kernels blistered only over the scutellum were intermediate in size.

Brown compared seed lots in which the blisters were intact with those in which the blisters had been broken with a dissecting needle that did not, however, injure the underlying tissue. In those samples with broken blisters the reductions in germination, seedling height, and seedling green weight were large and all highly significant. Brown also compared seed lots having blisters over only the scutellum with lots having them over both the germinal and abgerminal surfaces. When the blisters were not broken, results of the germination tests were practically the same, but when the blisters were broken the samples having them on both surfaces gave a reduction in germination that was again highly significant.

Tatum and Zuber[14] checked the relation between the percent of field corn kernels with damaged pericarp over the embryo and their cold-test germinations. The correlation coefficient was −0.81. The cold test consisted of planting the seeds in a wet, unsterilized field soil and holding it at 45° F. for seven days. At this temperature the seeds lie dormant, thus approximating field conditions during a cold wet spring. After seven days, germination was completed at a higher temperature.

Wortman and Rinke[15] followed a different procedure in cold testing. Their flats were first held at 78° F. for 48 hours, presumably to permit germination to start, and were then transferred to a cold chamber held at 48° F., where they were held for either 6 days or for 12 days. Significant correlations between physical injuries and both cold-test germinations were observed in nearly all cases, the correlations of the greatest magnitude usually being between germination and damage over the embryo. One of the hybrids showed closer association between injury and germination in the 6-day test; the other showed closer association in the 12-day test.

The cold test has been the subject of considerable discussion as it would be a useful tool for seedsmen if standardization were possible. The variables in this test are (1) the holding temperature, (2) its duration, (3) the field soil, (4) the sprouting temperature and (5) the method of reading germination. Haskell[8] compared the effectiveness of holding sweet corn seed planted in field soils at temperatures of 40° and 50° F. for various periods. Increasing the length of the holding period reduced germination, the reduction being greater at 50° than at 40°. Haskell concluded that the loss of germinability was due partly to direct damage to the seed by the low temperature and partly to soil pathogens that attack the weakened seed sprout. Since the activity of soil organisms is greatly reduced at 40°, this temperature would give a more reliable index to cold injury, but Haskell considered 50°

more suitable as the seed would be subject to a combination of cold and attack by soil organisms. Porter[11] cold-tested sweet corn seed in field soils infested with *Pythium debaryanum* Hesse and *P. graminicola* Subr. at 10° C. (50° F.) for seven days and transferred the flats to a temperature of 26° to 28° C. (79°-82° F.). The germinations thus obtained were correlated with field stands, giving a coefficient of 0.655. Porter therefore considered his cold test an excellent index of emergence in the field. The general practice at the present time is to plant the corn in soil taken from a cornfield, water the flats thoroughly, permit the surplus water to drain, and then hold the flats without further watering at 45° to 50° F. for seven days. The flats are then removed to a greenhouse or to a special germinating chamber held at temperatures varying from 70° to 90° F.

The greatest source of error in cold-testing is in the use of field soils. These are usually modified by the addition of washed building sand to prevent packing and cracking. Porter[11] used 2 parts of sand to 1 part of field soil. Practically all field soils are contaminated with various organisms, the most common being species of *Pythium* and molds such as *Penicillium*. No two soils, of course, contain the same types and populations of organisms. Some workers have proposed standardizing the cold test by sterilizing the soil and then adding artificial cultures of several organisms. The merits of this procedure still remain to be tested.

Experimental Materials

The samples taken in the field and at different points during processing ranged in size from 2 to 10 pounds and pains were taken to make them representative, as the lots were very large, running into thousands of pounds. From these samples 100 kernels were taken for counts of physical damage. An additional 100-kernel sample was removed for germination.

Crookham Company collected 45 samples of seed from the 1946 crop. These were produced by 12 growers in Idaho. The 45 samples consisted of the following: 2 of Illinois Hybrid No. 10 (101q × 73c); 40 of Golden Cross Bantam (P39 × P51); and 3 of Ioana (P39 × I45). Thus all but two samples had P39 as the seed parent and for this reason they are comparable. In 1947 Crookham Company collected 93 samples produced by 16 growers. Thirteen samples, all from the same grower, were of the Lincoln variety (P39 × C23); 19 samples, from four growers, were of the Ioana variety (P39 × I45); and 57 samples, produced by 11 growers, consisted of Golden Cross

Bantam (P39 × P51). Four additional samples consisted of a warehouse lot of Golden Cross Bantam. Thus all of the samples from the 1947 crop had P39 as the seed parent.

The three other cooperators sent in samples of seed from the 1946 crop as follows: Green Giant Company, 11; F. H. Woodruff & Sons, 5; and California Packing Corporation, 6. Each of these three cooperators furnished samples from single lots of seed. The method they used in collecting the samples is discussed later.

The sampling technique followed by Crookham Company was more complex than that followed by the other cooperators. Field sampling was emphasized in 1946 and seed-house sampling in 1947. The principal objectives in collecting the 1946 samples were to determine the damage inflicted by corn pickers, combines, and corn shellers. As each field was harvested, samples were taken directly from the stalk by the fieldman. These samples were placed in mesh bags and dried in the drier and shelled by hand. Such samples were classed as controls. Additional controls were taken in certain instances as, for example, when machine-shelling and hand-shelling were compared. No information can be given as to the type of corn picker or combine used, because each grower used and operated his own machine. This accounts also for some of the differences between lots of seed. The sampling schedule used by Crookham Company in 1946 follows:

A. Where entire field was hand-harvested or machine-harvested
   1. Control was hand-harvested separately, ears were put in mesh sacks, dried, and hand-shelled.
   2. Green ears were sorted or not as indicated, dried, and hand-shelled.
   3. Green ears were sorted, dried, and machine-shelled.
   4. Green ears were sorted, dried, machine-shelled, milled, gravity-separated, and hand-picked.

B. Where entire field was combined
   1. Control was taken and handled as under A.
   2. Sample was taken before shell-drying, placed in a mesh sack, then shell-dried separately if necessary.
   3. Bulk corn was shell-dried if necessary, milled, gravity-separated, hand-picked, and then sampled.

All controls which were removed prior to milling were screened by hand, the same size of screen being used as in the milling machine.

The sampling schedule that Crookham Company followed after the shelling stage in 1947 is outlined below. The procedure was the same as in 1946 except that samples were taken after more of the steps in processing. The terms used for the steps are explained in the outline on the following page.

1. "Before milling." Sample was taken at the discharge end of a bag elevator on the third floor of the warehouse just before dumping into a hopper.
2. "After milling." Sample was removed at the discharge spout of the fanning mill.
3. "After gravity separation." Sample had been milled and was removed from the discharge spout of the separator.
4. "After elevating." Samples were taken from the discharge spout of the bagging hopper. (Corn from the gravity separator is discharged to a bucket elevator which conveys it to the bagging hopper.)
5. "Before hand-picking." Samples were removed before corn was dumped into the hopper which supplies the hand-picking room. (The bagged corn mentioned under 4 was elevated to the third floor of the warehouse before being dumped into the hopper.)
6. "Hand-picked." Samples were hand-picked and inspected at individual sorting tables equipped with a small conveyor belt. (Hand-picked corn is the finished commercial product.)

In the above outlines terms have been used which are generally accepted in the seed trade, but some of them are a trifle confusing. "Hand-harvesting" refers to the operation of harvesting and removing the husks from sweet corn in the field and should not be confused with "hand-picked," which is the final operation in the mill before seed corn is shipped and refers to removal of discolored, broken, and other substandard kernels as they travel over a moving belt.

Other terms used throughout this publication may need some explanation. "Hand-sorting," for example, is confined to inspection of the ears either as they are received at the plant or after drying. In the first instance the term "green-corn sorting" is used and in the latter "dry-corn sorting."

"Processing" and "milling" are rather loose terms often used interchangeably. However, "processing" should include whatever artificial drying has been necessary as well as the remaining warehouse operations, and in this publication it is used in that sense. The term "milling" is used in its specific sense, namely, running the corn through the fanning mill. Thus the term "before milling" means that each step in processing has been taken up to the fanning mill. The term "after milling" means that each step in processing has been taken up to and through the fanning mill.

Classification of Seed Damage

All lots of seed submitted by Crookham Company were classified for physical damage by a competent person in the employ of the company, on the basis of 100-kernel samples. Many of the lots were checked again when they were received in Urbana. Crookham Company made their classifications with a 7x hand lens, but at Urbana all examinations were made under the 10x binocular microscope. The 1946 crop was examined without staining, but a portion of the 1947 crop was stained in Belling's iron aceto-carmine solution for 30 seconds and then washed with water. The use of a stain greatly facilitates examination. The authors have also used a 2-percent aqueous solution of fast green for 30 to 60 seconds followed by washing. One seedsman uses Lugol's solution which consists of 5 percent of iodine dissolved in a 10-percent aqueous solution of potassium iodide. This is a starch stain and stains only the endosperm exposed by injuries to the pericarp. The seeds stain in 30 seconds and are then washed.

The detection of damaged seeds is not difficult, but classification as to location and severity will vary with the individual. A detailed outline of damage may be made. One which was used in part of this work is given below, but for practical purposes a simpler classification would be better.

A. Pericarp damage over the embryo region
   1. *Slight,* consisting of one small break in the pericarp
   2. *Severe:* (a) extensive breakage of pericarp; (b) same but with damage to plumule-radicle also

B. Pericarp damage in areas other than over the embryo
   1. *Slight,* consisting of one or minor abrasions or breaks in the pericarp
   2. *Severe,* consisting of more extensive breaks in the pericarp which may be accompanied by chips knocked off the endosperm

C. Cracked endosperms
   1. Not counted as damage when there are no breaks in the pericarp
   2. *Slight,* if accompanied by minor abrasions of the pericarp
   3. *Severe,* if accompanied by extensive breaks in the pericarp

One seed company, Associated Seed Growers, Inc., uses a much simpler method of estimating injury, and from their unpublished data it is evident that the correlation between injury index and germination is very close. The method consists of counting the total number of breaks in the pericarps of 100 kernels. This total may range all the way from a few to several hundred.

In the subsequent tables the kernels are classified into three groups: (1) undamaged, (2) with slight external damage, and (3) with severe external damage. The 1946 samples are classified also as to endosperm cracking with or without external damage. The cause of endosperm cracking is not known. It occurs during the maturation period and is found in both field-dried and artificially dried sweet corn. Cracking in the absence of pericarp damage does not seem to affect germination. This type of cracking should not be confused with cracks due to rough handling. The latter type is always accompanied by extensive pericarp breakage.

Evaluating Seedling Emergence

The method of evaluating the emergence of seedlings after a cold test has also been a subject of considerable discussion. The factors involved are (1) time of emergence, (2) total emergence, and (3) vigor of the seedlings. In ordinary germination tests time of sprout emergence may be governed to some extent by injured pericarps, as such seeds take up moisture more rapidly than uninjured seeds. In a cold test, however, time of seedling emergence is probably not determined by rate of water absorption. The seven-day holding period would equalize this rate. Time of emergence is therefore most likely governed by weakening caused by direct physical damage and attack by the soil organisms. Total emergence and seedling vigor seem to be determined by the same factors. Thus in evaluating the cold test, total emergence of seedlings is sometimes expressed in terms of numbers of strong and of weak seedlings. In this publication total emergence is expressed in terms of percent of germination, and seedling vigor in terms of average plant height and green weight. None of these three methods takes into account the variability in growth of seedlings, which is characteristic of damaged seed lots when planted in the field. No practical method of measuring the variability in growth of thousands of seedlings growing in the greenhouse has been found.

The rate of seedling emergence was the subject of considerable study, and daily counts of the 1946 crop samples were taken for a period of 14 days. The 1947 crop samples were planted relatively late in the spring and counts were taken for nine days only, as germination was rapid. These readings were plotted as emergence curves on the basis of the following formula in order to eliminate the factor of total number of seedlings emerged:

$$\frac{\text{Number seedlings emerged on given day}}{\text{Total number of seedlings emerged}} \times 100 = \text{percent of total emerged}$$

The emergence rates of paired samples proved to be very nearly the same no matter how widely the pairs differed with respect to total physical damage, total germination, and seedling vigor. The irregular seedling growth, which is characteristic in field stands of badly damaged seed lots, does not seem to depend as much on time of emergence as on differences in the growth rate of the seedlings.

Germination Methods

All samples were screened by hand before planting, thus removing the smallest kernels. Broken kernels were also removed since they would be discarded during hand-picking. If any remained in a hand-picked sample, they were probably overlooked. This screening practice may have been a source of error, as screening would improve the germination of lots that had been badly damaged.

One hundred kernels were counted out from each lot and divided into five groups of 20 kernels each. The five groups were randomized so that each was in a different flat, care being taken to properly scatter the flats. Seven lots of 20 kernels each were planted per flat, the center row in each flat being used as a uniform control. The purpose of the control rows was to determine the extent of the variations, if any, due to location in the greenhouse. Thus it was possible to repeat the tests on samples from those 20-kernel replications that showed variation due to location.

Unsterilized cornfield soil mixed with manure and sand was used in these experiments. The proportions were three parts of field soil, one part of building sand, and two parts of rotted manure. The seeds were not treated with a seed protectant. They were planted 20 kernels to the row, in rows 2 inches apart. The depth of planting was ¾ inch. After planting, the flats were saturated with water and allowed to drain. The soil was then considered to be at field capacity with respect to moisture.

The flats were then removed to cold-storage rooms and held at 50 ± 1° F. for seven days without additional watering. The relative humidity was maintained at 70 to 75 percent. At the end of seven days the flats were removed to the greenhouse, which was maintained at 80° F. during the day and 70° F. at night. The respective soil temperatures were 75° and 68° F.

The tests of the 1946 crop were completed the 14th day after the flats had been placed in the greenhouse. The plant heights and fresh weights of seedlings were recorded on the 17th day. The heights consisted of the distance between the ground level and the tip of the longest leaf. The seedlings were then cut off at ground level with a razor blade and immediately weighed. The tests of the 1947 crop were identical with those of the 1946 crop except that the greenhouse tests were conducted a month later in the season, the end of March. Consequently emergence was much more rapid, owing not only to higher soil temperatures — the greenhouse benches being provided with bottom heat — but also to the greater duration and intensity of the light. The 1947 crop was not measured for plant height, as it was evident from the previous year's work that plant height was merely a function of plant weight.

Average green-plant weight, as given in the subsequent tables, was calculated by dividing the total weight of all the plants emerging in each replication by the actual number of plants weighed. Much wider differences could have been obtained by dividing the total green weights of each replication by 20, the actual number of seeds planted in each replication, but it is evident that this would have distorted the results. As it is, the method used distorts the results in another way, as the seedling survivors in a low-germinating sample tend to grow more vigorously because of the reduced competition, thus giving an index of seedling vigor which is too high. The change in the results due to the different methods of calculation may be illustrated by the first item in Table 3. The hand-harvested sample of Ioana germinated 90 percent and the combined sample 53 percent. The average green weights of seedlings were 0.92 and 0.57 gm. respectively, a difference of 0.35 gm. If the total green weights of each replication were divided by 20 (the number of seeds planted) they would average 0.83 and 0.30 gm. respectively, a difference of 0.53 gm., which is much larger.

Use of Corn Picker for Harvesting Seed

To an observer watching a corn picker harvesting sweet corn seed, there can be no question about the rough treatment the ears receive. It is also obvious that the picker must be carefully adjusted. Many farmers either do not know how to adjust the machine or are careless. In addition different makes of pickers vary in the amount of damage they do. Ground speed, condition of the picker, and many other factors influence the physical damage. Hand-harvesting, in contrast, does little damage. The practice in Idaho is to hand-harvest the corn into bags, which are filled to about half their capacity. The bags are loaded on trucks and emptied by hand onto a conveyor at the warehouse. The corn harvested with a picker is handled in bulk.

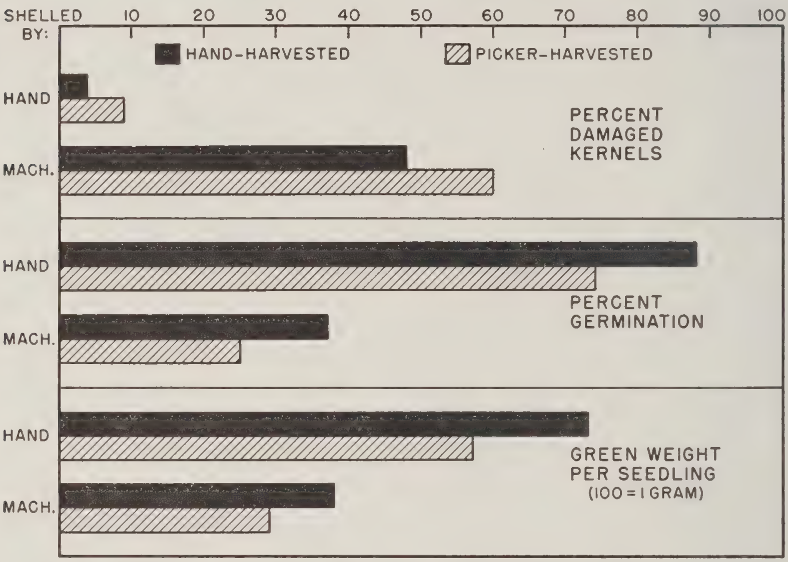
The damaging effects of the corn picker have been the subject of considerable controversy, and some seedsmen are paying growers a premium for hand-harvesting. In this study the average visible damage on picker-harvested seed was 9 percent and on hand-harvested seed 4 percent when both were hand-shelled (Table 2 and Fig. 1). (Two lots which were shelled by machine are not included in this average. In those lots the picker increased the damage by 12 kernels per hundred). The small difference in visible damage (5 percent) between

Table 2. — Physical Damage, Germinability, and Seedling Growth in 100-Kernel Samples of Sweet Corn Seed Harvested and Shelled by Hand and by Machine
(Golden Cross Bantam, Idaho, 1946)

Harvest method	Moisture at harvest	Un-damaged kernels	Kernels with internal cracks only	Kernels with external damage				Kernels germinated (cold test)		Seedling growth	
				Slight	Severe: With internal cracks	Severe: Without internal cracks	Total damaged	Total	Decrease	Green weight	Height
Shelled by hand											
	perct.									*gm.*	*mm.*
Hand	35	75	17	7	1	0	8	75	..	.59	125
Picker	30	67	21	11	1	0	12	67	8	.54	115
Hand	29	79	14	6	1	0	7	91	..	.70	132
Picker	29	43	43	11	2	1	14	85	6	.46	105
Hand	22	70	30	0	0	0	0	92	..	.79	143
Picker	22	77	18	5	0	0	5	70	22	.60	119
Hand	19	75	25	0	0	0	0	92	..	.85	143
Picker	19	67	27	6	0	0	6	74	18	.69	124
Average											
Hand	..	75	21	3	1	0	4	88	..	.73	136
Picker	..	64	27	8	1	0	9	74	14	.57	116
Shelled by machine											
Hand[a]	29	41	11	30	17	1	48	37	..	.38	84
Picker	29	19	21	34	25	1	60	25	12	.29	76

[a] Milled and hand-picked.

the paired samples shelled by hand fails to account for the relatively large difference in average germination of the picker-harvested seed, which was 14 percent (14 kernels) less than that of the hand-harvested. The green weights of seedlings from the picker-harvested seed were also considerably less, as Fig. 1 and Table 2 show. Internal injuries, such as invisible ones induced by crushing, may have been a factor.



Kernel damage, germination, and seedling vigor of sweet corn seed harvested by hand and same for seed harvested with a corn picker. Bars represent averages of four hand-shelled lots and data for one lot shelled by machine, as shown in Table 2. (Fig. 1)

In another experiment (Table 15, Items 1 and 2), picker-harvested corn germinated better than hand-harvested, but this was probably due to an error in sampling since the seedling growth of the hand-harvested seed was considerably more vigorous.

Four factors should be considered in assaying the damage caused by pickers in relation to moisture content of the seed. These are (1) total external damage, (2) decrease in germination as compared with the paired hand-harvested lot, (3) the green weights of seedlings, and (4) their heights. The trends are diverse. The paired germination differences in Table 2 tend to increase as the moisture content of the corn decreases. On the other hand, the total damage tends to decrease. Green weights and heights of seedlings of the four hand-shelled samples tend to increase, though this may be an expression of better vigor due to more advanced maturity as well as to a decrease in physical damage. From the limited data available it is impossible to determine the moisture range in which picker-harvesting causes the least damage. However, the results in Table 2 leave no doubt that the picker damages sweet corn much more than hand-harvesting.

Two lots in Table 2 were shelled by machine, one having been harvested by hand and the other with a picker. Both lots were damaged much more severely than the hand-shelled samples, indicating that the corn sheller was also a source of damage, especially as the percentage of cracked seeds showing external damage increased materially. The effect of machine shelling will be discussed in detail later. It is sufficient to indicate here that the picker-harvested sample was more severely injured by the sheller than the hand-harvested sample.

The matter of internal cracking, both with and without external damage, has thus far received no attention. Cracks confined entirely to the endosperm occur frequently in sweet corn, and the number of kernels so affected varies from ear to ear within the same genetic group. The cracks occur during maturation; and inspection of a considerable number of ears, both artificially dried and field dried, seemed to show that rapid artificial drying was not the cause. Strains with large, smooth, plump kernels seemed to be more subject to internal cracks than those showing considerable shrinkage as indicated by angularity and deep crown depressions. Small kernels also seemed to crack less than large kernels. When cracking is accompanied by external damage it is difficult to determine the origin of the cracks, whether mechanical or physiological, except where the pericarp is broken on the same axis as the endosperm crack. In such a case the external damage is undoubtedly mechanical, whereas the internal damage may be either physiological or mechanical. There is no evidence that endosperm cracking unaccompanied by other damage has any effect on germination or seedling viability.

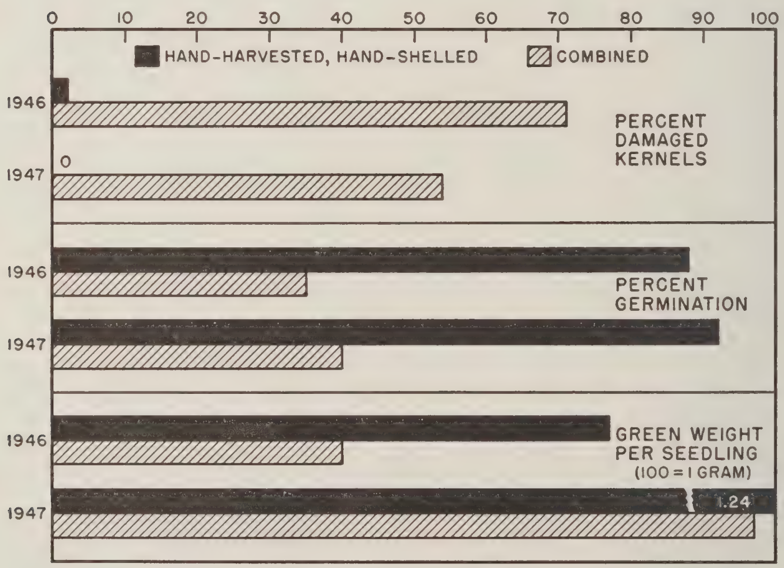
The average percentage of kernels having cracked endosperms but no external damage is only slightly larger in the picker-harvested samples than in the hand-harvested samples (Table 2). Since there were very few cracked kernels with external damage, it may be assumed that kernels with cracked endosperms are not more subject to additional damage than kernels with whole endosperms. Experience with the sixth lot in Table 2, which was shelled by machine, would seem to contradict this statement, but in this lot it is impossible to dissociate corn-sheller damage from picker damage.

Combining Sweet Corn Seed

Twelve fields of sweet corn were combined in 1946 and 1947. The five combined in 1946 were sampled directly in the field; and hand-harvested, hand-shelled lots were taken as paired controls at the same time. Of the seven fields combined in 1947, paired samples were taken from only one field of Ioana. Two fields in 1947 were partially combined at different times, thus giving a succession of maturities which may be compared with reference to the relation between maturity and the extent of combine damage.

The six sets of paired samples (five in 1946 and one in 1947) are compared in Table 3. Combining clearly caused extensive kernel damage, the average number of damaged kernels in 1946 from this cause being 71 percent, whereas only 2 percent of the hand-harvested, hand-shelled controls showed damage (Fig. 2). Decreases in germination and in seedling weights and heights were all very large, indicating the serious damage caused by the combine.

The 1946 combined samples averaged 12 percent cracked seeds with severe external damage plus 4 percent also severely damaged but without internal cracks; whereas the hand-harvested, hand-shelled



Kernel damage, germination, and seedling vigor of sweet corn seed harvested and shelled by hand and same for seed harvested with a combine. Bars represent averages of five lots, as shown in Table 3. (Fig. 2)

Table 3. — Physical Damage, Germinability, and Seedling Growth in 100-Kernel Samples of Sweet Corn Seed Harvested and Shelled by Hand and by Combine, Idaho, 1946 and 1947

Variety and method of harvesting and shelling	Moisture at harvest	Un-damaged kernels	Kernels with internal cracks only	Kernels with external damage				Kernels germinated (cold test)		Seedling growth	
				Slight	Severe: With internal cracks	Severe: Without internal cracks	Total damaged	Total	Decrease	Green weight	Height
1946 crop											
	perct.									*gm.*	*mm.*
Ioana											
Hand	20	79	20	1	0	0	1	90	..	.92	148
Combine	20	16	27	29	21	7	57	53	37	.57	112
Golden Cross Bantam											
Hand	19	71	28	1	0	0	1	86	..	.68	130
Combine	19	14	27	34	20	5	59	47	39	.52	93
Hand	16	100	0	0	0	0	0	78	..	.71	134
Combine	16	28	1	62	9	0	71	38	40	.34	88
Hand	18	80	17	3	0	0	3	92	..	.85	144
Combine	15.5	18	0	68	9	5	82	22	70	.30	81
Hand	13	94	0	6	0	0	6	93	..	.67	131
Combine[a]	13	12	1	84	2	1	87	16	77	.26	62
Average											
Hand	..	85	13	2	0	0	2	88	..	.77	137
Combine	..	18	11	55	12	4	71	35	53	.40	87
1947 crop											
Ioana											
Hand	15.5	100	..	0	..	0	0	92	..	1.24	...
Combine	15.5	46	..	54	..	0	54	40	52	.97	...

[a] Also milled and hand-picked.

samples showed no severe damage (Table 3). As there was practically no difference between combined and hand-harvested samples so far as endosperm cracks without external damage are concerned, it may be concluded that the externally damaged kernels in the combined lots had not necessarily been cracked internally before the combining.

The five 1946 fields are arranged in Table 3 in the order of seed maturity at the time of harvest based on the moisture content of the kernels, the range being from 20 percent to 13 percent. There was a marked increase in total mechanical damage accompanied by a marked decrease in germination and seedling vigor as maturity advanced at the time of combining. The hand-harvested samples fail to show a trend of this kind, indicating that the damage caused by the combine is affected by the moisture content of the kernels.

Table 4. — Physical Damage, Germinability, and Seedling Growth in 100-Kernel Samples of Sweet Corn Seed Combined at Different Moisture Contents, Idaho, 1947

Variety, Field No., and where sampled	Moisture when combined	Shell dried	Kernels with external damage				Kernels germinated (cold test)	Green weight of seedlings
			None	Slight	Severe	Total damaged		
Golden Cross Bantam	*perct.*							*gm.*
1. Field samplings from a succession of four harvests	24.7	Yes	36	61	3	64	33	1.11
	19.2	Yes	22	76	2	78	38	.84
	15.0	Yes	22	75	3	78	18	.72
	11.2	No	25	71	4	75	27	.87
2. Field samplings from a succession of three harvests	25.8	Yes	57	40	3	43	55	1.03
	17.0	Yes	37	62	1	63	41	1.12
	10.8	No	51	49	0	49	33	.97
3. From bag elevator[a]	20.0	Yes	38	60	2	62	18	.73
4. After hand-picking	20.0	Yes	28	71	1	72	41	1.03
Ioana								
5. From bag elevator	15.5	Yes	47	52	1	53	36	.94
Golden Cross Bantam								
6. From bag elevator	15.0	No	10	84	6	90	23	.95
7. From bag elevator	13.0	No	12	87	1	88	26	.86
8. From bag elevator	12.0	No	24	75	1	76	20	1.00

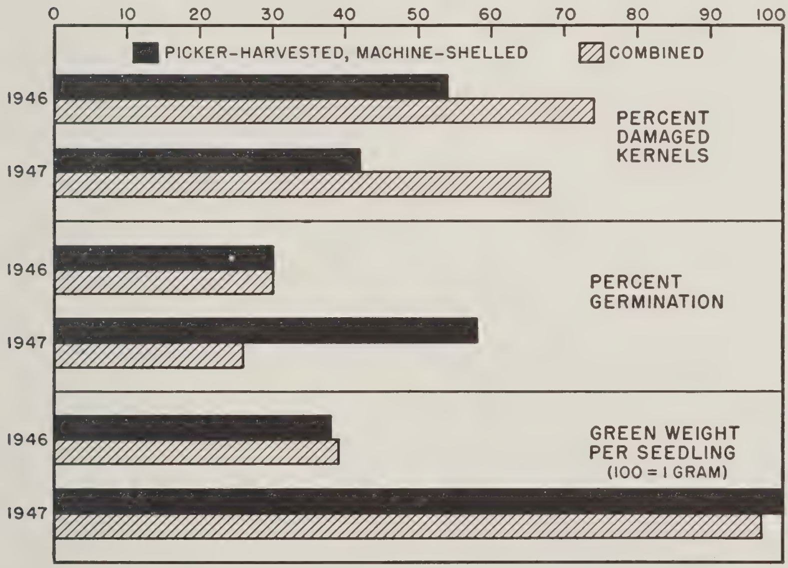
[a] "From bag elevator" indicates that the sample has been milled, gravity-separated, and bagged.

In 1947 one field was partially combined at four different times and a second field at three different times (Table 4). The germination tests of the samples from the first field were all extremely low and showed no trend in relation to maturity. Neither did physical damage increase in relation to maturity. The samples from the second field gave a somewhat higher germination and showed a decided drop as maturity advanced, accompanied by an irregular increase in physical damage. The samples from the remaining six fields raised by as many different growers are arranged in Table 4 in the order of advancing maturity. The samples from the three fields combined at 15 to 12 percent moisture had a higher percentage of damaged kernels than the samples from the three fields combined at 15.5 to 20 percent. The germination tests were very low, especially in five of the six fields, and showed no trend in relation to maturity.

The data are too limited and inconsistent to permit definite conclusions, but the evidence suggests that physical damage is likely to increase and germination to decrease when sweet corn having less than 15 percent moisture is combined.

Comparison of Different Harvest Methods

The question is raised whether it is better to use a corn picker or a combine if no labor is available for hand-harvesting. Picker-harvested seed must be mechanically shelled, and the subsequent discussion will show that the sheller is a serious source of damage. The problem here is to determine whether the cumulative damage due to the corn picker plus the sheller is as serious as that due to the combine.



Kernel damage, germination, and seedling vigor of sweet corn seed harvested with a picker and shelled by machine, and same for seed harvested with a combine. Bars represent averages shown in Table 5. (Fig. 3)

Table 5. — Physical Damage, Germinability, and Seedling Growth in 100-Kernel Samples of Sweet Corn Seed Combined or Harvested With a Picker and Shelled by Machine, Idaho, 1946 and 1947

Variety	Moisture when harvested	Un-damaged kernels	Kernels with internal cracks only	Kernels with external damage				Kernels germi-nated (cold test)	Seedling growth	
				Slight	Severe: With internal cracks	Severe: Without internal cracks	Total damaged		Green weight	Height
1946 crop harvested and shelled by machine, then milled and hand-picked										
	perct.								*gm.*	*mm.*
Golden Cross Bantam	30	26	11	48	13	2	63	33	.33	83
	29	19	21	34	25	1	60	25	.29	76
	22	41	16	26	15	2	43	20	.47	104
Ioana	19	35	16	34	14	1	49	43	.44	94
Average	..	30.2	16.0	35.5	16.8	1.5	53.8	30	.38	89
1946 crop combined, then milled and hand-picked										
Ioana	20	36	7	43	12	2	57	38	.56	108
Golden Cross Bantam	19	16	21	24	38	1	63	42	.41	83
	16	16	3	56	21	4	81	37	.41	94
	15.5	18	0	68	9	5	82	22	.30	81
	13	13	2	65	9	11	85	11	.26	67
Average	..	19.8	6.6	51.2	17.8	4.6	73.6	30	.39	87
1947 crop harvested and shelled by machine, then milled (not hand-picked)										
Ioana	30	46	..	53	..	1	54	52	.92	..
	23	71	..	24	..	5	29	63	1.08	..
Average	..	58.5	..	38.5	..	3.0	41.5	58	1.00	..
1947 crop combined, then milled (not hand-picked)										
Golden Cross Bantam	20	33	..	65	..	2	67	22	.90	..
	20	28	..	71	..	1	72	41	1.03	..
Ioana	15.5	47	..	52	..	1	53	36	.94	..
Golden Cross Bantam	15	10	..	90	..	0	90	17	.92	..
	13	29	..	71	..	0	71	18	1.00	..
	12	42	..	58	..	0	58	24	1.05	..
Average	..	31.5	..	67.8	..	0.7	68.5	26	.97	..

Comparison of the averages in Fig. 3 and Table 5 shows that the physical damage due to combining was considerably greater than the cumulative damage due to the picker and sheller, but on the other hand the average germinations and the green weights were almost identical in 1946.

The 1946 averages also show that the percentages of externally damaged cracked seeds were practically the same in the two methods. In the combined samples there were fewer undamaged internally cracked kernels, but the difference is probably due to chance. In 1947 only two fields were harvested with a picker, six with a combine. The data from the picker-harvested fields are therefore not as reliable as those from the six combined fields. However, combining again caused more damage. The green weights of seedlings were practically the same, but combining reduced germination to less than half.

From the results in Table 5 it may be concluded that the damage caused by the combine is much more severe than the cumulative damage occurring in picker-harvested corn shelled by machine. The combine should not be used if other means of harvesting are possible.

Physical Damage Caused by Corn Sheller

Six paired samples from as many different fields were available from the 1946 crop for comparison between hand-shelling and machine-shelling. Three paired lots from three fields were available from the 1947 crop. The results reported in Tables 6 and 7 and Fig. 4 show that hand-shelled corn has consistently less injury, better germination, and more seedling vigor than corn shelled by machine.

The machine-shelled samples had a much higher average percentage of externally damaged cracked seeds than the hand-shelled samples in Table 6. The latter, however, had a higher percentage of seeds that were undamaged except for internal cracks. This apparent inconsistency may be explained by the fact that many of the internally cracked seeds were also externally damaged by the sheller, whereas the hand-shelled samples received no damage.

Since this work was undertaken seedsmen have become very conscious of the serious damage caused by the sheller. Practically all of the shellers used by the industry are of the type that shell the ears by rubbing them against each other. The cylinder is usually equipped with a series of iron pegs or helical fins which cause the ears to churn and twist and travel toward the discharge end. The cylinder is usually a rough casting, and the pegs in many models are square with sharp corners. There are several ways to modify a sheller in order to reduce

Table 6. — Physical Damage, Germinability, and Seedling Growth in 100-Kernel Samples of Sweet Corn Seed Shelled by Hand and by Corn Sheller, Idaho, 1946

Variety and shelling method	Moisture at harvest	Un-damaged kernels	Kernels with internal cracks only	Kernels with external damage: Slight	Kernels with external damage: Severe, With internal cracks	Kernels with external damage: Severe, Without internal cracks	Kernels with external damage: Total damaged	Kernels germinated (cold test): Total	Kernels germinated (cold test): Decrease	Seedling growth: Green weight	Seedling growth: Height
Harvested by hand											
Golden Cross Bantam	*perct.*									*gm.*	*mm.*
Hand	31	63	34	3	0	0	3	86	..	.69	134
Sheller	31	27	11	47	14	1	62	49	37	.39	96
Hand	29	79	14	6	1	0	7	91	..	.70	132
Sheller[a]	29	28	8	54	8	2	64	46	45	.37	85
Hand	24	67	29	2	2	0	4	91	..	.85	145
Sheller[b]	24	11	29	27	28	5	60	46	45	.49	102
Average											
Hand	..	70	26	3	1	0	4	89	..	.75	137
Sheller	..	22	16	43	17	2	62	47	42	.42	94
Harvested with picker											
Golden Cross Bantam											
Hand[a]	30	88	9	3	0	0	3	86	..	.71	134
Sheller	30	37	3	48	8	4	60	39	47	.33	86
Hand	22	77	18	5	0	0	5	70	..	.60	119
Sheller[a]	22	30	20	40	10	0	50	49	21	.48	87
Ioana											
Hand	19	67	27	6	0	0	6	74	..	.69	124
Sheller[a]	19	21	9	48	22	0	70	34	40	.47	100
Average											
Hand	..	77	18	5	0	0	5	77	..	.67	126
Sheller	..	29	11	45	13	1	60	41	36	.43	91

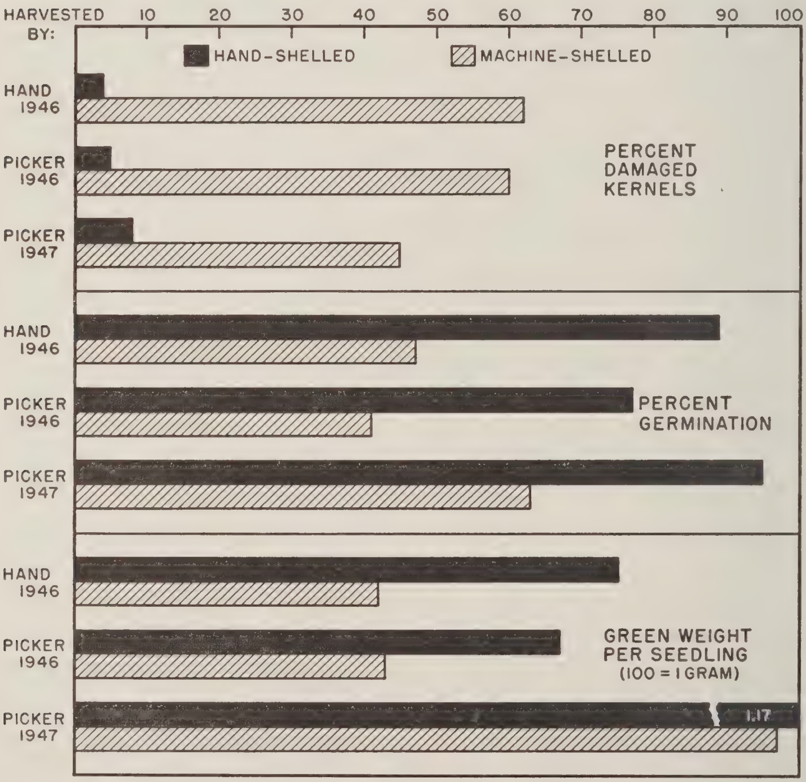
[a] These ears had been sorted before they were dried for shelling.
[b] Shelled at 24 percent moisture, then dried and milled.

Table 7.—Physical Damage, Germinability, and Seedling Growth in 100-Kernel Samples of Sweet Corn Seed Shelled by Hand and by Corn Sheller, Idaho, 1947

Variety and harvest method	Moisture when harvested	Shelling method	Moisture when shelled	Kernels with external damage				Kernels germinated (cold test)		Green weight
				None	Slight	Severe	Total damaged	Total	Decrease	
	perct.		*perct.*							*gm.*
Ioana										
Picker	23.8	Hand	23.8	98	2	0	2	92	..	1.25
Picker	23.8	Sheller	23.8	65	35	0	35	74	18	1.09
Picker	28.5	Hand	12	89	11	0	11	94	..	1.04
Picker	30	Sheller	11	55	45	0	45	58	36	.82
Golden Cross Bantam										
Hand	40	Hand	12	90	10	0	10	98	..	1.23
Hand	40	Sheller	12	46	52	2	54	57	41	.99

the possibility of damaging kernels. The cylinder should be ground smooth, many of the pegs may be removed, their corners should be rounded, and in some cases the pegs may be shortened. Many shellers are fitted with an iron screen pierced with round holes. The edges of the holes become sharpened through wear and cause injuries to the kernels. Removing the screen and substituting round iron bars parallel with the long axis of the sheller is more satisfactory. These bars are usually ⅝ to ¾ inch in diameter and spaced about ½ inch apart.

A variable-speed transmission should be installed so that the speed may be reduced to the lowest point compatible with a satisfactory job. All shellers are designed for field corn, and manufacturer's recommendations for optimum speed are always too high for sweet corn. The large sheller used in the 1946-1947 experiments reported



Kernel damage, germination, and seedling vigor of sweet corn seed shelled by hand and with a sheller. Each bar represents an average of three lots, as shown in Tables 6 and 7. (Fig. 4) here was operated at 700 r.p.m. After installing a variable-speed motor, some lots of corn were shelled at speeds as low as 125 r.p.m., with corresponding reductions in damage. Slowing the speed will also reduce shelling capacity, but not proportionally. This sheller had a fan attached to the main shaft for removing chaff. At reduced speeds the fan failed to work satisfactorily, so the shaft was cut and the fan operated from a separate motor at normal speed irrespective of the cylinder speed.

Sweet corn kernels at moistures above 25 percent are relatively soft and rubbery in texture. On the other hand they become glassy-hard and extremely brittle below 12 percent. The ears shell more readily as the moisture content decreases, and it is possible to reduce the speed of the sheller progressively. A number of seed lots were shelled both by hand and with a sheller at moistures ranging from 30 percent down to 9 percent. Many of the samples were paired with reference to type of shelling, as shown in Table 8. Lots 1 to 9, all from the same field, show the usual sheller damage in the six paired samples. Lot 4, shelled at 30 percent moisture with a sheller, contained a high percentage of severely damaged kernels (12 percent). On the other hand, Lot 1, paired with Lot 4 but shelled by hand, contained no severely damaged kernels. Lots 4 to 9 were shelled by machine at moistures ranging from 30 percent to 9 percent, but except for Lot 4 mentioned above there was practically no severe damage. The total damage showed no trend in relation to moisture content. Lot 8, shelled at 9 percent moisture, had the highest total damage and also the lowest germination in the group. Apparently kernels having the extremes in moisture content, that is, a high of 30 percent and a low of 9 percent, are damaged the most by the sheller.

Lots 14 to 23 are a replication of the above experiment. In this group the corn shelled by machine at 30 percent moisture failed to show unusual damage, but there appears to be an irregular trend toward increasing total damage as the moisture decreases, corn shelled at 9 percent showing much the greatest damage and the lowest germination. The moisture range of the remaining lots in Table 8 was not wide enough to show any trend.

Additional data with reference to the relation of moisture to damage at the time of machine-shelling appear in Table 7. These results (not duplicated in Table 8) show that damage was less and germination better when corn was shelled at 23.8 percent moisture than at 12 percent.

From the data on the large number of samples taken (6 in Table 7

Table 8. — Physical Damage, Germinability, and Seedling Growth of 100-Kernel Samples of Sweet Corn Seed Shelled by Hand and by Machine at Different Moisture Percentages, Idaho, 1947

Variety, Lot No., and method of harvesting	Moisture when harvested	Shelling method	Moisture when shelled	Kernels with external damage				Kernels germinated (cold test)	Green weight of seedlings	Paired with Lot No.
				None	Slight	Severe	Total damaged			
Lincoln	*perct.*		*perct.*						*gm.*	
1. Hand	30	Hand	30	92	8	0	8	94	1.22	4
2. Hand	30	Hand	25	96	4	0	4	94	1.40	5
3. Hand	30	Hand	20	95	5	0	5	99	1.36	6
4. Hand	30	Sheller	30	63	25	12	37	65	1.16	1
5. Hand	30	Sheller	25	51	48	1	49	65	1.11	2
6. Hand	30	Sheller	20	60	38	2	40	73	1.23	3
9. Hand	30	Sheller	12	63	37	0	37	58	.94	..
7. Hand	30	Sheller	11	56	44	0	44	58	1.26	..
8. Hand	30	Sheller	9	46	54	0	54	43	1.07	..
Golden Cross Bantam										
14. Hand	30	Hand	30	98	2	0	2	91	1.25	18
15. Hand	30	Hand	25	97	3	0	3	96	1.25	19
16. Hand	30	Hand	20	99	1	0	1	94	1.28	20
17. Hand	30	Hand	15	99	1	0	1	94	1.23	21
18. Hand	30	Sheller	30	70	30	0	30	70	.91	14
19. Hand	30	Sheller	25	73	24	3	27	78	1.02	15
20. Hand	30	Sheller	20	55	43	2	45	70	1.09	16
21. Hand	30	Sheller	15	59	41	0	41	69	1.15	17
23. Hand	30	Sheller	13	67	32	1	33	64	.96	..
22. Hand	30	Sheller	9	36	64	0	64	41	.97	..
Ioana										
56. Picker	23	Sheller[a]	23	73	24	5	29	63	1.08	55
55. Picker	16.8	Sheller[a]	16.8	69	29	2	31	70	1.11	56
Golden Cross Bantam										
76. Hand	21	Hand	12	99	1	0	1	91	1.05	77
69. Hand	20	Hand	12	98	2	0	2	91	1.21	70
58. Hand	19.2	Hand	12	95	5	0	5	90	1.21	59
77. Hand	21	Sheller[a]	21	40	60	0	60	40	.70	76
70. Hand	20	Sheller[a]	20	59	41	0	41	55	.92	69
59. Hand	19.2	Sheller[a]	19.2	35	65	0	65	35	.78	58

NOTE—Each of the first three groups represents a set of samples from a separate field. In the last group, each pair of samples (Lots 76-77, 69-70, and 58-59) comes from a different field.

[a] Also milled and hand-picked.

and 27 in Table 8) one conclusion is that shelling at moistures as low as 9 percent may cause extensive damage. The usual commercial practice is to shell at about 12 percent moisture. Shelling at moistures above 20 percent is not a commercial practice but may be feasible on the basis of the above results.

Seed Damage and Germination in Relation to Processing

The Asgrow Monograph[1] emphasizes that each handling of bean seed subsequent to threshing increases the physical damage to the seed and reduces the germination. The results of the present experiment with sweet corn seed indicate that processing may improve the germination of some lots but not others, and that it may actually cause a reduction. Samples were taken from the 1946 crop both before and after milling and hand-picking. Nine lots were sampled in this way. Of these nine lots eight showed a decrease in germination varying from 1 to 29 percent; only one showed an increase (Table 9). The green weights of the seedlings either remained practically unchanged or were reduced. The heights of the seedlings increased slightly in two lots, but in the others decreased. Reductions in total external damage after milling and hand-picking occurred in four samples, but five lots either remained unchanged or were more extensively damaged.

Six of the nine lots (Table 9) showed a higher percentage of externally damaged cracked kernels after milling and hand-picking, and three showed a lower percentage. The average increases were 7 percent in both the hand-harvested machine-shelled lots and in the combined lots (Table 10); but in the picker-harvested machine-shelled lots, milling gave a decrease of 1 percent. The reason for these variations is not known; but considering the experiment as a whole, the increase in externally damaged cracked kernels as a result of milling averaged 4 percent (Table 10), from which it is clear that milling and hand-picking do nothing to remove this type of damaged kernel.

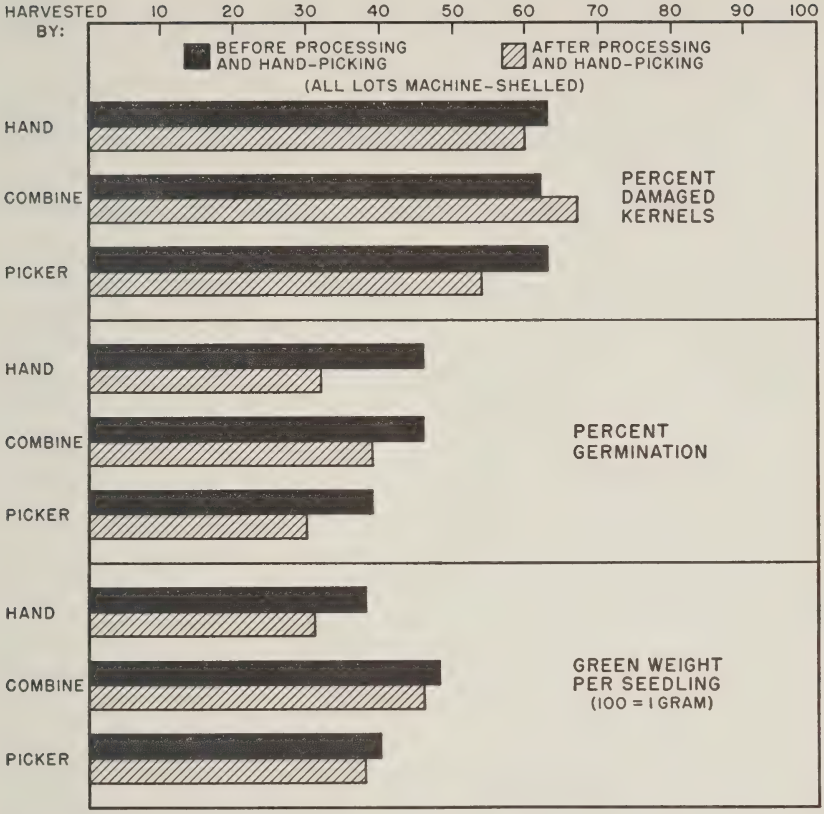
The average cold-test germinations in Table 10 and Fig. 5 dropped consistently after processing, no matter what method of harvesting had been used. The mean seedling vigor also failed to improve following processing.

Eight lots of sweet corn seed from the 1947 crop were sampled during various steps in processing, in a somewhat more elaborate continuation of the work with the 1946 crop. All lots had Purdue inbred 39 as a seed parent, but the male parents varied. The sampling consisted of five lots of Golden Cross Bantam, two of Ioana, and one of Lincoln.

Table 9. — Physical Damage, Germinability, and Seedling Growth in 100-Kernel Samples of Sweet Corn Seed Before and After Milling and Hand-Picking, Idaho, 1946

Variety and method of harvesting and shelling	Milled and hand-picked	Moisture when milled and hand-picked	Un-damaged kernels	Kernels with internal cracks only	Kernels with external damage				Kernels germinated (cold test)		Seedling growth	
					Slight	Severe: With internal cracks	Severe: Without internal cracks	Total damaged	Total	Decrease	Green weight	Height
Golden Cross Bantam		perct.									gm.	mm.
Hand, sheller	No	....	28	8	54	8	2	64	47	..	.37	85
	Yes	9.6	41	11	30	17	1	48	37	10	.38	84
Hand, sheller	No	11.0[a]	27	11	47	14	1	62	46	..	.39	96
	Yes	11.0[a]	19	9	53	18	1	72	27	19	.24	70
Combine	No	....	14	27	34	20	5	59	46	..	.52	93
	Yes	10.0	16	21	24	38	1	63	43	3	.41	83
Combine	No	....	28	1	62	9	0	71	38	..	.34	88
	Yes	9.2	16	3	56	21	4	81	37	1	.41	94
Ioana												
Combine	No	....	16	27	29	21	7	57	53	..	.57	112
	Yes	8.8	36	7	43	12	2	57	38	15	.56	108
Golden Cross Bantam												
Picker-sheller	No	....	37	3	48	8	4	60	39	..	.33	86
	Yes	9.0	26	11	48	13	2	63	33	6	.33	83
Picker-sheller	No	....	18	10	40	32	0	72	35	..	.33	82
	Yes	9.6	19	21	34	25	1	60	25	10	.29	76
Picker-sheller	No	....	30	20	40	10	0	50	49	..	.48	87
	Yes	8.7	41	16	26	15	2	43	20	29	.47	104
Ioana												
Picker-sheller	No	....	21	9	48	22	0	70	34	..	.47	100
	Yes	9.4	35	16	34	14	1	49	43	−9	.44	94

[a] Moisture when shelled.



Kernel damage, germination, and seedling vigor of sweet corn seed before and after processing and hand-picking. Bars represent the averages shown in Table 10. (Fig. 5)

Three different methods of harvesting were used, as indicated in Table 11. Samples were taken before and after milling, after gravity cleaning, and after elevating the seed from the gravity cleaner. The results given in the table are somewhat erratic, but are consistent in showing that neither the fanning mill nor the gravity cleaner will reduce the percentage of damaged seeds in a sample. The tests for germination and seedling vigor are likewise variable, but they are consistent in showing that processing fails to improve the quality of sweet corn seed. In the group of three lots harvested with a combine, seedling vigor tended to decrease slightly with each step in processing. This failure of processing to improve seed quality becomes much clearer when the average readings for the eight lots in Table 11 are compared.

Table 10. — Physical Damage, Germinability, and Seedling Growth in 100-Kernel Samples of Sweet Corn Seed Before and After Processing, Idaho, 1946

(Increases to the nearest whole number)

Processed and hand-picked	Undamaged kernels	Kernels with internal cracks only	Kernels with external damage: Slight	Severe: With internal cracks	Severe: Without internal cracks	Total damaged	Kernels germinated (cold test)	Seedling growth: Green weight	Seedling growth: Height
Hand-harvested, machine-shelled (average of 2 lots each)									
								gm.	*mm.*
No.	27	10	50	11	2	63	46	.38	90
Yes.	30	10	41	18	1	60	32	.31	77
Increase.	3	0	−9	7	−1	−3	−14	−.07	−13
Combined (average of 3 lots each)									
No.	19	18	42	17	4	62	46	.48	98
Yes.	23	10	41	24	2	67	39	.46	95
Increase.	4	−8	−1	7	−2	4	−7	−.02	−3
Picker-harvested, machine-shelled (average of 4 lots each)									
No.	27	10	44	18	1	63	39	.40	89
Yes.	30	16	35	17	2	54	30	.38	89
Increase.	3	6	−9	−1	1	−9	−9	−.02	0
All samples									
Average increase. .	3	−1	−6	4	−1	−3	−10	−.04	−5

The fanning mill increased physical injury slightly; there was a slight decrease in germination after gravity cleaning, but seedling vigor remained substantially the same.

Another series of experiments was undertaken in cooperation with the Green Giant Company, Le Sueur, Minnesota, using Minnesota grown seed of a hybrid originated by the company. The results in Table 12 show a consistent increase in physical damage, especially of the type classified as severe, with each step in processing (Stages 3 to 8 in the table). This increased damage was accompanied by a consistent decrease in germination. Ear samples were taken at three points, both before and after drying (Stages 1, 2, and 3 in the table). These samples were all hand-shelled, but no consistent differences in injury, germination, or seedling vigor were noted. Samples of dried corn accidentally shelled were also taken from the inspection belt. Compared with the whole-ear samples removed at the same point, these accidentally shelled samples averaged slightly greater injury, lower germination, and a very slightly lower seedling vigor.

Table 11. — Physical Damage, Germinability, and Seedling Growth in 100-Kernel Samples of Sweet Corn Seed Taken at Various Stages of Processing, Idaho, 1947

Number of lots	Processing step at which sampled				Externally damaged kernels	Kernels germinated (cold test)	Green weight of seedlings
	Before milling	After milling	After gravity cleaning	After elevating			
Hand-harvested, machine-shelled							
							gm.
4	X	..	..	..	46	52	.92
4	..	X	..	..	53	53	.99
4	..	..	X	..	55	49	1.01
4	..	..	..	X	54	49	.95
Picker-harvested, machine-shelled							
1	X	..	..	..	45	58	.82
1	..	X	..	..	54	64	.97
1	..	..	X	..	47	41	.90
1	..	..	..	X	46	52	.88
Combined							
3	X	..	..	..	67	30	1.10
3	..	X	..	..	68	25	.98
3	..	..	X	..	66	29	.96
3	..	..	..	X	72	28	.93
Weighted average, all samples							
8	X	..	..	..	54	44	.98
8	..	X	..	..	59	44	.98
8	..	..	X	..	58	40	.98
8	..	..	..	X	60	41	.93

Table 12. — Physical Damage, Germinability, and Seedling Growth in 100-Kernel Samples of Sweet Corn Seed Taken at Various Stages of Processing, Minnesota, 1946

Samples and stages at which taken	Kernels with external damage				Kernels germinated (cold test)	Seedling growth	
	None	Slight	Severe	Total damaged		Green weight	Height
Hand-shelled						*gm.*	*mm.*
1. Before ears entered drier	86	9	5	14	75	.68	136
2. After ears left drier	80	13	7	20	91	.64	135
3. Ears at end of inspection belt	83	12	5	17	89	.76	143
Shattered							
4. At end of inspection belt (shattered kernels)	79	6	15	21	72	.74	140
Machine-shelled							
5. From corn-sheller discharge spout	62	17	21	38	75	.67	133
6. After elevating to mill	49	15	36	51	63	.61	124
7. From discharge end of mill	36	32	32	64	56	.62	123
8. Screenings from mill	..	..	..	..	49	.50	114
9. After ring-grading, Grade 1	19	39	42	81	57	.62	122
Grade 2	26	35	39	74	42	.58	113
Grade 3	23	42	35	77	55	.82	138

The first marked increase in physical damage occurred during shelling, although the sheller used in these experiments had been considerably altered. Most of the pegs had been removed from the cylinder and those that remained had been rounded to remove sharp corners. The cast-iron cylinder itself had been machined and polished, and bars substituted for the screen. In addition the speed of the sheller had been reduced to slightly more than 100 r.p.m. Elevating and milling added to the damage and reduced the germination.

Ring-grading damaged the seed severely, but caused no consistent reduction in germination. Grade 3 had the best seedling vigor of the three ring-graded lots.

Another experiment during 1946 in cooperation with the F. H. Woodruff & Sons plant, then located at Clinton, Illinois, summarized in Table 13, gave decided decreases in germination due to processing. Of the two hand-harvested samples, the one going through the sheller and mill had a considerable drop in germination and seedling vigor. Samples of picker-harvested corn were taken at the discharge ends of both the fanning mill and the gravity separator and were compared with unprocessed hand-shelled samples. The results in Table 13 show clearly that the successive steps in milling reduced germination and seedling vigor.

Table 13. — Germinability and Seedling Growth in 100-Kernel Samples of Sweet Corn Seed Taken at Various Stages of Processing, Illinois, 1946

(Country Gentleman sweet corn seed)

Samples and stages at which taken	Kernels germinated (cold test)	Seedling growth	
		Green weight	Height
		gm.	*mm.*
Hand-harvested			
Hand-shelled, not processed	74	.56	135
Machine-shelled and milled	55	.50	126
Picker-harvested			
Hand-shelled	58	.54	135
Machine-shelled and milled	48	.52	128
Machine-shelled, milled, and gravity-separated	33	.51	128

That successive steps in processing sweet corn seed increase the physical damage to the seed and reduce the percentage of seeds germinating (cold test) is shown also in a privately circulated mimeograph from Donald N. Clark, Associated Seed Growers, Inc., New Haven, Connecticut. A summary of Clark's data is given at the top of page 35.

Samples and where taken	*Percent germination*	*Total number of breaks in pericarp per 100 seeds*
Room-dried, not processed (control)	73	7.2
Bin-dried		
Not processed	66	13
At discharge end of dried-ear conveyor	72.7	14
After shelling	59.5	53
At discharge end of cup elevator	55.5	56.5
At discharge end of fanning mill	43.7	101.7

The corn sheller, according to these data, causes more damage than any other piece of equipment. The fanning mill comes next. Every other step in handling also causes some deterioration.

These results agree with the data in Tables 10, 12, and 13, but the damage shown in Table 11 was much less serious. This inconsistency can be very simply explained. The data in Tables 10 and 11 originated from the same plant in two successive years. Processing caused considerable damage the first year; but after extensive alterations in plant and equipment the next year, the damage was greatly reduced.

The writers have discussed fanning-mill damage with various seedsmen. The primary cause of the damage is believed to be the screens. These wear rapidly; and the edges of the holes, becoming very sharp, are likely to cause abrasions. Also, many kernels, being only slightly larger than the hole size of the screens, become lodged in the holes and must be removed by the travelling brushes. How many times such kernels must be removed in this way before reaching the discharge end of the screen, and how much damage is incurred, are not known.

It is also believed that shortening the vibrating stroke of the screens and increasing the number of strokes per minute would be advantageous. One prominent seedsman feels that the fanning mill could be omitted and the seed cleaned by means of two gravity separators followed by a size grader.

Sorting Ears Over the Inspection Belt

Sweet corn ears are inspected when received at the processing plant, and all diseased, pollen-contaminated, malformed, and cull ears are removed. This process is called "green-corn sorting" and is usually the only inspection given the corn before it is shelled. If the moisture content of the sorted green corn is 12 percent or lower, the corn is shelled; if it is higher, the ears are dried by artificial heat before they are shelled. After being shelled and milled, the corn is hand-picked, usually just prior to shipping.

The purpose of the following experiments was not to determine the value of green-corn sorting, for it is obvious that the removal of undesirable ears will improve the quality of the seed lot, but to determine the possible damage caused by the mechanical equipment used in handling the ears. In the Idaho experiments the ears were dumped on a short rubber belt that discharged them into the boot of a bucket elevator, running at a low rate of speed. The elevator was equipped with large buckets, about a half-bushel capacity each, which raised the ears to the second floor. The ears were then discharged onto a rubber inspection belt at the end of which was a rubber-lined chute through which the ears were returned to the first floor.

For this experiment only two pairs of Idaho samples were secured. The results in Table 14 show that in physical damage the sorted ears had a slight increase, their germination was also slightly improved, but seedling vigor was almost identical with that of the unsorted ears. The green-corn sorting equipment used by the Idaho company seems to have been efficient, inasmuch as the damage inflicted was so slight.

In the Illinois experiment at Rochelle (Table 15) the sorting equipment was different. The corn came from the field in bulk and was scooped by hand onto a horizontal conveyor which carried it to a re-husker which, in turn, discharged it onto a rubber sorting belt. Item 2 (Table 15) consists of corn not carried through the above process and

Table 14. — Germinability and Seedling Growth in 100-Kernel Samples of Sweet Corn Seed Before and After Inspection and Sorting

(Ears inspected at sorting belt on arrival at processing plant)

Variety	Moisture when harvested	Kernels with external damage				Kernels germinated (cold test)	Seedling growth	
		None	Slight	Severe	Total damaged		Green weight	Height
1946 crop, picker-harvested and hand-shelled								
Golden Cross Bantam							*gm.*	*mm.*
Not sorted	....	88	11	1	12	67	.54	115
Sorted	....	82	15	3	18	72	.54	114
1947 crop, hand-harvested and hand-shelled								
Ioana								
Not sorted	19.2	91	9	0	9	83	1.20	...
Sorted	19.2	95	5	0	5	90	1.21	...

should be compared with Item 3, which was removed at the end of the sorting belt. The sorting process was followed by a slight drop in germination, but had no effect on seedling vigor.

Some of the canning companies, but none of the seedsmen, pass the artificially dried corn over an inspection belt before shelling it. As the ears shatter more or less there is always some shelled corn passing over the belt. In the Minnesota experiments (Table 12) shelled corn, as well as dried ears, was removed from the end of the inspection belt. The dried ears so removed and then hand-shelled (Item 3) showed a slight decrease below the control (Item 2) in both physical damage and germination. For some unknown reason the seedling vigor was better than that of the control. The dried and shelled corn removed from the inspection belt (Item 4) was much more severely damaged and had a much lower germination than the dried ears (Item 3). Whether the damage occurs at the time of shattering is not known.

In the Illinois experiment, ear samples were also taken from the dried-ear sorting belt (Table 15, Item 5, with Item 4 the control). No sample of accidentally shelled corn was taken. In this test the sorting belt seemed to cause no damage; both germination and seedling vigor were increased.

Table 15. — Germinability and Seedling Growth of 100-Kernel Samples of Sweet Corn Seed Taken at Various Stages of Processing, Illinois, 1946

Samples and stages at which taken	Kernels germinated (cold test)	Seedling growth	
		Green weight	Height
Hand-harvested		*gm.*	*mm.*
1. Hand-shelled	66	.84	140
Picker-harvested			
2. Hand-shelled	75	.58	129
Picker-harvested and rehusked			
3. Sorted (green-corn sorting belt), dried separately, and hand-shelled	72	.58	126
4. Same as 3 but dried in bulk and hand-shelled	71	.63	124
5. Dried in bulk, sorted (dry-corn sorting belt), and hand-shelled	82	.65	132
6. Same as 5 but sheller-shelled	56	.55	120

Damage Caused by Piling Sacked Sweet Corn

Upon removing piles of sweet corn seed stored in standard two-bushel seamless sacks, grease stains were noted on the new concrete floor of a warehouse. It was obvious that these stains had come from the sweet corn and probably resulted from the fats being pressed out by long continued pressure.

Table 16. — Physical Damage, Germinability, and Seedling Growth in 100-Kernel Samples of Sweet Corn Seed Taken at Various Points in a Storage Pile

(After one year of storage in the warehouse, Idaho, 1947 crop of Golden Cross Bantam)

Position of bag in pile, by tier	Kernels with external damage				Kernels germination		Green weight of seedlings
	None	Slight	Severe	Total damaged	By seedsman	At Urbana	
							gm.
Tier 1 (top)	24	76	0	76	28	25	.79
Tier 6	33	67	0	67	21	33	.79
Tier 11	28	72	0	72	23	25	.96
Tier 16 (bottom)	31	69	0	69	29	22	.72

Samples were taken from bags of sweet corn seed which had been stacked for one year without being disturbed. This stack of standard 2-bushel seamless bags, each containing 100 pounds, had been piled 16 bags high, which would mean that each sack in the bottom tier was under approximately 1,500 pounds pressure. Samples were taken from the top and bottom tiers and two between, as indicated in Table 16. Variations in physical damage will be noted, but they showed no particular trend. Germination and seedling vigor appear to be unaffected by position in the stack.

Relation Between Physical Damage and Life Span

Seeds which have a marginal germination do not have a long life span, and the seed trade usually disposes of such lots as soon as possible. Stevens[13] shows that the life span or longevity of certain legumes, grasses, millets, weeds, and flax is reduced when the seeds are injured. Apparently no similar information is available for sweet corn.

The seed lots from the 1947 crop were cold-tested for germination early in 1948 and were tested a second time early in 1949 after one year of storage. Commercial lots of sweet corn are rarely held over for more than one year, although it is known that small experimental samples will still germinate satisfactorily after five years if held under the proper storage conditions.

The germination percentages in 1948 and in 1949 after the seeds had been stored for one year are closely related to the percentages of damaged seeds. In 1948 the relationship was rectilinear, the regression coefficient being -0.887 ± 0.027. The estimated germinations were 95.16 ± 1.32 percent for the class having no visible damage and 6.46 ± 1.84 percent where 100 percent of the seeds were visibly damaged.

After one year of storage the 1949 germination tests showed a definitely curvilinear relationship with respect to visible damage. No explanation can be offered as to why the relationship changes from rectilinear in 1948 to curvilinear in 1949. The estimated germination in the class with no visibly damaged seeds dropped to 72.77 ± 3.52 percent in 1949, a decrease of 22.39 ± 3.76 percent. A decrease would also be expected in the class having 100 percent damaged seeds. The estimated germination in this class in 1949 was 6.63 ± 2.98 percent, an increase of 0.17 ± 3.51 percent over the 1948 germination. The difference is much smaller than the standard error and has no significance.

Summary and Conclusions

Physical damage due to mechanical harvesting. Samples were taken from sweet corn seed produced by five growers in Idaho and harvested with corn pickers. Samples of sufficient size for controls were harvested by hand from each field. Four of the paired samples were shelled by hand but received no further processing. The fifth pair of samples was milled and hand-picked. The four hand-shelled samples harvested with a picker averaged 9 percent damaged seed, whereas those harvested by hand averaged only 4 percent. The fifth pair of samples contained respectively 60 percent and 48 percent damaged seeds. The average reduction in cold-test germination due to mechanical harvesting was 14 percent, and seedling growth was considerably reduced by this method of harvesting. Another experiment in northern Illinois gave similar results.

The picker-harvested samples of the five pairs had moisture contents ranging from 30 percent down to 19 percent. The visible physical damage tended to decrease as the moisture content decreased, but germination percentages became successively lower.

The results show that mechanically harvested sweet corn seed is inferior in germination to hand-harvested seed. The experiments did not, however, establish the optimum moisture content — the content at which mechanically harvested sweet corn seed will suffer the least damage.

Endosperm cracks. Endosperm cracks were noted in all samples examined, apparently occurring during the maturation period, and as the pericarp was not involved they were assumed to be of internal origin. These cracks, when not accompanied by external damage, seemed to have no effect on germination. They were most frequently found in large, plump, smooth kernels. Cracked endosperms were not caused by artificial drying, as they were found just as frequently in the field-dried samples. Where endosperm cracks are associated with cracks in the pericarp, especially if the pericarp cracks are on the same axis as those of the endosperm, it may be assumed that the pericarp cracks are either of mechanical origin or that an impact force has caused a previously cracked kernel to break open.

No evidence was found that harvesting with a corn picker is associated with endosperm cracks either with or without physical damage. Combining is the source of a considerable percentage of externally damaged cracked seeds, but there is no evidence that such seeds had been cracked internally prior to harvesting, since the hand-harvested controls contained slightly more cracked endosperms not accompanied by other damage than the combined lots. The percentage of externally damaged cracked kernels in combined samples was practically the same as in the picker-harvested, machine-shelled lots. This type of cracking appears to be entirely dissociated from the normal endosperm cracks that are not accompanied by external damage. The corn sheller is also the source of a considerable percentage of externally injured cracked seeds.

Processing the seed through the fanning mill might be expected to reduce the percentage of externally damaged cracked seeds, but although there were some variations among the lots, the averages indicate no improvement.

Combining. Five fields of sweet corn were combined in 1946 and seven in 1947. The samples from all fields showed a very high percentage of damaged kernels accompanied by low germination. The extent of the damage was so great that combining cannot be recommended as a method of harvesting sweet corn seed.

Since the moisture content of the corn varied from 25.8 percent to 10.8 percent at harvesttime it was possible to determine whether damage could be reduced by combining the corn before it reached full maturity. Sweet corn kernels are exceedingly brittle and fragile when the moisture falls below 12 percent. Since hand-harvested, hand-shelled controls were taken in 1946, a valid comparison could be made. The seed corn harvested at 19 to 20 percent moisture showed less total damage, better germination, and greater seedling vigor, but the percentage of severely damaged kernels was higher. At 16 percent moisture and below, total damage increased progressively and was accompanied by progressive decreases in germination and seedling vigor. The experiments were repeated in 1947, but only one hand-harvested control was available for comparison. The limited data indicate that combining sweet corn when it had less than 15 percent moisture increased kernel injuries and reduced the germination as compared with combining at slightly higher moistures.

Comparison of mechanical harvesting methods. Combined corn is delivered by the grower in bulk as shelled corn which may have to be dried by artificial heat if the moisture exceeds 12 percent. Picker-harvested corn is delivered on the ear and may or may not be dried, depending on the moisture content, and then shelled by machine. Since the sheller is the source of considerable damage, the question then arises whether combine damage exceeds the cumulative damage due to the picker followed by the sheller.

The two years' tests show that the combine damaged the seed much more than the cumulative damage caused by the picker and the sheller. On the other hand, both the germination and the seedling vigor of the 1946 crop showed only slight differences between the combined and the picker-sheller samples. The 1947 combined samples had a much lower germination rate than the picker-sheller samples, but the seedling vigor was almost exactly the same. Combining cannot be recommended as a method of mechanically harvesting sweet corn seed.

Corn-sheller damage. The corn sheller is the source of severe physical damage to sweet corn seed. No other step in processing causes as much damage. Each of the comparatively numerous paired samples, one of which was hand-shelled and the other run through the sheller, showed the same results — the hand-shelled samples suffered little damage and had good germination while the sheller samples were damaged more or less severely and their germination was consequently impaired. Although no experimental data were secured concerning the effect of sheller adjustments, seedsmen have found that by making certain changes in the sheller and lowering its speed the physical damage to the corn can be greatly reduced. No corn sheller is yet designed specifically for sweet corn and much improvement is possible in this direction.

Experiments designed to test the relation between moisture content and sheller damage indicate that shelling at moistures as low as 9 percent should be avoided.

Processing. During the first year, the Idaho grown sweet corn was sampled both before and after processing through the fanning mill. Milling caused a slight average increase in the percentage of physically damaged seeds, but some lots having a relatively high percentage of initial damage were considerably improved. Germination was further impaired by milling, but seedling vigor remained practically unchanged.

During the second year, the Idaho grown seed was sampled not only before and after milling, as in the first year, but also after gravity cleaning and after it was elevated from the gravity separator. The fanning mill was responsible for slight increases in physical injury, but neither the gravity separator nor the elevator caused any further damage. Neither germination nor seedling vigor was consistently improved by processing.

Another experiment in Minnesota indicated that elevating to the mill and milling caused further damage to the seed, reducing the germination and seedling vigor. Ring-grading proved to be a source of severe additional damage. An Illinois experiment involving milling and gravity separation also gave the same results.

Although processing is a necessary operation in order to put sweet corn seed into marketable condition, it is not likely to reduce the percentage of damaged seeds or improve germination. In some installations the fanning mill may cause considerable damage. Whether or not processing is the source of additional damage seems to depend upon the type of equipment and conveyors as well as the care exercised in handling the seed.

Green-ear and dried-ear sorting. Sweet corn is inspected over a sorting belt when received at the plant, and sometimes another inspection is made after artificial drying. The equipment varies at each plant, and it is obvious that if the ears are roughly handled damage and impaired germination will result. Samples were taken at two plants, in both of which the corn is carefully handled. At one plant a slight amount of physical damage was noted, but with no accompanying drop in germination. At the second plant no record of physical damage was kept, but the handling incidental to sorting caused a slight drop in germination. Green-corn sorting equipment properly designed and operated is apparently not injurious to the ears.

Artificially dried ears were inspected over a sorting belt at two plants. The equipment at one plant was the source of slight damage and slightly impaired germination, but at the second plant germination was improved. No record of physical damage was kept at the second plant. At the first plant the shelled corn gathered at the end of the sorting belt was more severely damaged and had reduced germination compared with the unshelled ears. This would indicate that the damage may be attributed to whatever agent caused the shelling.

Warehouse piling of bagged sweet corn. Grease spots on a new concrete floor where sacked sweet corn seed had been stacked for an extended period led to the belief that germination might be impaired by long-continued pressure, which would be greatest in the bottom tiers. Samples taken from one pile stacked 16 bags high showed no evidence of impairment when they were taken from the first (top), 6th, 11th, and 16th (bottom) tiers.

Life span of physically damaged seeds. The 1947 Idaho grown crop was tested for germination early in 1948 and again a year later. The germination both years was closely related to the percentage of physically damaged seeds. The first year the relationship between germination and physical damage was rectilinear, but the second year it was definitely curved. The drop in germination after one year of storage was from 95.16 ± 1.32 percent to 72.77 ± 3.52 percent, a difference of 22.39 ± 3.76 percent in the class having no visible damage. No significant drop was noted in the class with 100-percent damaged seeds, but the germination both years was extremely low.

Practical suggestions. Careful handling of sweet corn seed, both in harvesting and in processing, is essential in order to hold physical damage to the minimum. For this reason hand-harvesting is preferable to mechanical harvesting. At the time of publication (October, 1952) the senior author, during a visit to Idaho, found that a premium was still being paid for hand-harvested seed.

Of the two available methods of mechanical harvesting, the corn picker does much less damage than the combine, which should be used as little as possible. If the combine must be used, the sweet corn should be harvested when the moisture content averages between 16 and 20 percent. The present types of corn pickers and combines are not designed for sweet corn. The damage they do can be minimized by properly adjusting the machine, but it cannot be reduced to where the seed is comparable to that harvested by hand.

Such factors as the make and model of picker or combine will cause variations in damage. Also, the speed and adjustment of the machine are probably rather critical, but no information on this point was secured in this study.

After the corn is harvested, each step in handling it causes some damage which is cumulative. Plant equipment such as elevators, conveyors, chutes, shellers, fanning mills, and gravity separators all contribute to the damage. The best type of elevator is one which moves at a slow speed and has relatively large buckets. The high-speed type with small buckets should be avoided. All chutes, elevator boots, and other points where the ears or shelled corn hit with appreciable impact should be lined with rubber. Rough handling, whether mechanical or by hand, should be avoided.

All corn shellers should be provided either with a variable-speed motor or a variable-speed transmission. Slow-speed shelling reduces injury. The sheller should not receive corn any faster than the shelled corn can be taken care of by the fanning mill. The cylinder which in some models is helical and in others is provided with pegs, usually consists of a rough casting. This should be smoothed. Some models have square pegs with sharp corners which ought to be rounded off. In some instances half the pegs have been removed without reducing the capacity of the sheller. In addition the screen should be removed and longitudinal bars provided.

Discussion with seedsmen brought out the suggestion that fanning-mill damage might be reduced by shortening the vibrating stroke of the screens and increasing the number of strokes per minute. One prominent seedsman feels that the fanning mill could be omitted and the seed cleaned by means of two gravity separators followed by a size grader. The ring type of grader causes severe damage.

Processing may be regarded as improving the superficial appearance of the sweet corn sample by removing dirt, chaffy seeds, large seeds, etc., but it does not reduce physical damage, nor does it improve germination.

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