Science Societies

Is freeze damage ever as bad as we think it will be?

By Megan Sever

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Photo by Carrie Knott.

> The amount of damage to both plants and potential yield after a hard freeze depends on a lot of different weather factors, plus the life stage of the plant, topography, varietal hardiness, and what happens after the freeze, among other factors.

Farmers in southern Texas don't usually worry too much about freezing temperatures destroying their winter wheat. But last February, they were walloped by an unimaginably intense winter storm. Winter Storm Uri froze North America from the Pacific Northwest into Mexico between February 12 and 21. Temperatures in Houston and San Antonio reached low single digits and snow blanketed the area. In College Station, temperatures reached –2°F. Farther north in the Texas Panhandle, temperatures bottomed out at –15°F. The frigid temperatures stayed low for nearly a week. Farmers panicked. Citrus crops, vegetables, and grains were all endangered. Texas A&M extension specialists fielded dozens of calls from farmers worried their crops were destroyed.

One such extension expert, small grains and oilseed crops specialist **Fernando Guillen-Portal** of Texas A&M AgriLife Extension, says he told farmers then what he tells them every time there's a hard freeze: "Wait."

That's because although you can often assess some freeze damage immediately after a cold night, the true extent of damage—and potential yield loss—will take at least a week to be revealed.

Heavy frost. Photo by USDA-NRCS.

Sure enough, though initial signs for Texas winter wheat looked as bleak as the snow-covered horizon, for the most part, the crops came through just fine. A potential catastrophe for Texas grain farmers was averted.

The lessons to be learned from this storm about freeze damage are myriad, such as what factors go into determining how badly a crop may be damaged and what to look for to determine damage and under what time frame.

At a macro level, two factors affect freeze damage most: weather and stage of growth of the crop. But before getting into those, let's explore what freeze even means and define one very important differentiator: freeze damage versus yield damage.

Different Types of Freeze

First of all, frost and freeze are not the same thing. "A frost is when we get a visible frost. A freeze is when the air temperature drops below freezing," wrote Mark Longstroth of Michigan State University Extension in an extension **blog**. "Sometimes we get frost when the temperatures are above freezing, and we often have a freeze without frost. It has to do with the amount of water in the air." A frost is that silvery icy coating on the exterior of plants when it's chilly and there's a lot of water in the air. A freeze is when it's cold enough that ice crystals can form inside plants—below 32°F.

Usually, when we're talking about "frost damage" in crops, we mean "freeze damage," says **Carrie Knott**, an agronomist at the University of Kentucky Research and Education Center at Princeton. Freeze damage is the most destructive.

Two different types of freeze exist: advection and radiation. **Advection freezes** occur when cold dry air masses 450 to 3,000 feet thick roll through with windy conditions. Skies are often cloudy, and temperatures can be below freezing during the day. In these cases, plant tissue is usually warmer than the air, and damage occurs when warmer air radiating from the soil is carried away by wind—that warm air around the plants rises and cold air comes in from the side, freezing the plants.

Radiation freezes occur on dry clear nights with much thinner cold air masses, like 30 to 200 ft thick, sinking to the ground and a warmer layer rising above (called an inversion) as the warmth from the day blows off into the night sky. Daytime temperatures are often above freezing. Overnight, the coldest air sinks to the lowest spots, and there's virtually no wind. Radiation freezes often follow a cold front moving through.

Photo by Joe deSousa.

Freeze protection systems don't do much to protect plants from advection frosts. Such systems usually provide a decent level of protection in radiation freezes.

Extension services usually list the first and last days of a season when a frost or hard freeze is likely. It's important to know for your exact location, since in the Great Plains and westward, growing seasons and first/last freeze dates may change by as few as 15 miles.

But whichever type of freeze we're talking about, the weather and the growth stage matter most in terms of freeze damage.

Variable 1: Weather Conditions

For crop damage, freezing conditions occur not just when the thermometer hits 32°F, but also when it stays at a lower-than-freezing temperature for some duration. "Say I had a field that dropped to 28 degrees, but it only lasted for 30 minutes versus a field that dropped to 29 [degrees] but sat there for six hours. I might have more freeze damage from the latter case than the previous," says **Calvin Trostle**, an extension agronomist and professor at Texas A&M AgriLife Extension.

A general rule of thumb, Knott says, is that it takes two hours of freezing temperatures to result in freeze damage to crops. But there's ample evidence of colder temperatures and longer durations that didn't result in freeze damage, she says. "It's perplexing."

Besides temperature and duration, wind speed is also critical, Guillen-Portal says. Other weather-related variables that affect freeze damage include:

- relative humidity
- difference between soil and air temperature
- soil temperature
- air temperature before and after the freeze event
- how rapidly temperatures rise after the freeze event
- moisture levels in the soil and plant prior to the freeze

Moisture levels, including drought, can also affect freeze damage. Moisture within the plant can give it more capacity to handle cold. A strong canopy can also protect it, which a drought-stressed plant might not have. However, moisture within a plant can also make it more susceptible to freeze injury if the cold stays long enough to freeze

that moisture within the plant. In that case, “you could potentially have even heavier freeze damage,” Trostle says. Any stressed plant is more susceptible to freeze injury than a happy plant, he adds.

Variable 2: Growth Stage

Stem injury can lead to severe lodging in wheat. Photo by Calvin Trostle.

The temperature threshold for when freeze injury begins for a crop depends on growth stage. For grass crops, such as wheat and corn, the worst damage typically happens if a freeze occurs after the growing point emerges above the soil surface, Knott says. Flowering stage is the most delicate.

For example, at the flowering stage of wheat, damage occurs at 32°F and impact on yield is usually severe. Meanwhile during the tillering stage, damage doesn’t tend to occur until temperatures hit about 12°F for at least two hours. And even then, the impact to yield is usually minimal. During Winter Storm Uri, most of the Texas winter wheat was still in the jointing phase, or with the growing point near or even below the soil surface farther north in Texas. This is largely why the damage to crops was minimal, Guillen-Portal says. Since growing points were largely unexposed, he notes, they were protected by the soil and snow, which provided an insulating effect. When growing points just reach above the surface, they’re much more susceptible to freeze, “and the level of damage is going to be determined by the magnitude of the freezing temperature and the duration of the event,” he says.

Plants are also extremely vulnerable during pollination, Guillen-Portal says. Freezing temperatures can make the pollen grains sterile, he says, meaning there’s no seed

formation, which would obviously have a significant impact on yield.

Compared with a healthy wheat spike on the left, the sterile wheat spike on the right was not bleached by a freeze event and is a paler green color, has dead anthers and stigmas, and did not completely emerge from the stem. Photo by Carrie Knott.

Timing of when a freeze strikes is key for any crop, not just wheat. But crops damaged by freeze early in the growing season can compensate, especially if growing conditions for the rest of the season are ideal. Crops are resilient and, depending on the variety, may have a good chance to recover, Guillen-Portal says. We saw from Winter Storm Uri, for example, that Texas varieties of wheat were far more resilient and resistant to cold than previously suggested. This is also why it's important to wait to see how damaged your crop is, he says.

Assessing Damage

"Initially assessing freeze damage can be pretty subjective—even a wild guess," Guillen-Portal says.

Trostle agrees. But in time, he says, you do learn what you're looking for, and you learn that what you see in the field may not be what is actually there. "A colleague of mine once said, 'wheat freeze injury is never as bad as it looks.' I have learned that wheat freeze injury is *usually* never as bad as it looks, but sometimes it is, and once in a while, it is worse," Trostle says. "There is no substitute for walking into a field and cutting plants."

Damage can only be estimated by walking entire fields, Knott says. “It is vitally important to check different elevations in the field: Hilltops, side slopes, and low points can have different levels of damage.” Freeze damage can vary significantly within and between fields, she says, which is why damage assessments are so laborious.

But before we even get too far into how to assess damage, Guillen-Portal says, “we need to be careful when we say ‘freeze damage.’” Looking at burned leaves in the field, for example, you can tell what happened at that moment, he says—you can tell there were leaves damaged by freeze. “But how can you say what’s going to be the effect of that freeze damage on the final yield at harvest? It’s really hard to infer because you don’t know what’s going to happen from that moment until the plant matures.” The ultimate effect on yield, he says, “will depend to a great extent on what happens until the plant is ready to harvest.” That’s because of plants’ resiliency and ability to compensate for injury.

For example, a field may have 50% freeze damage and look really bad, Trostle says. Maybe the main stems are even lost. But with the right timing and conditions, the outer tillers can make up for that main stem loss, he says, and ultimate yield loss may end up at less than 25%.

Healthy wheat anthers prior to pollen shed are turgid, shiny, and bright green (left panel). Damaged anthers are shriveled and are white (center panel) or dark yellow (right panel). Photos by Carrie Knott, University of Kentucky.

Although assessing final damage can be really hard, there are qualitative ways of estimating damage and potential yield losses—with experience. Splitting stems to assess the growing point is one such way,

Trostle says. But you can also tell the growing point is dead if the latest emerging leaf from the whorl is dead, he says. At that point, you might know that your crop is now hay and not grain.

Knott has been working on quantitative ways to estimate yield reduction for freeze-damaged wheat. She recently published two papers in *Crop, Forage & Turfgrass Management* with analyses that provide yield reduction estimates based on field observations of freeze damage.

You start with the level of freeze damage—which the farmer or consultants would have to determine with boots on the ground—and then you can estimate the final grain yield. This is meant to be just one tool that a producer could use to determine potential profitability of the crop, not an end-all-be-all. But "I think [our] estimates are about as close to real-world scenarios as you can get," she says. "And they match anecdotal observations from farmers, consultants, and other scientists." That said, she notes, so many variables could impact final grain yield of wheat following a freeze event. Which again, is why farmers need to wait at least a week if not longer before assessing for potential yield loss. (Don't wait too long, though, Trostle advises: "If you wait too long, you might miss a critical decision in crop management," such as changing fertilizer management based on a freeze or deciding whether to continue with the crop to maturity.)

Ultimately, Guillen-Portal says, yield will be defined by three principles: number of tiller heads, number of seeds/kernels per head, and the weight of the seeds.

Photo courtesy of Adobe Stock.

So What's a Farmer to Do?

First, Guillen-Portal says, wait. Then, if needed, wait some more.

Then, go look at your fields. Walk your property, Knott says. Maybe call in an expert for help—your extension specialist, for example, or your CCA. Maybe your crop insurance agent if they are trained.

Take **Texas A&M's** or **Kansas State University's** guides to wheat freeze injury out into the field with you. It tells you what to look for, how to test for freeze damage and potential yield loss, and how to assess economic losses.

If your crop is something other than wheat or sister small grains, check with your CCAs and extension specialists for whether similar guides exist. Purdue has a **great resource**

for freeze damage in corn, in the form of dozens of articles written by "King Corn" himself, Bob Nielsen. The University of Minnesota has a **guide to freeze damage in soybeans**. Kansas State offers a **guide to fall freeze damage** in summer grain crops that covers corn, soybeans, sunflowers, and sorghum.

Also, get to know your state climatologist. While first/last freeze dates have been known for decades, they are changing. And though the climate overall is warming, extreme events like Winter Storm Uri are becoming even more frequent. Kentucky has seen an increase in freeze events in the last 10 years, Knott notes. "I am concerned that this trend may continue because variability in temperatures is predicted to continue," she says. The more you know about the changing climate, the better prepared you and your crops can be. After all, farmers are on the front lines.

The good news is that not only are crops resilient, but farmers are too.

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