University of Kentucky
College of Agriculture, Food and Environment
Cooperative Extension Service

Identifying Damage and Estimating Yield Reductions following a Spring Freeze in Winter Wheat

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Wheat, and other small grains, can be damaged when air temperatures fall below certain thresholds for two or more continuous hours (Table 1). These temperatures do not necessarily mean that damage will occur. Rather, these temperatures are general guidelines of when damage may occur. It is important that the crop be scouted to determine the extent of the damage, if any.

When identifying freeze damage in wheat (and other small grains), it is essential to wait until high temperatures are at least 40°F for a minimum of five to seven days. Depending on the time of the year several weeks may be required for a total of seven days with high temperature of at least 40°F to occur. Inspecting fields too early may result in underestimating the freeze damage. Symptoms will continue to develop as the weeks pass, and the best estimate of damage may come several weeks to up to a month after the freeze event, particularly if the high temperatures following the freeze event are not much above 40°F.

When inspecting fields, the type of damage caused by a freeze event depends on the growth stage of the wheat when the freeze occurred (Table 1).

For wheat that is in the tillering growth stages (Feekes 1 to 5), freeze damage consists of yellowing of the leaf tips (Figure 1). In most cases, this damage is merely cosmetic and does not result in yield reductions later in the season.

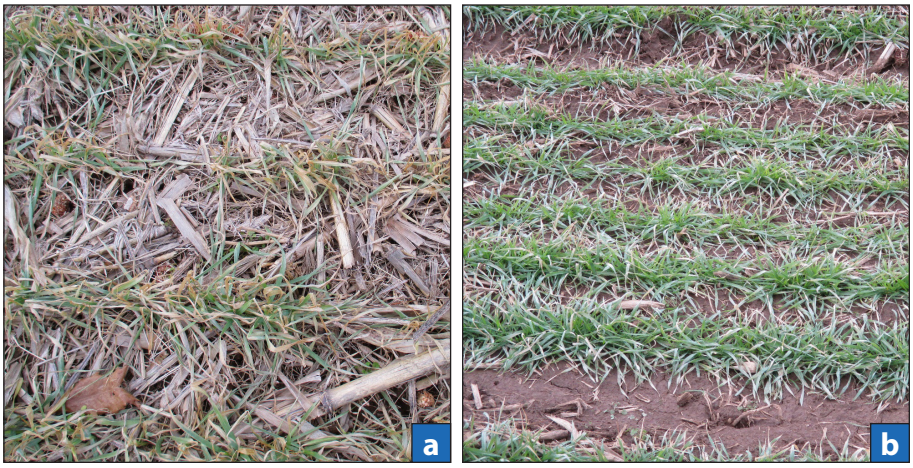

Figure 1. Yellowed wheat leaves characteristic of cosmetic freeze damage in the tillering growth stages. (A) shows approximately Feekes 2 growth stage, and (B) shows approximately Feekes 3 growth stage.

Table 1. Growth stage and approximate air temperatures at which freeze damage can occur in wheat.

Growth Stage	Feekes	Zadoks	Approx. Temp. for Injury (≥2 hours)	Primary Symptoms
Tillering	1 to 5	10 to 30	12°F	• Yellowing of leaves • Silage odor • Fields appearing to have a 'blue' color
Jointing/ Stem Elongation	6 to 9	31 to 39	24°F	• Yellowing of leaves • Water-soaked or split stems • Stems with lesions • Stems that bend or break • Death of the growing point
Boot	10	45 to 49	28°F	• Sterile florets (dead anthers and/or stigma) • Spike trapped in the boot • Damage to lower stem • Leaf discoloration
Heading	10.1 to 10.5	50 to 58	30°F	• White/bleached awns and/or spikes • Sterile florets (dead anthers and/or stigma) • Damage to lower stem • Leaf discoloration
Flowering	10.5.1 to 10.5.3	60 to 68	30°F	• White/bleached awns and/or spikes • Sterile florets (dead anthers and/or stigma) • Damage to lower stem • Leaf discoloration
Kernel Development	10.5.4 to 11.2	71 to 85	28°F	• White/bleached awns and/or spikes • Shriveled, discolored kernels • Poor germination of damaged kernels • Damage to lower stem • Leaf discoloration

Adapted from Table 3-3 in UK Cooperative Extension publication *A Comprehensive Guide to Wheat Management in Kentucky* (ID-125).

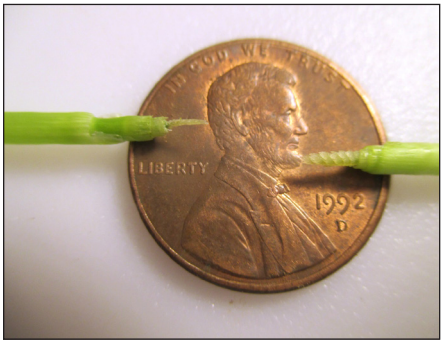

Figure 2. Healthy wheat spikes are shiny, firm, and somewhat transparent at approximately Feekes 6 (right); freeze damaged spikes are dull and lose all definition and resemblance of a developing wheat spike (left).

Once wheat reaches the jointing and stem elongation phases of development (Feekes 6 to 9), freeze damage can result in severe damage. To determine damage at these growth stages the spikes will need to be dissected out of the stems. For Feekes 6 and 7 growth stages, the spikes are quite small, from about 1/16 to 1/8 inch (2 to 3 mm) at Feekes 6; spikes are about 1 inch (1.5 to 2 cm) at Feekes 7.

Evaluating the spikes at these stages requires careful dissection of the developing wheat spike from the stem. At about Feekes 6 to 7 growth stage, healthy spikes will be very shiny and transparent (Figure 2). Freeze damaged spikes that are examined within the first week to 10 days of active growing conditions (high temperatures greater than or equal to 40°F) after the wheat freeze may have a dull, limp appearance. In some cases, the definition of the spike and any resemblance to a developing spike will be lost.

As development continues into Feekes 8 and 9, freeze damage to the spike typically manifests as dull, white spikelets (the structures that hold the developing kernels) that can easily fall off the bright green rachis (portion of the stem to which the spikelets are attached) within the first week to ten days of active growing conditions. Approximately two to three weeks after the freeze event, the wheat spikes will typically have emerged, and the characteristic freeze-damaged spike will be visible (Figure 3).

At this growth stage, stem damage may also occur. It may be subtle, but affected stems may initially appear as water-soaked or pale yellow and become very brittle and break easily (Figure 4). With time, the stems may also show signs of girdling and eventually may deteriorate entirely (Figure 4).

If freeze damage occurs during the boot, heading, or flowering development stages (Feekes 10 to 10.5.3), damage to the anthers (a portion of the male reproductive organ that produces pollen) and

Figure 3. Freeze damage about two to three weeks after the freeze event on wheat spikes that were approximately Feekes 8 (A) to 9 growth stage (B) at the time of the freeze.

Figure 4. Wheat stems showing freeze damage as pale, yellow stems that are brittle and break easily (A), with girdling (B), and stem deterioration (C). (B and C photos by Ethan Snyder).

Figure 5. Healthy wheat anthers prior to pollen shed are turgid, shiny, and bright green. In addition, the receptive stigma, which is white and feathery is visible in the middle of the three anthers.

Figure 6. Damaged anthers are shriveled and are white (A) or dark yellow (B).

stigma (a portion of the female reproductive organ) generally occurs. This can lead to sterile spikes that do not produce any kernels. Most healthy anthers are shiny, turgid, and bright green when they are immature and prior to anther release (Figure 5); mature anthers that are shedding pollen are turgid and bright yellow. Damaged, sterile anthers typically appear shriveled and can be either white or dark yellow (Figure 6). These anthers will not produce viable pollen and can result in sterile spikes that do not produce any kernels. From Feekes 10 to 10.5.3, freeze damage on other wheat spikes can cause white/bleached spikes and awns that are sterile and will not produce kernels (Figure 7).

Other factors can also bleach wheat heads. Fusarium head blight (FHB) and sawfly damage are probably the most two common ones in Kentucky. Freeze damage can be distinguished from FHB because it is generally a brighter white color than FHB. In addition, FHB typically produces orange fungal structures, called sporodochia, on FHB damaged wheat spikes (Figure 8). Sawfly damage also produces brightly bleached wheat spikes and stems. Freeze damage typically only produces bleached spikes. In addition, sawfly damage results in plants with entire plants, spikes, and stems that are easily pulled out of the wheat canopy.

Figure 7. Wheat spike and awns bleached by a freeze event that occurred sometime during the heading and flowering growth stage.

Figure 8. Bleached awns with bright orange sporodochia characteristic of fusarium head blight. (Photo: Carl Bradley)

Figure 9. Sterile wheat spike that was not bleached by a freeze event is a paler green color and has dead anthers and stigmas and did not completely emerge from the stem (spike on right) as compared to the healthy spike (left).

Figure 10. (A) Healthy, plump, developing wheat kernels in the middle of the spike and shriveled, freeze-damaged kernels at the bottom of the spike. (B) Shriveled, discolored kernels that have ceased developing following a freeze event. Photo is approximately 9 days after the freeze event. (Photo: Chad Lee).

In some years, freeze damage does not produce the characteristic spike bleaching; rather a wheat spike that is a paler green color and sterile is produced (Figure 9). These spikes can be quite difficult to identify as freeze damage, but inspection of anthers make it obvious that they are indeed sterile. In these cases, the damaged spikes will not fully emerge from the stem. They seemingly become "stuck" and do not progress any further out of the boot.

Damage during kernel development (Feekes 10.5.4 to 11.2) is quite rare in Kentucky. However, when it occurs, kernels are generally shriveled and discolored (Figure 10) and eventually have a very low germination rate.

Once damage has been accessed, estimating potential yield reduction following freeze events will provide a way for producers to determine the economic impact of a freeze damage (Table 2). This information can be used to decide whether maintaining or terminating the crop will be most profitable.

Table 2. Estimated yield loss following spring freezes at different growth stages

Growth Stage	Feekes	Zadoks	Temp. Injury can Occur (≥ 2 hrs)	Primary Symptoms	Visual Damage	Estimated Yield Effect (% Reduction)
Stem Elongation	4 to 9	30 to 39	24°F	• Death of growing point	Minor	0
				• Leaf burning and yellowing	Moderate	0 – 10
				• Lesions, splitting, bending of stems	Severe	0 – 20
				• Odor		
Boot	10	40 to 49	28°F	• Floret sterility	Minor	0 – 20
				• Spike trapped in boot	Moderate	n/a
				• Damage to stems and peduncles	Severe	n/a
				• Leaf discoloration		
Heading	10.1 to 10.5	50 to 58	30°F	• Floret sterility	Minor	0 – 20
				• Bleached or white awns or spikes	Moderate	0 – 45
				• Damage to stems and peduncles	Severe	30 – 50
				• Leaf discoloration		
Flowering	10.5.1 to 10.5.3	60 to 68	30°F	• Floret sterility	Minor	n/a
				• Bleached or white awns or spikes	Moderate	n/a
				• Damage to stems and peduncles	Severe	60 – 85
				• Leaf discoloration		

Source: Knott, 2020. https://acsess.onlinelibrary.wiley.com/doi/10.1002/cft2.20080

Additional Resources

Bruening, B., B. Roberts, S. Swanson, J. Connelley, G. Olson, A. Clark, and D. Van Sanford. 2017. 2017 Kentucky Small Grain Variety Performance Trial. PR-724. http://www2.ca.uky.edu/agcomm/pubs/PR/PR724/PR724.pdf

Bruening, B., P. Shine, S. Swanson, J. Connelley, G. Olson, and D. Van Sanford. 2020. 2020 Kentucky Small Grain Variety Performance Trial. PR-778. http://www2.ca.uky.edu/agcomm/pubs/PR/PR778/PR778.pdf

Bruening, B., S. Swanson, J. Connelley, G. Olson, and D. Van Sanford. 2012. 2012 Kentucky Small Grain Variety Performance Trial. PR-640. http://www2.ca.uky.edu/agcomm/pubs/pr/pr640/pr640.PDF

Knott, C. Assessing wheat freeze damage. 2017. YouTube. https://www.youtube.com/watch?v=oaPiOU-s-Ro

Knott, C.A. 2020. Estimated winter wheat yield reduction following spring freeze events in field conditions. Crop, Forage, and Turfgrass Management. https://acsess.onlinelibrary.wiley.com/doi/10.1002/cft2.20080

Knott, C. Identifying wheat freeze damage during flowering. 2020. YouTube. https://www.youtube.com/watch?v=u0DUgEa23bE&feature=youtu.be

Knott, C. Identifying wheat freeze damage during grain fill. 2020. YouTube. https://www.youtube.com/watch?v=OhcqjeiIE8s

Lee, C., J. Herbek, D. Van Sanford, and B. Bruening. Cultural Practices: Winterkill and Freeze Injury. pp 17 to 18 in Comprehensive Guide to Wheat Management in Kentucky (ID-125). University of Kentucky Cooperative Extension Service.

Lee, C., J. Herbek, D. Van Sanford, and B. Bruening. Determining Plant Populations, Tiller, and Head Counts. pp 18 to 19 in Comprehensive Guide to Wheat Management in Kentucky (ID-125). University of Kentucky Cooperative Extension Service.

Shroyer, J.P., M.E. Mikesell, and G.M. Paulsen. 1995. Spring Freeze Injury to Kansas Wheat, Kansas State University. https://bookstore.ksre.ksu.edu/pubs/c646.pdf

Unless otherwise noted, all photos by Carrie Knott.

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