GRAIN QUALITY
Task Force
Fact Sheet #27
September 4, 1996
Purdue University

Harvesting, Drying, and Storing Frost-Damaged Corn and Soybeans

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Much of this year's late maturing corn and soybean crop in the Eastern Corn Belt could be severely damaged by an early frost. Options for harvesting, drying, and storing frost-damaged corn and soybeans depend on the plant's developmental stage when frost occurred. Frost damage will affect crops in at least five ways: reduced yields, dockage due to lower test weights or undesirable color, reduced harvest efficiency, wetter than desirable grain, and higher drying costs.

HARVESTING FROST-DAMAGED CORN

During corn harvesting, the wet corn kernels will be harder to thresh from the wetter-than-normal cobs. The tougher shelling and cleaning process in the combine will result in increased dockage and drying-storage problems due to broken kernels and foreign material.

To improve shelling efficiency when kernel moisture is above 30%, higher cylinder speeds and closer concave spacing will usually be required—with both conventional and rotary machines. High threshing RPM is the main culprit causing kernel damage and cob breakup, which can also lead to poor separation, and excess loading on the combine's cleaning shoe. So it is best to keep threshing cylinder or rotor speed as low as possible, or as low as recommended for the particular combine make and model. Start by reducing concave clearance. If this does not achieve satisfactory threshing, then begin to increase cylinder speed as required. Follow this same adjustment sequence even if corn is below 30% moisture. And, as (if) field-drying continues, remember to "back-off" cylinder speed as much as possible as the harvest season progresses.

Corn harvest under these "unusual" circumstances will also require increased awareness of the performance of the combine's separator unit, and the settings for chaffers, sieves, and the fan blast in the cleaning shoe. And don't forget cornhead adjustments, especially if the late-planted, under-developed corn has smaller ear and stalk sizes, short stalks with ears set closer to the ground, or excessive lodging.

One key factor for minimizing ear loss: the speed of snapping rolls and gathering chains must be reasonably well-timed to combine ground speed. Don't be tempted to run much faster than normal (due to reduced yield level) or much slower than normal (due to excessive lodging) without appropriate speed changes to the cornhead drive shaft.

To prevent ear loss and excessive shelling at the header, both the stripper plates and snapping rolls will need to be tighter (closer) for smaller stalk and ear sizes. The spacing between stripper plates should always be slightly wider at the back (about 1/4 inch). The feeder housing conveyor may also need adjustment to handle smaller ears. Such settings, however, can lead to plugging problems when normal-size stalks and ears are encountered—a dilemma in fields where the crop condition is extremely variable.

In down or tangled corn, expect more trouble and greater field loss. Operate the header lower (without picking up dirt or stones). Tilt the gathering points more downward. And operate at a slower ground speed. If corn is uniformly lodged in one direction, harvesting only in one direction may help. Increased aggressiveness of gathering chains can also help—retime, if needed, so the points on each side move together.

DRYING FROST-DAMAGED CORN

Milk Stage

Yield potential for corn frozen during the milk stage is low. Ears are difficult to pick and shell, kernel tips may stay on the cobs, and grain will be very chaffy. Therefore, green chopping or ensiling whole plants may be the only reasonable options for handling frost-damaged corn in this stage. Further information on harvesting corn silage is available in various publications, such as the National Corn Handbook NCH-49 *Corn Silage Harvest Techniques* from Purdue University, and Extension Circular 396 *Harvesting and Utilizing Silage* from Penn State University.

Dough Stage

Yields and test weights for corn frozen in the dough stage will be low. Test weights will likely be less than 50 lb/bu (a few years ago Michigan farmers and elevators reported test weights of frost-damaged corn of as low as 34 lb/bu). Corn will also be very wet; kernel moistures in the soft dough stage are 60-62%. Although dry-down of frosted corn in the field can require 4 to 9 extra days, the ears will eventually reach an acceptable maximum grain harvest moisture level of 35%. However, at this kernel moisture content the cob may be as wet as 56% (see Table 1). Cob and kernel moistures are equal at about 13%, while at higher kernel moistures the cob is generally significantly wetter. During this extended drying period field losses, due to stalk breakage and ear dropping, will increase especially in fields that have been severely damaged by corn borers. Ear molds will likely develop if warm ambient temperatures follow the frost.

Corn kernels in the dough stage turn brown and darken when exposed to high drying air temperatures. However, as long as kernel temperatures are kept below 120-140˚F, immature corn can be artificially dried using medium and low temperature drying systems. In medium temperature drying systems, corn is either transferred hot into a dryeration bin (at 17-18% moisture) or a storage bin equipped for cooling hot corn (at 16-17% moisture), or dried and cooled in column or bin dryers at no more than 140-160˚F. At the higher harvest moistures reasonable drying capacities can be maintained with immature corn by transferring it hot at 19-21% moisture into a second stage natural air/low temperature drying bin, or at 20-22% moisture into a second stage bin dryer with stirring devices.

Corn that was frost-damaged at the dough stage should be dried to kernel moistures below 14% for short-term storage during the winter, and sold and/or consumed by spring. Longer storage times will increase spoilage risks (“hot spots”) due to a greater spread of moistures among dried corn kernels within the grain mass. Although aeration will help to redistribute uneven kernel moistures, the higher amounts of broken kernels and cob pieces further increase storage problems.

Dent Stage

Corn frozen in the fully dented stage will contain 54-55% moisture. Test weights will be below normal. The same drying procedures as given under the “Dough Stage” should be followed. Generally, dry corn with test weights down to 50 lb/bu will not have drastically different feeding properties than corn of the same composition (protein, oil, starch) but with a higher test weight. On the other hand, corn with test weight below 50 lb/bu may contain hard-to-digest free sugars, less oil and incompletely

Table 1. Kernel versus cob moisture contents for corn.

Kernel moisture%	10	15	20	25	30	35	40
Cob moisture%	9	18	33	45	52	56	59

(Source: ASAE Standards D241.3)

developed protein. Extra fat and protein concentrates may be needed to restore animal performance.

Corn frozen in the late dent stage will have kernel moistures of about 40%, and be close to normal in test weight. Harvest should be delayed until kernel moistures drop below 30-35%. If the corn was black-layered prior to being frosted, it has already reached its physiological maturity, and harvest can occur following the normal fall drying period.

Harvest Moisture Trends and Impact on Drying

Table 2 summarizes the corn harvest moisture trend for Indiana. During years with record high harvest moistures, the field dry-down rate in Indiana on average is 1.29 points of moisture loss per week over the first 7 weeks. Dry-down virtually stops in early November at a harvest moisture of 23%. The 5-year average field dry-down rate in Indiana is 1.33 points of moisture loss per week over the first 6 weeks. Harvest moistures subsequently stagnate at 20% in late October and trend upward by 1-3 points of moisture in November. During years with record low harvest moistures, the field dry-down rate is on average 1.4 points of moisture loss per week over the first 5 weeks after which harvest moistures stagnate at 16% in mid-October and trend upward by 1-2 points during November.

Table 2. Statewide harvest moisture contents of corn for Indiana.

Date	Record High MC(year)	5-yr Avg (1991-94)	Record Low MC (year)
9/10	32 (84)	28	23 (91)
9/20	30 (84)	26	20 (91)
9/30	29 (92)	25	19 (91)
10/10	27 (92)	24	17 (87)
10/20	26 (92)	22	16 (91)
10/30	25 (84)	20	16 (91)
11/10	23 (92)	21	16 (95)
11/20	23 (92)	20	17 (82)
11/30	23 (92)	23	17 (82)

(Source: Indiana Agricultural Statistics Service)

Given the growing conditions this year (1996), the potential for frost, and the already cooler than normal weather, we can expect at best a fall with average to record high field harvest moistures. Thus, one would expect lower field dry-down rates of 1.29-1.33 points of moisture loss per week. Statewide average harvest moistures may be 25-30% in September, 20-25% in October, and 20-23% in November.

The impact of higher harvest moisture contents on typical column and bin drying systems are significant. For example, raising the harvest moisture from 20 to 25% increases the drying time and costs of drying to 15% moisture by about 82% in a typical column dryer (see Table 3). Comparing a 30 ft diameter low temperature drying bin filled to a depth of 20 ft with corn at 20 versus 24% moisture, the drying time increases by 145% in a layer-filled bin without stirring, and by 57% in a layer-filled bin with stirring (see Table 4). In a 27 ft diameter medium temperature drying bin with a 9 ft deep, stirred 20 versus 24% corn batch, drying time increases by 61% (see Table 5).

Table 3. Crossflow dryer performance and drying costs when drying corn in a single pass to 15% moisture (60 cents/gal LP).

Moisture Content (%)	Drying Time (h)	Drying Costs (cents/bu)
20	1.2	10.8
22.5	1.6	14.4
25	2.2	19.5

(Note: Air temperature = 50˚F; Ambient air relative humidity = 55%; Drying air temperature 180˚F; Airflow rate = 75 CFM/bu)

Table 4. Bin dryer performance and layer fill schedule when drying corn to 14% moisture.

Without Stirring:

Moisture Content (%)	Drying Time (days)	Drying Rate (bu/day)	Layers to Fill Bin
20	31	368	1
22	56	203	9
24	76	149	14

With Stirring:

Moisture Content (%)	Drying Time (days)	Drying Rate (bu/day)	Layers to Fill Bin
20	7	1584	1
22	9	1231	2
24	11	1008	3

(Note: Drying air temperature = 61.5˚F; Drying air relative humidity = 47.5%; Drying fan = 10.5 HP; Bin diameter = 30 ft; Final grain depth = 20 ft)

Table 5. Batch-in-bin dryer performance when stir-drying corn to 14% moisture.

Moisture Content (%)	Drying Time (h)	Drying Rate (bu/day)
20	49	2029
22	64	1553
24	79	1258

(Note: Drying air temperature = 100˚F; Airflow rate = 2.99 CFM/bu; Bin diameter = 27 ft; Grain depth = 9 ft)

Corn dried from a high initial moisture, such as frost-damaged, immature corn, reads up to two percentage points lower in moisture meters immediately after drying. It may take 4-8 hours for the internal moisture to equalize in a closed container before such a rapidly-dried corn sample will read close to normal. Normally, corn test weight increases during drying at about 1 lb per 4 points of moisture removal. However, based on data from Iowa State University, in immature and frost-damaged corn very little test weight increase can be expected during heated-air drying in high-speed column dryers. At best an increase of 1-2 lb/bu may be expected in natural air/low temperature and medium temperature bin drying systems.

Higher harvest moistures and the resulting lower drying capacities mean longer storage times in wet holding bins. This will increase the incidence rate of blue-eye mold problems during storage even when corn is dried to as low as 14%. See Purdue University's BP-49 *Blue Eye in Corn* or Grain Quality Fact Sheet 18 *Blue Eye in Corn* for more information.

STORING FROST-DAMAGED CORN

Low test weight corn is notoriously hard to store because it is more breakage-prone. As a rule of thumb, the storage life of light corn with large amounts of fines and broken corn may be half that of normal corn at the same moisture content. Light corn is also significantly harder to use in wet and dry milling operations. Processors will discount low test weight corn, and most will reject corn with test weights below 50 lb/bu.

Preferably, all corn should be screen-cleaned before binning to remove as much of the fine material, cob pieces and broken kernels as possible. Chaffy material and bees wings can be effectively removed from corn dried in column dryers by adding a suction system on the outlet auger of the dryer. An 8-inch duct and a small 1-1.5 Hp centrifugal blower can fill an old grain wagon or truck with bees wings in a day or two. Various commercial systems are available for retrofitting existing dryers, though homemade systems can be just as effective. An old livestock fan can be used to blow chaff and bees wings out of wet corn while it flows from the truck gate into an auger filling a drying bin.

Once in storage, the dried corn should be leveled by unloading some grain (coring the bin), which removes the peaks and some of the fines that concentrate in the center of the bin. Aeration cooling to below 35˚F should be accomplished as quickly after harvest as possible. Bin tops should be regularly checked for moisture condensation and mold spoilage. (See ID-207 *Maximizing Grain Quality and Profits Using S.L.A.M.* from Purdue University for more information.)

In regions where below freezing temperatures occur consistently during the winter time, wet corn at 30 - 35% kernel moisture can be harvested "frozen", put in bins or piles, and dried throughout the winter, or kept cold until weather warms in the spring when it can be dried. Table 6 indicates that the term "frozen corn" is actually a misnomer. For example, above 24˚F and below 32% moisture less than 5% of water in a kernel will actually freeze, while below 24˚F and above 22% moisture only about 20-40% of kernel water freezes. This means that no extra energy will be needed to "melt the ice" during drying. However, the higher moisture content and the lower winter air temperature significantly increase the time and costs of drying late-harvested wet corn. In Northern China it is common practice to allow high-moisture corn to "freeze" either in the field or after shelling on the farm, and delivered to grain elevators for mechanical drying throughout the winter months.

Table 6. Percent of frozen water content in corn kernels at various temperatures and moisture contents.

Corn Kernel Temperature (F)	Moisture Content (%) 21.9%	27.3%	32.0%
24	0.37	2.7	5.3
14	3.7	17.9	34.3
1.4	7.3	21.3	38.1
-10	8.9	27.4	36.6

(Source: Liu et al., 1995)

HARVESTING FROST-DAMAGED SOYBEANS

An early frost on soybeans can greatly diminish soybean yield, reduce bean size, and lower test weights because the beans may not have had enough time to fill completely. Given a cool September and an early frost, one can expect harvesting difficulties, and lower than normal protein and oil levels of the beans.

Whether early-frosted or not, late-planted beans in many fields will be quite "short" this fall—both in height and yield. And special consideration will be needed for combine operation and adjustment. Cutting as low as practical, as usual, will be necessary to get what little crop is there. Slow down if needed to avoid stones. Crisp, clean cutting is essential to minimize shatter and pod drop if bean and pod moistures are low. Keep cutterbar in tip-top shape at all times—knife sharpness, guard alignment and positive clip hold-down are needed.

Don't set and forget the reel! Adjust as conditions change, which may be needed in different parts of the same field—as plant height varies. Position the reel axis a few inches ahead of the cutterbar, with bats just low enough to catch bean tops and tip plants onto the platform. Bats should usually run 25-40% faster than ground speed depending on conditions—just fast enough to avoid pile-up on the cutterbar and excessive shatter and pod drop.

If beans are at "normal" harvest moisture content, keep cylinder speed to a minimum to avoid bean crackage—especially as beans dry out more in mid-afternoon. If beans are wetter than normal, more aggressive threshing action may be needed. If so, reduce concave clearance first (as with corn), then increase RPM until acceptable threshing occurs.

In addition to threshing, pay attention to other internal settings and adjustments for beans—including the separation and cleaning units. Bean loss out the back of the combine are usually not significant, but can be when conditions change, settings slip, or plugging occurs. Monitors can signal dramatic changes, but can't replace attentive, skillful operating and diagnostic expertise.

DRYING OF FROST-DAMAGED SOYBEANS

Field and weather conditions in the fall are usually such that field drying is sufficient to reduce the moisture content in soybeans to a safe storage level. However, wet and cool conditions this fall especially in fields that were planted late and/or frost-damaged may require harvesting of soybeans at 16 - 20%. Provided that soil conditions support equipment and soybeans are sufficiently defoliated, high moisture beans up to 18% can be successfully harvested and dried. Essentially, all grain drying methods (see Grain Quality Fact Sheet 15) are adaptable with some restrictions on the use of heat and handling practices.

Too much heat while drying soybeans causes excessive seed coat cracking, which results in splits. Seed coat cracking destroys the integrity of the seed and its protection during storage and handling. The key factor in avoiding splits is to keep the relative humidity of the drying air above 40%. This is a significant limitation on heat input and drying capacity. For example, 50˚F outside air with 80% relative humidity can only be heated to 70˚F in order to maintain humidity above 40%. Thus, high temperature drying with air heated to 160-180˚F or above is not an option when drying soybeans.

Medium Temperature Drying

The heat input in column and bin dryers can be restricted either by using short heat-on cycles, or changing the burner jets to a low-fire type. The resultant temperature rise from ON/OFF cycling is proportional to the percent of ON time.

For example, a burner with a minimum continuous fire rate of 40˚F rise will average about 20˚F rise if fired only 50% of the time. The same unit will average 10˚F rise if fired only 25% of the total ON/OFF cycle time. Utilization of a proportional timer that allows calibration of the total cycle by turning a percent dial can be used to control the length of the fire cycle. If splits are not as much of a concern, drying air temperatures limited to 120 - 140˚F to avoid heat damaged beans can be used.

Low Temperature Drying

Natural air above 60˚F and below 75% humidity will require no supplemental heat to remove 2 to 3 points of moisture from soybeans. However, natural air and low-heat drying in deep bins are slow processes. For example, a 24 ft diameter bin filled to 16 ft depth with 18% moisture soybeans will require about 23 days to complete drying to 13% during an average weather year. This assumes a 7.5 HP fan delivering 1.4 cfm/bu and a temperature rise of 10˚F.

Drying speed can be increased by reducing the depth in the bin (which increases the airflow per bushel), by adding more than 10˚F of heat, and/or by utilizing stirring devices. When adding supplemental heat, the 40% humidity requirement becomes the limiting factor. The limitation on drying capacity can be further reduced by only harvesting during the afternoon hours when moisture contents are closer to 16%.

Fans (and low heat burners) should generally be operated continuously as long as the average 24 hour air conditions are below 70 - 75% relative humidity and soybean moistures are above 15%. Generally, only little rewetting occurs, and then only in the bottom 6 to 18 inches. The balance of good weather during the day or week more than off-sets short high-humidity periods during the night, or 1 to 2 days of drizzle. Additionally, heat generated by the fan motor reduces the outside air relative humidity by 10 to 20 percentage points.

STORAGE OF FROST-DAMAGED SOYBEANS

Green Soybeans

Green soybeans contain chlorophyll that will cause oxidation of the oil, and thus greatly reduce shelf-life. Although the chlorophyll can be removed as part of the oil bleaching process, processing costs and refining losses increase.

Data from the University of Minnesota indicates that the surface color does not change significantly during storage. During a six month test of green versus normal yellow soybeans under safe storage conditions, monthly surface color readings changed little. However, the green beans appeared to be slightly mottled at the end of the six months. Others have observed that green beans will fade somewhat after 4-6 weeks of aerated storage. They will also fade in the field if the stem has not been killed. Problems with green beans are generally most noticeable to processors at harvest time, and tend to diminish with time. This may be due to the perceived lightening of the surface bean color, or due to increased co-mingling with other beans.

Storage and Discounting of Green and Immature Soybeans

A related study by the University of Minnesota revealed that when either green or yellow beans at 18% moisture were stored, no significant difference in the rate of respiration of green versus yellow soybeans was determined. Thus, green beans dried in the field or in dryers do not appear to present a greater storage risk. The general recommendation for storing clean, high quality soybeans in aerated storage for up to six months is to maintain moisture contents at 13% or lower. However, given the concern over high FM levels due to ineffective weed control this past spring in many soybean fields and the kernel-to-kernel moisture variations among beans, it is advisable to reduce storage moistures to 11-12% moisture or lower to be safe. It has also been reported that moisture readings will generally read low on immature (“butter beans”) soybeans fresh out of the field. Readings should stabilize after a few hours of equilibration at room temperature in a closed container.

Green and immature soybeans are included in the total damage factor in the U.S. soybean grading standard. In order to assign an official grade, the kernels suspected of being damaged must be sectioned or cut open and compared to the appropriate GIPSA line slide (SB-3.0 for green beans, SB-6.0 for immature beans). Since the revisions to the grading standard in 1986 the line for “greenness” on these slides is much lighter (and thus the definition for the amount of green present much stricter). Thus, although the surface color of the beans may fade during storage, once they are cut open for grading the amount of greenness may not have changed significantly during storage.

Although elevators and processors set their own discount levels, a typical discount may be 2 cents for each percentage point of total damage between 2.1-5%, 4 cents per point between 5.1-8%, and 6 cents per point above 8.1% total damage. It has been reported that during the fall of 1995 a number of elevators in Indiana, Illinois, Iowa, and Missouri rejected green soybeans at a damage level above 7% during the harvest season. Thus, the worst plan is to harvest green or immature soybeans wet and market them immediately at harvest. To reduce the potential for discounts further, it may also be desirable to screen out small beans before binning or delivery.

END USE QUALITY

Given the concern over the end use quality of frost-damaged corn and soybeans in the Eastern Corn Belt, producers, handlers, and processors may want to consider having corn and soybean samples analyzed for composition (starch, oil, protein in corn; oil, protein, fiber in soybeans). Samples can be submitted to various laboratories across the Corn Belt including the Purdue University Grain Quality Laboratory. Call 317-494-2285 for more information on Purdue’s Grain Composition Analysis Service.

SUMMARY

Proper harvesting, drying, and storage of frost-damaged corn and soybeans can avoid further field losses, minimize drying costs, prevent excessive deterioration during storage, and reduce discounts.

Acknowledgment

The authors wish to express their appreciation to Charles P. Woloshuk, and Richard Stroshine, both of Purdue University, and Bill Wilcke, University of Minnesota, for their review of this publication. We also acknowledge contributions and input to this Grain Quality Fact Sheet from the following individuals: Bob Nielsen, Purdue University; Ellsworth Christmas, Purdue University; Ralph Gann, Indiana Agricultural Statistics Service;

Marvin Paulsen, University of Illinois; Charles Hurburgh, Iowa State University; Bill Wilcke, University of Minnesota; Gary Hoette, University of Missouri. Additionally, the following sources were consulted:

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