Managing for Delayed Corn Crop Development

Summary

- Corn development and maturity may be delayed in seasons with late planting and/or cool summer temperatures.
- Freezing temperatures occurring before normal crop maturity (i.e., prior to kernel “black layer” development) may reduce corn yields.
- The impact on corn yield from an early freeze depends on the stage of corn growth, low temperature reached, duration of the low temperature period, and other factors.
  - Corn leaf tissue can be killed by a few hours near 32°F, and in even less time at temperatures below 32°F.
  - Temperatures below 32°F for several hours would likely kill all the leaves and may stop ear development.
- When grain is wet at harvest or impacted by an early, killing freeze, quality may be reduced. Subsequent harvest, handling, drying and storage of this grain requires extra care to prevent further quality reductions.
- Cylinder/rotor speed and concave clearance are the combine adjustments most critical to reduce grain damage and threshing losses with wet/immature grain.
- Drying temperatures need to be limited on corn of 25 to 30% moisture content or higher to avoid scorching grain and causing stress cracks that increase kernel breakage.
- Follow optimum grain storage procedures to minimize quality issues with wet or immature grain.
  - Screen grain. “Core” bin and level grain mass after filling.
  - Maintain aeration until grain mass equilibrates.
  - Monitor grain in storage by checking every two weeks.

Introduction

Corn maturity may be delayed by late planting and/or below normal summer temperatures. When slow corn development continues into the fall, corn grain may be significantly wetter at harvest. This can result in higher drying costs, mechanical damage to grain, and if a killing frost occurs before corn reaches maturity, yield reductions. This article discusses the possible impacts of cool temperatures and an early freeze on corn development, grain yield, field drydown, harvest, artificial drying and storage.

Effect of planting delays

Because growing degree unit (GDU) accumulation in early to mid-May is similar to GDU accumulation in late September when corn is maturing, each day of planting delay could result in a commensurate 1-day delay in maturity. However, corn is able to adjust to late planting by reducing its total GDU requirement slightly, by about 5 GDUs for each day planting is delayed beyond May 1. This means that corn maturity is usually delayed by only about 1 day for each 1.5 days of planting delay.

Effect of cool summer temperatures

“Cool” or “moderate” summer temperatures are rarely more than one or two degrees below normal when considering the entire summer period. Such conditions would result in a deficit of 90 to 180 GDUs that has to be made up in late summer/early fall. This would result in about a one- to two-week delay in corn maturity in the central Corn Belt, and up to three weeks in Northern corn-growing areas.

Corn maturity development

During the ear-fill stage of corn development, kernels progressively gain in “dry weight” as starch accumulates and displaces moisture in the kernel. Beginning at the “dent” stage (R5), a line of demarcation is visible between the hard, structural starch deposited in the crown of the kernel, and the milky content of the rest of the kernel (toward the tip). This border is known as the “milk line” (Figure 1).

![Figure 1. Progression of milk line in corn kernels from R5, or early dent (left) to R6, or physiological maturity (right).](image1)

Corn physiological maturity is complete when an abscission layer (“black layer”) forms at the tip of the kernel, halting further nutrient transport into the kernel and marking the end of yield accumulation (Figure 2).

![Figure 2. Progression of black layer development in corn kernels (at tip of kernels), indicating physiological maturity (R6).](image2)
As corn reaches the R6 stage, moisture content of the kernel is at about 30% to 35%. At this point, grain quality can still be reduced due to combining, drying and handling of wet grain, but the crop is no longer at risk of yield loss due to frost.

**Yield reduction caused by an early freeze**

The impact on corn yield from an early freeze is dependent on stage of corn growth, low temperature reached, duration of the low temperature period, and other factors (Lauer, 2004). A freeze event with temperatures below 32° F for several hours would likely kill all the leaves and may stop ear development entirely. Should this occur, growers need to determine the ear development stage at the time of the freeze to estimate percent yield loss (Table 1 and Figure 3).

**Table 1.** Potential grain yield losses after frost.

<table>
<thead>
<tr>
<th>Corn development stage</th>
<th>Killing frost (leaves, ear shank and stalk)</th>
<th>Light frost (leaves only)</th>
<th>percent yield loss</th>
</tr>
</thead>
<tbody>
<tr>
<td>R4 (Soft dough)</td>
<td>55%</td>
<td>35%</td>
<td>35-40%</td>
</tr>
<tr>
<td>R5 (Dent)</td>
<td>40%</td>
<td>25%</td>
<td>25-30%</td>
</tr>
<tr>
<td>R5.5 (50% kernel milk)</td>
<td>12%</td>
<td>5%</td>
<td>12-15%</td>
</tr>
<tr>
<td>R6 (Black layer/no milk line)</td>
<td>0%</td>
<td>0%</td>
<td>0%</td>
</tr>
</tbody>
</table>

Derived from Afuakwa and Crookston (1984)

Corn leaf tissue can be killed by a few hours near 32° F, and in even less time at temperatures below 32° F. At temperatures between 32 to 40° F, the extent of damage may vary considerably, depending on microclimate effects, the aspect of the field slope, and whether or not atmospheric conditions favor a radiation frost. In such cases, it is possible that only upper leaves in the canopy would be killed, while leaves lower in the canopy survive and remain photosynthetically active. If the leaf tissue is killed, it will be evident in 1 to 2 days as a water-soaked appearance, which will eventually turn brown. Therefore, it is best to wait 5 to 7 days before making an assessment of percentage leaf damage for purposes of estimating yield reduction.

**Corn kernel drydown**

The period from black layer to harvest is defined as the “drydown” period. Kernel moisture loss during the drydown period is entirely due to evaporative moisture loss affected by air temperature, relative humidity and wind. When corn reaches maturity late in the season, field drydown is slower due to cooler air temperatures. For example, according to Ohio State University Extension, corn drying rates of 1% per day from black layer to harvest are:

- **Stage R5**
  - Beginning Dent
  - Milk line starting to appear at top of kernel
  - Grain Moist.: ~50-55%
  - ~400 GDUs remaining to maturity
  - Yield loss from killing frost at this stage: ~35-40%

- **Stage R5.25**
  - 1/4 milk line
  - Grain Moist.: ~45-50%
  - ~300 GDUs remaining to maturity
  - Yield loss from killing frost at this stage: ~25-30%

- **Stage R5.5**
  - 1/2 milk line
  - Grain Moist.: ~40-45%
  - ~200 GDUs remaining to maturity
  - Yield loss from killing frost at this stage: ~12-15%

- **Stage R5.75**
  - 3/4 milk line
  - Grain Moist.: ~35-40%
  - ~100 GDUs remaining to maturity
  - Yield loss from killing frost at this stage: ~5-6%

- **Stage R6**
  - Black layer or “no milk line”
  - Grain Moist.: ~30-35%
  - 0 GDUs remaining to maturity
  - Yield loss from killing frost at this stage: = 0%

**Figure 3.** (Right side of page) Kernel growth stages and approximate grain moisture, GDUs to maturity (black layer or “no milk line”), and yield loss from a hard, killing frost that stops kernel development.
day in September will usually drop to \( \frac{1}{2} \) to \( \frac{3}{4} \)% by early to mid-October, \( \frac{3}{4} \) to \( \frac{5}{6} \)% per day by late October to early November, and only \( \frac{1}{4} \)% or less by mid-November (Thomison, 2011).

DuPont Pioneer research indicates that it takes approximately 15 to 20 GDUs to lower grain moisture each point from 30% down to 25%, 20 to 25 GDUs per point of drydown from 25% to 22%, and 25 to 30 GDUs per point from 22% to 20% (DuPont Pioneer, unpublished). If a hard freeze occurs that stops corn development prior to maturity, these field drying rates may be affected. For example, corn frosted as early as the dough stage may require 4 to 9 extra days to reach the same harvest moisture as corn not frosted (Maier and Parsons, 1996).

Grain moisture at harvest affects the time and cost required to dry the grain to acceptable storage moisture levels, as well as grain quality. Wet grain can incur damage during combining, handling and drying. If grain quality is significantly reduced during harvest and drying, allowable storage time is also reduced, dockage may result, and losses of fines and broken kernels can trim bushels of saleable grain.

**Pre-harvest tips**

In seasons with delayed corn crop development, many growers will have to deal with wetter than normal grain at harvest. Several steps can be taken prior to harvest to make this job go more smoothly (Lauer 2009).

- If you have recorded silking dates by field, use these notes to predict the order in which fields will reach black layer and harvestable moisture. This will help in setting up a harvest schedule. However, be sure to base the schedule on crop condition as well as grain moisture, taking into account stalk quality and insect or disease damage.
- Where such options exist locally, consider harvesting (or selling) more of your crop as silage or high moisture corn.
- Explore locking in a price for the additional fuel needed for grain drying. Compare the fuel costs vs. possible dockage for shrink if wet corn is delivered to the elevator.
- Consider some field drying if grain moisture levels are high, but don’t wait too long! Wet field conditions can keep combines out of the field as crops deteriorate, and snow and ice may increase harvest losses due to ear droppage and stalk breakage.

**Harvest management of wet / immature grain**

**Combine Adjustments:** Grain above 30% moisture can be difficult to remove from the cob and is easily cracked and damaged by over-threshing in the cylinder or rotor of the combine. Cylinder/rotor speed and concave clearance are the adjustments most critical to reduce grain damage and threshing losses. At high grain moisture growers may have to strike a balance between damaged grain and higher than normal grain loss from unshelled cobs.

With very wet grain, some ag engineers suggest beginning harvest with combine settings that would likely under-thresh a typical, lower moisture crop (Brook and Harrigan, 1997):

- Set cylinder/rotor speed near the low end of the suggested range.
- Set concave clearance near the widest recommended setting.
- Open the chaffer and sieve to the maximum recommended openings.
- Check with the combine manufacturer for machine-specific recommendations. (Combine mechanics or other dealership staff are often a good source for this information).
- Begin with above settings but check immediately and re-adjust as necessary to achieve best results. Continue to check and readjust as crop conditions change.
- For more tips on combine settings for wet grain, go to: [http://www.ipm.msu.edu/pdf/HarvGrain&Dmg.pdf](http://www.ipm.msu.edu/pdf/HarvGrain&Dmg.pdf)

**Drying wet / immature grain**

Properly drying very wet, lower quality corn is essential to avoid further quality reductions. Growers should screen lower quality grain prior to drying, using a rotary screen, gravity screen or perforated auger housing section. This will help prevent foreign material and broken kernel fragments (or “fines”) from blocking air flow essential to uniform grain drying and storage. Next, growers should plan to dry lower quality grain 1 or 2 points lower than the normal 14 to 15% often recommended for long-term storage. This is because of greater variations of moisture content within the grain mass and increased physical kernel damage and broken cobs, which could magnify mold problems.

According to extension specialists at North Dakota State University, energy efficiency is increased at maximum temperatures in high temperature drying systems, but these temperatures could scorch very wet or immature kernels. In addition, high temperature drying causes stress cracks in the kernel, which allows more breakage during handling and storage. The amount of stress cracking depends on initial grain moisture, rate of moisture removal, maximum grain temperature reached in the dryer, and rate of grain cooling. Therefore, drying temperatures need to be limited on corn of 25 to 30% moisture content (or higher).

With natural-air or low-temperature drying systems it will be difficult to adequately dry corn wetter than 26% grain moisture. The maximum moisture content for natural air drying of corn is 21 percent using an airflow rate of at least one cubic foot per minute per bushel of corn (Hellevang, 2009).

### Consider these investments to help manage harvest, drying and storing wet, lower-quality grain:

- Moisures tester – $300 to $2000
- “Bee’s wings” and fines cleaner – $1500 to $3000
- Moisture controllers for the grain dryer – $2500 to $5000
- Temperature cables in the grain bin – $2500 to $5000
The University of Wisconsin gives these additional grain drying tips (Lauer, 2009):

• Fine-tune your dryer so that over- or under-drying does not occur. Over-heating the grain in the dryer or filling the bin too fast for drying to occur will increase costs and decrease grain quality, thus reducing profitability.

• Hire and train the skilled labor that will be required to monitor dryers, fans, augers, and other equipment during the drying process.

To reduce drying time and speed harvest, some growers have discussed partially drying and aerating corn while holding it for further drying after completion of harvest. This strategy requires skill and intensive management, especially with low-quality grain. For more tips on grain drying to maximize grain quality, see Appendix I on page 5.

**Storing wet / immature Grain**

Low test weight, lower quality grain is harder to store because it is breakage-prone and subject to mold and “hot spot” occurrence in the bin. Because the storage life of this grain may be only half that of normal corn at the same moisture content, consider selling this grain early rather than storing long-term.

To minimize storage problems, begin by screen-cleaning grain before binning to remove as much of the fine material, cob pieces and broken kernels as possible. After filling, “core” the bin (remove up to 10% of the total bin capacity) to eliminate broken kernels and fines that accumulate in the center. Next, level the grain in the bin to minimize moisture accumulation at the top of the grain. Finally, cool grain as soon as it is dry to within 10 degrees of air temperature, and continue to aerate for 10 to 14 days to ensure grain moisture “equilibrium” has been achieved.

Monitoring lower quality grain on a twice-monthly basis is essential to ensure that grain condition is maintained. For more tips on grain storage and monitoring procedures, see Appendix I and II on page 5.

**Conclusions**

When growers have fields of wet or immature corn in October, deciding when to start combining is difficult. Experiences during several late harvest years suggest that excessive delays may not be a good idea, for these reasons:

• Delaying starting may also delay finishing at a reasonable date. Most growers require about 6 weeks to harvest the entire crop in a normal year, and another 2 weeks to complete fertilization and tillage. This means growers must start the first week of October to finish before December.

• Drying corn with ambient temperature in the 20s requires more energy than drying corn with ambient temperatures in the 40s.

• Harvesting in the winter limits fall tillage and fertilization, reducing options for crop rotation the following spring.

• Finally, there are safety concerns and potential for increased damage to machinery when harvesting on frozen soils and driving on snow or ice-covered roads.

For these reasons, timely harvest is usually advantageous, even though drying costs may be increased.

**Credits**


**References**


Appendix I - Optimal management practices for drying and storage (John Gnadke, AGS, Inc.)

Continuous Flow Grain Dryers

<table>
<thead>
<tr>
<th></th>
<th>Operating Plenum Temp.</th>
<th>Grain Temp. Maximum</th>
</tr>
</thead>
<tbody>
<tr>
<td>Food Corn</td>
<td>130 – 140 F</td>
<td>100 F</td>
</tr>
<tr>
<td>Wet Milling Corn</td>
<td>170 – 190 F</td>
<td>130 F</td>
</tr>
<tr>
<td>Livestock Feed</td>
<td>170 – 190 F</td>
<td>130 F</td>
</tr>
</tbody>
</table>

1To maintain high capacity and grain quality, keep your grain dryer clean!  
2Temperature ranges must be within 15 – 20 F anywhere within your plenum.

InBin Drying

InBin with stirring equipment - for best results, the operating temperature should be 95-105° F.

InBin with low temp heaters (LP or electric) should be operated on a Humidity Controller. This will condition the ambient air to the proper relative humidity (RH). For best results, the RH setting is approximately 70%.

Natural Air InBin

Fan Size: 1.5 CFM of air per bushel.
Clean grain to 2% or less BCFM.
Wet grain moisture: 20% for best results
Roof Venting: 1.5 sq. ft. per fan HP.

InBin Continuous Flow

Clean Grain to 2% or less BCFM.
Operating Temp: 130-160° F.
Keep grain depth from 4'-6' for highest capacity of this unit.
Proper roof vent is a must (1.5 sq. ft. per fan HP).
Grain discharge temp will be 95-115° F.

InBin Cooling

If stress fractures are a part of a grain contract, take special steps to prevent this from occurring (grain temp: 95-105 F).
If wet grain is 20% or less, steep for 12 hours before cooling.
If wet grain is 22-24%, steep for 18-24 hours before cooling.

If ambient air temps fall below 40 F at night, then DO NOT operate cooling fans.

Operating cooling fans at 40 F or above will reduce stress on grain (may require day-time operation of these cooling bins.)

Cooling Grain to Proper Storage Temperatures

Cool grain to 35 F (DO NOT freeze food corn as it can cause additional stress on the grain.)
Freezing grain at 18-20% moisture can cause ice crystals to form on the kernels.
When temperature rises in Feb. or March, ice crystals will melt and cause grain to go out of condition very quickly.

Final Note

All stored grain should be checked every two weeks!

Appendix II - Grain storage principles (John Gnadke, AGS, Inc.)

Initial Storage

- Dry grain to the “equilibrium” moisture level (15%).
- Use LOW temperature drying to minimize stress cracks.
- For ideal grain storage, target 2% cracked/broken.
- Level the grain in the bin to minimize moisture accumulation at the top of the bin (core or use a mechanical “spreader”).
- “Core” the bin by removing 10% of the total bin capacity after filling to remove fines that accumulate in the center.
- In the coring process try to keep the bin as level as possible.
- Cool grain as soon as it is dry to within 10 degrees of air temperature.
- Aerate the grain for 10 to 14 days after filling to ensure grain “equilibrium” has been achieved – based on ¼ CFM.
- Monitor grain temperature and moisture regularly (minimum every two weeks, preferably on a continuous basis with “in-bin” probes and visual inspection).
- Monitor grain for insect and rodent infestation on a regular basis (minimum every two weeks).

Long-Term Storage

- Keep cooling grain on a regular basis until grain temp reaches 35° F. Never cool grain below 32° F.
- Check grain regularly (minimum every two weeks) while in storage. 1) Lock out power. 2) Climb into the bin, look, feel, smell, and walk on the surface. 3) If automated controls are used, bi-weekly inspections are still recommended to ensure controls are functioning properly.
- Aerate on a regular basis while in storage, discontinue fan run-time when temperatures fall below 32° F.
- Additional questions call John Gnadke 515 964-9885.