# SPRING FREEZE INJURY

## TO KANSAS WHEAT

**AGRICULTURAL EXPERIMENT STATION**
**AND**
**COOPERATIVE EXTENSION SERVICE**

**KANSAS STATE UNIVERSITY • MANHATTAN**

## Introduction

Wheat in Kansas is subjected to adverse weather conditions during much of its growth period. Low-temperature injury during winter and spring can be particularly destructive. The winter hardiness of modern varieties and good management practices have reduced winterkilling of wheat, so injury during winter is less common than it was years ago.

Wheat has little resistance to low temperatures after it begins growing in the spring; therefore, injury from freezes at this time can occur in any part of the state. This publication describes temperature conditions that cause spring freeze injury, symptoms of injury at different spring growth stages, and management practices to use when wheat is injured.

## When and Where Spring Freeze Injury Occurs

Spring freeze injury occurs when low temperatures coincide with sensitive plant growth stages. Injury can cover large areas of the state or only a few fields or parts of fields. It is most severe along rivers, valleys, and depressions in fields where cold air settles.

The risk of spring freeze injury is greater when wheat initiates spring growth early due to higher than average temperatures and inadequate moisture and advances through its developmental stages quicker than normal. If a freeze occurs, wheat has a greater chance of being damaged because it is further advanced.

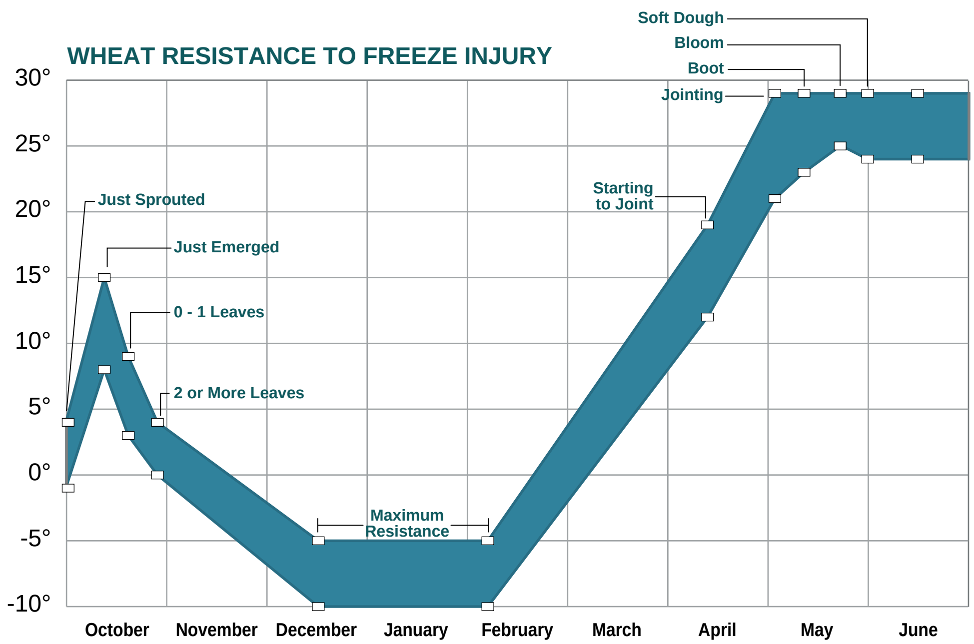


***Figure 1.*** *Temperatures that cause freeze injury to winter wheat at different growth stages. Winter wheat rapidly loses hardiness during spring growth and is easily injured by late freezes (graph adapted from A.W. Pauli).*

**Table 1. Temperatures that cause freeze injury to wheat at spring growth stages and symptoms and yield effect of spring freeze injury.**

| Growth stage | Approximate injurious temperature (two hours) | Primary symptoms | Yield effect |
|---|---|---|---|
| Tillering | 12 F (-11 C) | Leaf chlorosis; burning of leaf tips; silage odor; blue cast to fields | Slight to moderate |
| Jointing | 24 F (-4 C) | Death of growing point; leaf yellowing or burning; lesions, splitting, or bending of lower stem; odor | Moderate to severe |
| Boot | 28 F (-2 C) | Floret sterility; spike trapped in boot; damage to lower stem; leaf discoloration; odor | Moderate to severe |
| Heading | 30 F (-1 C) | Floret sterility; white awns or white spikes; damage to lower stem; leaf discoloration | Severe |
| Flowering | 30 F (-1 C) | Floret sterility; white awns or white spikes; damage to lower stem; leaf discoloration | Severe |
| Milk | 28 F (-2 C) | White awns or white spikes; damage to lower stems; leaf discoloration; shrunken, roughened, or discolored kernels | Moderate to severe |
| Dough | 28 F (-2 C) | Shriveled, discolored kernels; poor germination | Slight to moderate |

Early maturing wheat is more likely to be injured by freezes than late-maturing wheat. Susceptibility to freezing temperatures steadily increases as maturity of wheat advances during spring (Figure 1). Some varietal difference in resistance to spring freeze injury has been reported, but it is mostly caused by differences in plant growth stages when freezes occur. There is little or no difference in susceptibility among wheat varieties at the same growth stage and, therefore, little opportunity to increase freezing resistance in improved varieties.

Wheat that has had good growing conditions, optimum fertility, particularly nitrogen, and is actively growing is sensitive to freeze injury because of its lush growth and high moisture content. Drought stress tends to harden plants to cold and decreases their water content and the severity of freeze injury. Ample soil moisture, cool temperatures, and high soil fertility slow plant maturity, however, so that injury may be less severe than when plants have less favorable growing conditions and are at a more advanced growth stage when freezing occurs.

## Temperatures that Cause Spring Freeze Injury

During fall, winter wheat goes through a complex process of cold hardening that increases its resistance to cold during winter. Wheat quickly loses its cold hardiness when growth resumes in the spring. Little resistance to freezing is present at that time.

Cold temperatures that cause injury to winter wheat after hardening in the fall and dehardening in the spring are shown in Figure 1. Wheat is most sensitive to freeze injury during reproductive growth, which begins with pollination during late boot or heading stages. Temperatures that are only slightly below freezing can severely injure wheat at these reproductive stages and greatly reduce grain yields.

The degree of injury to wheat from spring freezes is influenced by the duration of the low temperatures as well as the low temperature reached. Prolonged exposure to freezing causes much more injury than brief exposure to the same temperature. Temperatures at which injury can be expected, shown in Figure 1 and Table 1, are for two hours of exposure to each temperature. Less injury can be expected from shorter exposure times. Injury might occur at somewhat higher temperatures from longer exposure times.

**Figure 2:** *Leaf tip burn and yellowing are common spring freeze symptoms at the tillering stage.*

**Figure 3:** *More severe freeze damage causes the entire leaf to turn yellowish-white and the plants to be flaccid. A silage odor may be detected after several days.*

**Figure 4:** *A healthy growing point has a crisp, whitish-green appearance.*

***Figure 5:** A growing point that has been damaged loses its turgidity and greenish color within several days after a freeze. A hand lens will help detect subtle freeze damage symptoms.*

The many factors that influence spring freeze injury to wheat — plant growth stage, plant moisture content, duration of exposure, wind, and precipitation — make it difficult to predict the extent of injury. This is complicated still further by differences in elevation and topography in and between wheat fields. Official weather stations may not reflect true in-field temperatures. It is not unusual, for instance, for wheat growers to report markedly lower temperatures than are recorded at the nearest official weather station.

The probability of a late spring freeze on a given date is lower in the south central and southeastern areas than in other parts of Kansas (Table 2). Wheat initiates growth earlier in those areas, however, and is at a more sensitive, advanced stage of development on a given date. The crop develops latest in the northwestern part of the state, so it is usually most resistant in areas where the chance of freeze is greatest.

**Table 2.**
**Probability of a 32° freeze at various Kansas locations.**

| **Location** | April 25 | May 2 | May 9 | May 16 | May 23 |
|---|---|---|---|---|---|
| | **Probability (%)** | | | | |
| Colby | 79 | 57 | 33 | 15 | 5 |
| Tribune | 80 | 60 | 37 | 18 | 7 |
| Garden City | 57 | 34 | 16 | 6 | 2 |
| Phillipsburg | 60 | 37 | 19 | 8 | 2 |
| Hays | 56 | 35 | 17 | 6 | 2 |
| Winfield | 14 | 4 | 1 | <1 | 0 |
| McPherson | 26 | 11 | 4 | 1 | <1 |
| Horton | 50 | 26 | 10 | 3 | 1 |
| Clay Center | 44 | 24 | 10 | 3 | 1 |
| Iola | 14 | 4 | 1 | <1 | 0 |

***Figure 6:** A yellow or necrotic leaf emerging from the whorl indicates the growing point is damaged.*

## Symptoms of Spring Freeze Injury

Knowing the symptoms of freeze injury enables early assessment of the extent of injury. This gives more time for choices on ways to use the damaged crop or to replant to alternative crops. Waiting until harvest to learn that wheat has been damaged by freezing decreases the value of the damaged crop for some uses and limits management choices.

Assessment of freeze injury is aided by several characteristic symptoms that develop at each growth stage. Cold temperatures after spring freezes delay development of injury symptoms, but injury to vital plant parts usually can be detected by careful examination. It is important to know the plant parts that are most vulnerable at each growth stage, where they are located on the plant, and their appearance when they are normal as well as when they have been injured.

## Tillering Stage

Spring tillering of wheat in Kansas usually begins during late February and continues through March. The growing point is near the soil surface during this stage and is protected against injury. Most damage at this stage occurs to leaves, which become twisted and light green to yellow in color and are necrotic (burned) at the tip within one or two days after freezing (Figures 2 and 3). A strong odor of dehydrating vegetation may be present after several days.

Injury at this stage slows growth and may reduce tiller numbers, but growth of new leaves and tillers usually resumes with warmer temperatures.

## Jointing Stage

The jointing stage of wheat usually occurs from late March through April. Leaves of freeze-injured plants show the same symptoms as at the tillering stage, but the most serious injury occurs to the growing points.

The growing point, which is just above the uppermost node, can be located by splitting stems longitudinally with a sharp blade. A normal, uninjured growing point is bright white to yellow-green and turgid (Figure 4); freeze injury causes it to become off-white or brown and water soaked in appearance (Figure 5). This injury can exist even in plants that appear otherwise normal because the growing point is more sensitive to cold than are other plant parts.

Damaged tillers remain green, but growth of stems in which the growing points are injured stops immediately. A chlorotic or dead leaf may appear in the whorl, indicating that the growing point is dead (Figure 6). Growth from later uninjured tillers may obscure damage. Partial injury at this stage may cause a mixture of normal tillers and late tillers and result in uneven maturity and some decrease in grain yield.

Injury to the lower stems in the form of discoloration, roughness, lesions, and enlargement of nodes frequently occurs at the jointing stage and the following stages after freezing (Figure 7). Injured plants often break over at the affected areas of the lower stem so that one or two internodes are parallel to the soil surface.

Mild stem injury does not appear to interfere with ability of wheat plants to take up nutrients from the soil and translocate them to the developing grain. Microorganisms might infect injured

***Figure 7:*** *Discoloring and roughening of the lower stem are symptoms of spring freeze damage.*

**Figure 8*:*** *Splitting of stems occurs with severe freeze damage.*

**Figure 9:** *Collapse of internodes, which may lead to lodging, occurs with severe freeze damage.*

areas causing further stem deterioration. Lodging, or falling over, of plants is the most serious problem following stem injury. Wind or hard rain will lodge the plants easily, slowing harvest and decreasing grain yields. With severe stem injury, splitting of stems and collapse of internodes is common (Figures 8 and 9). The growing point does not appear damaged immediately after a freeze. It will become dry and off-white to brown if the stem is damaged. Also, the growing point will not move upward. The loss of these early tillers releases the later tillers that would not normally develop because of too much competition.

## Boot Stage

Freeze injury at the boot stage causes a number of symptoms when the spikes, commonly referred to as heads, are enclosed in the sheaths of the flag leaves. Freezing may trap the spikes inside the boots so that they cannot emerge normally. When this happens, the spikes will remain in the boots, split out the sides of the boots, or emerge base-first from the boots (Figure 10).

Sometimes spikes emerge normally from the boots after freezing, but remain yellow or even white instead of their usual green color (Figure 11). When this happens, the spikes have been killed.

Frequently, only the male parts (anthers) of the flowers in the spikes die because they are more sensitive to low temperatures than the female parts. Since wheat is self-pollinated, sterility caused by freeze injury results in poor kernel set and low grain yield. Injury can be detected soon after freezing by examining the anthers inside each floret. Anthers are trilobed and normally light green and turgid when young and become yellow about the time they are extruded from the florets after anthesis or flowering (Figure 12). The anthers, still green, become twisted and shriveled within 48 hours after a freeze (Figures 13 and 14), but they turn white to whitish-brown quickly and may not be extruded from the florets (Figure 15). The female parts (stigma, style, and ovary) may be damaged, but if they are, the anthers also will have been injured. The stigma normally has a greenish-white, feathery appearance. A damaged stigma becomes off-white to brown and will not open. The ovary will also turn off-white to brown. Use of a hand lens will be helpful in detecting symptoms.

Many symptoms of freeze injury that occur at early stages might also be present at the boot stage (Figure 16). Leaves and lower stems might exhibit

**Figure 10:** *The twisted spike on the right was trapped in the boot and split out the side of the sheath. The awns of the middle spike were damaged while it was still in the boot stage. The spike on the left had partially emerged when freezing occurred so only the upper portion of the spike was damaged.*

symptoms described for the jointing stage, but these plant parts are less sensitive than are the anthers. It is important, for this reason, to examine the anthers. Freezing temperatures that are severe enough to injure leaves and lower stems are nearly always fatal to male flower parts, but less severe freezing may cause male sterility without any symptoms appearing on plant vegetative parts (leaves and stems).

## Heading Stage

Wheat spikes usually emerge from the boots during the first three weeks of May. Most symptoms of freeze injury at this stage — sterility, leaf desiccation or drying, and lesions on lower stems — are similar to symptoms at earlier growth stages. The most apparent symptom, however, is usually chlorosis or bleaching of the awns (beard) so they are white instead of the normal green color (Figure 17). Freezing temperatures that injure the awns may also kill the male flower parts (Figure 18).

A light green or white "frost ring" may encircle the stems one to two inches below the spikes several days after exposure to freezing temperatures (Figure 19). This area of yellowed chlorotic tissue marks the juncture of the stem and the flag leaf at the time the freeze occurred. The frost ring may be present on injured plants as well as on plants that show no other injury symptoms. It does not seem to interfere with movement of nutrients from the plant to the developing grain. As the plants mature, however, the spikes may break over at the frost ring. That is most likely to happen to well-filled spikes, particularly during windy conditions.

## Flowering (Anthesis) Stage

Wheat usually flowers about one week after the spikes appear. Symptoms of freeze injury at the flowering and heading stages are nearly similar.

The flowering stage is the most freeze-sensitive stage in wheat. Small differences in temperature, duration of exposure, or other conditions can cause large differences in amount of injury.

Exposure to freezing temperatures at the flowering stage kills the male parts of the flowers and causes sterility as described for the boot and heading stages. After freezing, the anthers are white and desiccated or shriveled instead of their normal light green or yellow color.

Freeze injury at the flowering stage causes either complete or partial sterility and void or partially filled spikes because of the extreme sensitivity.

***Figure 11:*** *This spike is emerging normally, but the yellow, water soaked appearance, instead of the normal crisp, green spike indicates it is damaged.*

***Figure 12:*** *Healthy wheat anthers are trilobed, light green and turgid before pollen is shed. Each wheat floret contains three anthers. Healthy stigmas are white and have a feathery appearance.*

***Figure 13:*** *Anthers become twisted and shriveled, yet they are still their normal color within 24 to 48 hours after a freeze. A hand lens is necessary to detect these symptoms.*

**Figure 14*:*** *Close-up of twisted anthers and unopened whitish stigma shown in Figure 13.*

***Figure 15:*** *If damaged, anthers become white after 3 to 5 days and eventually turn whitish-brown. The anthers will not shed pollen or extrude from the florets.*

Flowering proceeds from florets near the center of wheat spikes to florets at the top and bottom of the spikes over a 2- to 4-day period. This small difference in flowering stage when freezing occurs produces effects shown in Figure 20. The center or one or both ends of the spikes might be void of grain because those florets were at a sensitive stage when they were frozen. Grain might develop in other parts of the spikes, however, because flowering had not started or was already completed in those florets when the freeze occurred.

## Milk Stage

Young developing kernels normally grow to full size (volume) within 12 to 14 days after flowering, but do not reach maximum grain weight for another two weeks (Figures 21 and 22). Injured kernels may fail to develop after freezing temperatures. Injured kernels also may be white or gray and have a rough, shriveled appearance instead of their normal light green, plump appearance (Figure 23). Cool weather frequently delays these other symptoms, so failure of the kernels to develop may be the major indication of injury.

Kernels that are slightly injured at the milky-ripe stage may grow to normal size, but produce light, shriveled grain at maturity. Examination of these kernels before maturity, as at the early dough stage, may show that their contents are gray and liquid instead of white and viscous as they should be at this stage (Figure 24). The interior of the rachilla, the small stems that attach the spikelets to the stems, may also be dark instead of light-colored, so that the spikelets are easily stripped from the stems. These symptoms result from gradual deterioration of tissues and usually do not show up for a week or more after freezing occurred.

Wheat that has been injured by freezing at the milky-ripe stage often shatters easily at maturity, and the shriveled kernels cause the grain to have a low test weight. Freeze injury may also seriously reduce germination.

## Dough Stage

Wheat kernels reach full size and nearly full weight by mid-dough stage in late May to early June. Because kernel development is nearly complete and kernel moisture content may have decreased, wheat is usually more resistant to freezing temperatures at this stage than at most earlier spring growth stages. The only visible sign of freeze injury at the dough stage may be an unsightly wrinkled appearance of the kernels and a slightly reduced test weight.

The most serious consequence of freeze injury at the dough stage is reduced germination of kernels. The embryo or germ usually has a higher moisture content than other kernel parts, and its complex of cellular contents and structures makes it more vulnerable to freezing.

## Management of Freeze-Injured Wheat

### Harvest for Grain

Freezing frequently injures only part of the wheat spike or only plants in certain parts of fields such as low areas. In addition, late tillers that normally would not produce significant grain may develop rapidly after a freeze, particularly when it occurs at early spring growth stages. These late tillers may produce appreciable yields if suitable weather conditions follow the freeze. However, hot and dry conditions usually prevent late tillers from producing worthwhile yields when freezes occur at late spring growth stages.

When freeze injury is only partial, when alternative management practices might disrupt established rotation systems, or when good alternative uses or crops are unavailable, the best management practice might be patience. Except in the most severe cases, wheat that has been injured often produces yields that exceed harvesting and hauling costs. This might be offset somewhat, however, by the possibility of lodging caused by lower stem damage, which slows harvest, and by increased shattering losses of freeze-injured wheat.

Grain produced by wheat injured after the flowering stage is frequently of poor quality for making bread. Test weight may be low, kernels may be shriveled or discolored, and the grain may be a mixture of kernels of different sizes and maturities.

Wheat grain that is shriveled or germinates poorly makes excellent cattle feed. It is usually high in protein content, which enables the amount of protein from other sources to be decreased. Wheat grain should be gradually incorporated into the livestock ration over a one week period; in no case should it constitute more than one-third to one-half of the total grain in the ration.

### Use for Seed

The germination of grain from freeze-injured plants that is to be used for seed should be checked before planting. Grain of most wheat varieties has a natural dormancy that causes low germination

**Figure 16***: Damage to the lower stem and nodes can occur at the boot and heading stages. Freeze damage causes nodes to become enlarged and the stem to bend or have a crooked appearance.*

**Figure 17***: Symptoms of slight freeze damage may occur only on the awns as the spike is emerging from the boot or after heading. Awns become twisted and bleached or white instead of their normal green color. There may be no other damage to the rest of the plant.*

***Figure 18:*** *Freeze damage at heading causes glumes to become yellow and have a water-soaked appearance instead of green and turgid. The rachilla, the short stem that connects the floret to the spike, may become purplish-brown, indicating damage.*

**Figure 19***:* *A whitish frost ring encircles the stem at the juncture of the stem and flag leaf at the time of the freeze.*

**Figure 20:** *Damage may occur in different areas of the spike because flowering, which is the most sensitive stage to freeze, does not occur at the same time in all florets.*

**Figure 21***:* *Shortly after pollination healthy kernels begin to develop and are greenish-white.*

for several weeks after harvest. The grain should be given a cold treatment before testing, or germination tests should be delayed for about four weeks after harvest. If germination is slow and germination percentage is low four weeks or more after harvest, the wheat should not be used as seed. Shriveled seed should not be used in any case because field emergence is poor even if germination percentage is high. In addition, shriveled seeds produce less vigorous seedlings that usually yield less grain than seedlings from good quality wheat seed.

The suitability of grain from freeze-damaged wheat for use as seed might be improved by conditioning. This can be particularly important if the damage is widespread and the supply of seed for the next year's crop is short.

Proper conditioning removes the small, shriveled, or immature kernels, leaving the largest kernels and raising the test weight to acceptable levels. The amount of clean-out depends on the severity of freeze injury, but may be high. Germination of the grain that is saved for seed should be tested after conditioning and after any period of storage. Conditioned seed will usually maintain a high level of germination for one year if it is stored under proper conditions.

**Hay or Ensilage**

Cutting freeze-injured wheat for hay or ensilage may be the most economical and practical use if the forage is needed or can be marketed and equipment is available. The feeding quality of hay or ensilage is good through the soft dough stage. Moreover, it might be necessary to kill freeze-injured wheat plants so they will not become weeds if the land is replanted to other crops. It is also usually desirable to remove the wheat vegetation instead of directly working it into the soil to prevent excessive soil moisture loss.

The nitrate content of wheat used for hay or ensilage after freezing should be checked to avoid toxicity to livestock. Because late freezing usually injures only certain parts of the wheat spike and rarely kills the whole plant, plants may continue to absorb nitrate from the soil but lack any developing grain to utilize the nitrogen. Nitrate might accumulate under those conditions and poison livestock unless the feed is diluted with adequate quantities of low-nitrate feed.

Cattle on wheat hay or ensilage that was cut after the anthesis (flowering) growth stage should be closely observed for development of actinomycosis, commonly known as big jaw or lumpy jaw. The problem occurs when tissues inside the mouth of cattle are punctured by wheat awns and become infected. Actinomycosis is less likely when wheat is cut at young stages of maturity and when it is fed as ensilage than when it is fed as hay.

### Alternative Crops

Ample time usually is available after early assessment of spring freeze injury to wheat for replanting the land to other crops. The most likely alternative crop possibilities are soybeans and sorghum in eastern Kansas and sorghum in western Kansas. Other possibilities are sunflowers or corn, if damage is assessed early and the soil profile has at least 3 feet of moisture or irrigation is available.

Freeze-injured wheat needs to be killed with a herbicide or tillage if it is not cut for hay or ensilage to prevent it from becoming a weed in replanted crops. This is necessary because freezing rarely kills the entire plant. If the wheat is not removed, it should be chopped to prevent rapid drying of the soil.

With wheat-fallow or wheat-sorghum-fallow rotations, an alternative crop, usually sorghum or sunflower, may be planted on fallowed land with adequate moisture conditions. Cropping options may be limited if residue from a herbicide that was applied to the wheat remains in the soil. The land with injured wheat can be summer-fallowed and replanted to wheat in the fall. This scheme requires better-than-average moisture conditions for both the spring-seeded crop and for the wheat in the fall.

Before destroying damaged wheat and planting another crop, growers should consider that production costs, except for harvesting and hauling, have been incurred. Planting a new crop will have its own production and fixed costs. Therefore, the return of the new crop over its production costs must be greater than the wheat's value over harvesting/hauling costs to make it worthwhile.

**Figure 22:** *As healthy kernels continue to develop, they will contain a clear liquid.*

**Figure 23:** *Kernel development stops immediately after freeze damage. Damaged kernels are grayish-white, rough and shriveled.*

**Figure 24:** *These healthy kernels at the milk to early dough stage contain a whitish fluid. Damaged kernels contain a gray to brownish liquid that is less viscous than the whitish fluid in undamaged kernels.*

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