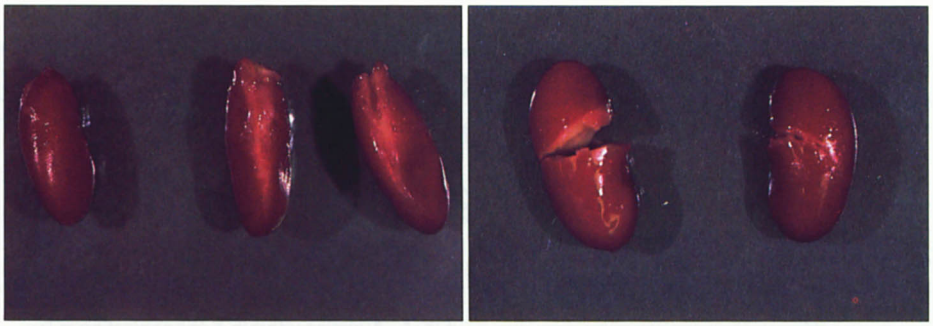

Both skin cracks (left) and transverse cracks (right) in kidney beans can result in rejection by canners and losses to growers.

Effect of harvesting and handling on damage in canned kidney beans

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Kidney beans become very susceptible to mechanical damage at moisture levels below 11.5% to 12%. It is important, therefore, to harvest early at higher moisture and to minimize mechanical impact during threshing and warehousing operations.

One of the most critical factors to canners of Dark Red Kidney beans is product appearance: a whole, uniformly shaped and colored bean, without skin cracks, transverse splits, or broken pieces. Every year, bean buyers scrutinize each lot of Dark Red Kidneys for sale through a series of soaking and canning tests. As much as 15% to 25% of the beans can be rejected for canning use annually because of transverse splits and skin cracks. Beans that fail to meet quality standards are substantially reduced in both price and marketability. After canning, a visual evaluation of bean quality is made at the cannery.

Skin cracks, also referred to as skin checks or mechanical cracks, are fractures in the bean seed coat caused by mechanical damage in harvesting and handling. They occur when the dry bean hits metal or other hard objects. Transverse cracks, or canning splits, are transverse splitting of the seed body. They become apparent after the bean has been subjected to high temperatures and pressures in canning.

The severity and extent of this problem prompted a 3-year study during the 1985-87 growing seasons. We conducted the study in cooperation with selected growers, warehouse operators, and a canning firm. Most of the work was done in San Joaquin County, but additional field observations were made in Colusa County. We evaluated harvesting and handling procedures to determine (1) their effect on skin cracks and transverse cracks in canned kidney beans and (2) the possibility of making changes to reduce the damage problems.

Field survey, 1985

The work began in 1985 with a survey of bean damage related to harvesting, handling, and cleaning. Four commercial bean fields were selected for the survey—two with Light Red and two with Dark Red Kidneys. The four fields were harvested by three different C. B. Hay three-cylinder, commercial harvesters.

Bean samples were collected at various points in the harvesting, handling, and cleaning process. In the field, samples were taken from the windrow and hand-threshed to obtain a benchmark for minimum mechanical damage. The pods were stripped by hand from the plants and put in burlap bags. Most of the beans were then removed from the pods by hand-rubbing. Any beans left were removed by opening the pods by hand. Samples were also taken from the harvesters at the same locations in the windrows. Each lot of beans was then followed through the handling and cleaning process, and additional samples were taken at various points.

The bean samples were divided into two subsamples. A soak test was run on one, and the percentage of skin cracks recorded. The second subsample was canned by a commercial canner and evaluated for both skin and transverse cracks.

The major increase in skin cracks occurred in all cases at the warehouse (table 1). The average value for skin cracks increased more than six-fold, from 4.8% as the beans entered the warehouse to 30.6% after cleaning.

Bean samples were also taken at various stages during the cleaning process at one warehouse and soaked to determine skin cracks. Two machines, the scalper cleaner and the bucket elevator, caused a substantial increase in skin cracks. Although further analysis of this source of damage is needed, it is clear that warehouse handling and cleaning procedures should be carefully monitored and controlled.

Survey results also suggested that bean damage in the warehouse is increased if bean moisture is low. It is possible that bean moisture levels are reduced during storage because of the hot dry conditions common in warehouses at that time of year.

The number two cause of skin cracks, as determined by the soak test, was the combine harvester. Skin cracks averaged 8.9% in samples taken as beans were transferred from the harvester to the truck. This compares with an average of 1.7% skin cracks for hand-harvested beans. Combine cylinder speeds and bean moistures varied from grower to grower, making it impossible to determine with certainty the effect of these two important variables on bean damage (table 2). A comparison of combine cylinder

TABLE 1. Soak test determination of damage in kidney beans, harvesting and handling survey, San Joaquin County, 1985

Point where sample taken	Skin cracks* Grower 1 Light Red	Grower 2 Dark Red	Grower 3 Dark Red	Grower 4 Light Red	Average
	% of sample				
Hand-threshed from windrow	3.1	1.6	.5	1.5	1.7
On combine	6.1	3.0	6.5	8.3	6.0
Combine to truck	8.5	3.5	9.0	14.5	8.9
Truck to pit	4.0	2.0	8.5	—	4.8
Out of scalper	8.5	5.5	13.5	—	9.2
Warehouse after cleaning	21.5	14.4	46.0	40.3	30.6

* Bean cracks were determined by soak test. Each value for percent cracks represents the average for four samples taken from a truckload of beans.

speeds showed no direct correlation to bean damage in lots tested in the 1985 survey.

Field studies, 1986 and 1987

Based on 1985 results, we decided to study in more detail the effects of bean moisture at harvest on cracking. The decision was also prompted by research done in 1961 and 1962 by F. L. Smith and D. G. Faris, of the Agronomy Department at UC Davis, on the effect of cutting dates (moisture content) on the cooking quality of Dark Red Kidney beans. They concluded that susceptibility to mechanical damage and splitting of the canned product increases as the average bean moisture content drops below the 50% level at cutting time. The recommendation was to cut the beans when their moisture drops to 50% and before it reaches 40%.

The first phase of our follow-up study was a 1986 observation trial conducted in cooperation with a grower in a field of California Dark Red Kidneys. Two cutting dates (high and low bean moisture) were combined with two threshing dates (high and low bean moisture) in each experiment. Moisture at cutting time was determined by oven measurement of in-pod bean samples; moisture at threshing time was determined from seed samples with a Motomco meter.

The treatments were: (1) early cut x early thresh, (2) early cut x late thresh, (3) late cut x early thresh, and (4) late cut x late thresh. This was a nonreplicated observation trial, because the grower's harvester was not available for conducting a replicated experiment. The harvester was a commercial, three-cylinder, C. B. Hay bean combine. Beans were also hand-threshed from the windrow to obtain control samples not exposed to mechanical threshing and handling.

The second phase of the follow-up study consisted of two replicated experiments in commercial fields during 1987. One experiment was in California Dark Red Kidneys, and the other in Montcalm Dark Red Kidneys. Each was a randomized split-plot design with four replications. Treatments were the same as in the 1986 observation trial. The harvester was a C.B. Hay "Jr.," two-cylinder machine provided by a grower. The no-load cylinder speeds of 260 rpm (1,498 feet per minute) for both cylinders were the same in all treatments in both tests.

During both years, bean samples were collected from each of the four treatments and divided into two subsamples. One subsample was subjected to a soak test and evaluated for skin cracks. The other was canned by a commercial canner and evaluated for both transverse and skin cracks.

In the 1987 study, we also evaluated the accuracy of a hand-held electronic moisture meter for kidney beans. We felt that a quick, accurate method of measuring moisture in the field would be helpful to growers wishing to harvest at higher moisture levels. A Dickey-john hand-held meter was compared with the Motomco Moisture Meter, the official meter used for bean samples.

Results

Although the 1986 results could not be analyzed statistically, they provided a general indication of the effect of the two harvest variables on bean damage (table 3).

Both skin cracks and transverse cracks were reduced by cutting at a high moisture level (shortly after bean maturity) and threshing at bean moistures of 11% to 12% or higher. The combined effect of late cut and late thresh was a four-fold increase in soak-test skin cracks, compared with early cut, early thresh (4.5% versus 20.5%). There was a similar trend in transverse cracks and skin cracks as determined from canned samples. Transverse cracks were much higher for late cut, late thresh than for early cut, early thresh. There were fewer skin cracks in the canned sample than the soaked sample, which probably reflects a healing of cracks in the canning process.

A comparison of bean damage between hand-threshed and machine-threshed treatments seems to indicate that the beans are predisposed to skin and transverse cracking as a result of the mechanical impacts they receive during machine harvesting and mechanical handling. Damage levels were very low in all of the hand-threshed treatments.

Harvest treatments and overall results for the 1987 California Dark Red Kidney experiment are shown in table 3.

A two-way analysis of the data shows how time of cutting and time of threshing individually affected bean damage (fig. 1). The two-way analysis compared the means of each treatment averaged across the effects of the other treatment. Of these two variables, only time of threshing had a statistically significant effect on bean damage.

Late threshing at low moisture increased skin cracks when compared with early threshing at higher moisture. Skin cracks in the soak test averaged 5.3% for early thresh versus 17.1% for late thresh. Skin cracks in the canning test averaged 13.4% for early thresh versus 21.9% for late thresh. These

TABLE 2. Combine cylinder speeds, harvesting and handling survey

Cylinder location	Cylinder speed			
	Grower 1	Grower 2	Grower 3	Grower 4
	ft/min			
No. 1	1,137	1,083	651	1,137
No. 2	1,137	1,060	708	1,152
No. 3	1,152	1,048	708	1,152

NOTE: Growers 1 and 4 used the same combine.

TABLE 3. Kidney bean damage , San Joaquin County, 1986 and 1987

Treatment: cut/thresh*	Moisture		Soak test	Canning test		
	Cut°	Thresh§	Skin cracks	Mech. skin cracks	Trans. cracks	Cannery rating¶
	%					
CALIFORNIA DARK RED KIDNEY BEANS, 1986						
Hand-threshed						
E/E	53	13.3	0	0	0.5	—
E/L	53	10.0	2.5	0	0	—
L/E	16	10.9	1.0	0	0.5	—
L/L	16	10.2	1.0	0	1.5	—
Combine-harvested						
E/E	53	13.3	4.5	1.0	0.5	—
E/L	53	10.0	10.5	2.5	5.5	—
L/E	16	10.9	11.0	1.5	5.5	—
L/L	16	10.2	20.5	5.5	33.0	—
CALIFORNIA DARK RED KIDNEY BEANS, combine-harvested, 1987						
E/E	48	14.1	6.3	11.2	7.6	2.3
E/L	48	9.8	17.3	20.5	7.9	2.5
L/E	11	11.5	4.3	15.2	6.2	2.3
L/L	11	9.7	16.9	23.2	8.4	2.7
MONTCALM DARK RED KIDNEY BEANS, combine-harvested, 1987						
E/E	55	15.5	19.0	12.0	0.25	1.8
E/L	55	11.6	33.0	14.8	0.5	2.0
L/E	19	16.9	11.0	7.5	0.25	1.9
L/L	19	12.0	31.0	25.5	0	2.3

* E = early. L = late.
° In-pod bean moisture, oven.
§ Seed moisture, Motomco meter calibrated to oven.
¶ Cannery rating: 1 = excellent, 2 = average, 3 = reject.

differences are statistically significant at the 99% level of probability. The effect of cutting time was not statistically significant, and there was no interaction between time of cutting and time of threshing. Neither threshing time nor cutting time had a statistically significant effect on transverse cracks in the canned samples.

A seed sample was taken from each treatment for germination and evaluation of cotyledons. Germination averaged 87% for early thresh versus 74.4% for late thresh (fig. 2), a statistically significant difference of 12.6% in favor of early thresh (99% probability level). The effect of cutting time wasn't statistically significant, and there was no interaction between cutting time and threshing time.

We tested the Montcalm Dark Red Kidney, a Michigan variety, to get an indication of varietal differences (table 3). The key results from this comparison are as follows: (1) transverse cracks in canned samples of the Montcalm variety were extremely low, 0.5% or less in each of the four treatments, suggesting that variety is a factor in the transverse cracking problem; (2) skin cracks were higher for late thresh than for early thresh; and (3) moisture at cutting time did not have a statistically significant effect on skin cracks.

We ran a statistical analysis of the combined data from both of the 1987 experiments. Time of threshing had a statistically significant effect on skin cracks both after canning and after soaking; late threshing times produced higher damage. The effects of cutting time were not statistically significant.

Our results show a sharp increase in skin cracks as bean moisture at threshing time drops below the 11.5% to 12% level (fig. 3). For example, skin cracks in the canned sample increase from 12% to 28% if threshing moisture drops from 13% to 9%.

The hand-held moisture meter used in the San Joaquin County tests gave moisture readings that were ± 0.3% of those taken with a Motomco meter. The hand-held meter thus appears to have potential for determining bean moisture in the field at harvest time.

Conclusions

Our research results showed that skin cracks, which result from exposure to impact, increased as beans moved through harvesting, handling, and cleaning operations. The greatest damage occurred in warehouse cleaning and handling. The combine harvester was the second largest cause of skin cracks.

Soak test data on skin cracks didn't correlate well with data on skin and transverse cracks in canned samples. The lack of correlation may be a result of the procedures and additives used in the canning process to minimize cracking.

Field experiments evaluating two harvest variables—bean moisture at cutting and at threshing time—confirmed our earlier results suggesting that low threshing moisture increases susceptibility to cracking. Moisture content of the beans at threshing time had a significant effect on skin cracks measured after soaking or in the canned product. Skin cracks decreased as threshing moisture increased. Our findings indicate that beans should be threshed at a moisture level above about 11.5% to minimize cracking.

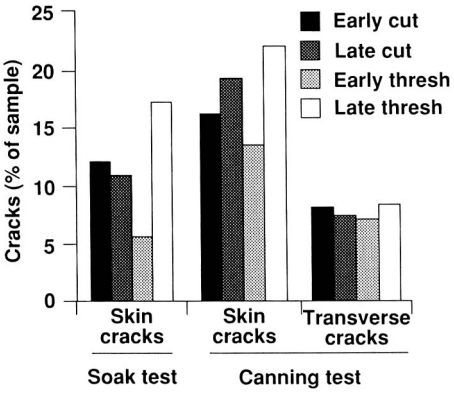

Fig. 1. Only time of threshing (moisture level) had a significant effect on damage in California Dark Red Kidney beans, 1987 tests.

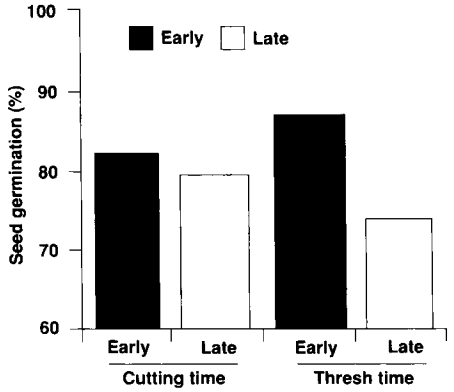

Fig. 2. Threshing time, but not cutting time, significantly affected seed germination in California Dark Red Kidney beans.

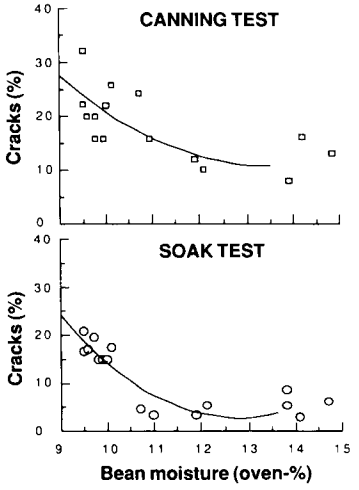

Fig. 3. Canning and soak tests both showed a sharp increase in skin cracks when beans were harvested at less than 11.5% to 12% moisture.

Although there were some differences between late-cut and early-cut treatments, they were not statistically significant in the 1987 California Dark Red Kidney experiment.

It was clear that the impact caused by mechanical threshing and handling of lower moisture beans predisposed them to transverse cracking. Neither cutting nor threshing moisture, however, had a statistically significant effect on transverse cracks in the canned sample. It was apparent, however, that variety and canning procedures also influenced transverse cracking.

The Montcalm variety had a consistently higher level of skin cracks in the soak test than the California Dark Red Kidney variety. On the other hand, Montcalm beans had a much lower level of transverse cracks—no higher than 0.5%.

Seed testing for germination and cotyledon defects supported the results of the canning and soak tests. There was a statistically significant advantage for early thresh compared with late thresh, and there was no statistical difference between early cut and late cut on seed planting quality.

It should be noted that the early-cut, early-thresh treatments, which produced significantly fewer skin cracks in our studies, also gets the beans threshed and out of the field 4 to 7 days earlier than late-cut, early-thresh treatments. This can be an important added advantage for cutting and threshing at higher moistures.

Bean damage results from the 1987 Colusa County observation test agreed quite well with the San Joaquin County data.

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