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Freeze Injury on Wheat



Dr. Billy E. Warrick, Associate Professor and Extension Agronomist, San Angelo, Texas
Dr. Travis D. Miller, Professor and Extension Agronomist, College Station, Texas

Introduction

Wheat 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 most varieties when combined with good management practices have reduced winterkilling of wheat.

Wheat has little resistance to low temperatures after it begins growing in the spring, therefore, injury from freezes at this time can occur. The following pages 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 to wheat can occur in different areas of the state. Injury usually occurs whenever low temperatures coincide with sensitive plant growth stages. The amount of injury may be large or only a few fields or parts of fields. It is most severe along river bottoms, valleys, and depressions in fields where cold settles.

Early-maturing wheat is more likely to be injured by freeze than is 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

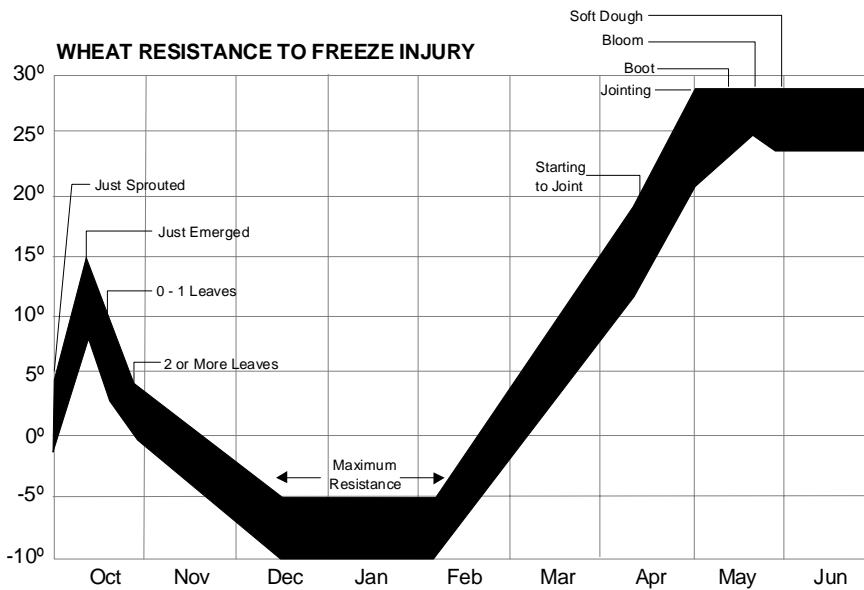


Figure 1. Temperatures that cause freeze injury to winter wheat at different growth stages. Winter wheat rapidly loses hardiness during spring growth and is easily injured by late freezes.

Table 1. Injury Symptoms of Wheat Resulting from Freezing Temperatures

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 heads; damage to lower stem; leaf discoloration	Severe
Flowering	32 F (0 C)	Floret sterility; white awns or white heads; damage to lower stem; leaf discoloration	Severe
Milk	28 F (-2 C)	White awns or white heads; 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

reported, but it is mostly caused by differences in plant growth stages when freezes occur. There is little difference among wheat varieties at the same growth stage and, therefore, little opportunity to increase freezing resistance.

Wheat that has had good growing conditions and high soil fertility, particularly nitrogen, is more sensitive to freeze injury because of its lush growth and high moisture content. Drought stress, on the other hand, 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 slows plant maturity which reduces its potential for injury as compared to plants that have had less favorable growing conditions and are in more advanced growth stage when freezing occurs.

Temperatures that Cause Spring Freeze Injury

Winter wheat goes through a complex process of cold hardening during the fall that increases its resistance to cold during winter. Its cold hardiness is quickly lost when growth resumes during 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 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 point they reach. 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, while injury might be expected at even somewhat higher temperatures from longer exposure times.

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



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

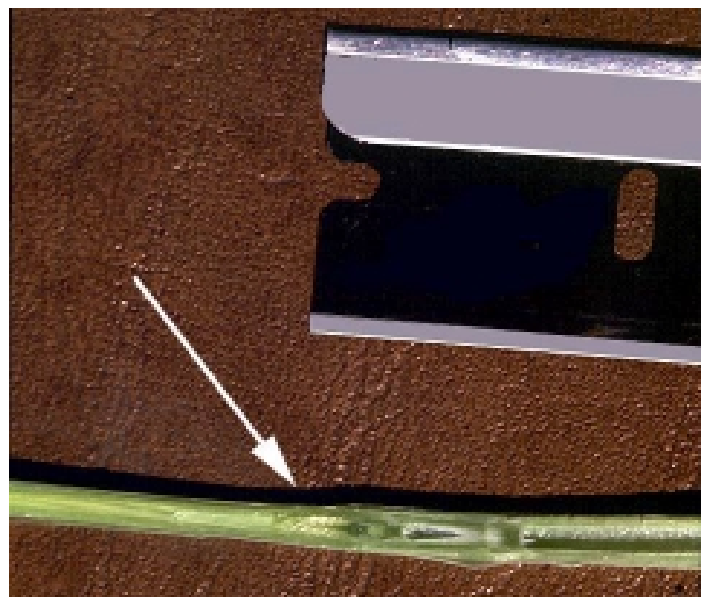


Figure 4. Growing points can be located by splitting stems longitudinally with a sharp blade



Figure 5. A healthy growing point has a crisp, whitish-green appearance.

Figure 6a



Figure 6. 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.

Note contrast in healthy (left) and damaged (right) growing point in **Figure 6a**.



Figure 7. 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 choices on ways to use the damaged crop and on alternate crops to plant. 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 might 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 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 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 Figure 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 points can be located by splitting stems longitudinally with a sharp blade (Figure 4). A normal, uninjured growing point is bright white to yellow-green and turgid (Figure 5); freeze injury causes it to become white or brown and water soaked in appearance (Figure 6). This injury can occur even in plants that appear otherwise normal because the growing point is more sensitive to cold than are other plant parts. 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 7). 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. If plants are large and stems collapse, small tillers can be killed due to lack of light as larger tillers collapse on them. Flash grazing may be a good management practice in the scenario.

Injury to the lower stems in the form of discoloration, roughness, lesions, splitting, collapse of internodes, and enlargement of nodes frequently occurs at the jointing stage and the following stages after freezing (Figure 8). 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.

Stem injury does not appear to seriously interfere with ability of wheat plants to take up nutrients from the soil and translocate them to the developing grain. Injured areas might become infected by microorganisms which can cause further stem deterioration. Severe stem injury can affect plant-water relations during the late season. Affected plants can suddenly dry down as evaporative demand exceeds the capacity of the stem to uptake water. Lodging (falling over) of plants is the most serious problem following stem injury. Wind or hard rain can easily lodge the plants, decreasing grain yields and slowing harvest. With severe stem injury, splitting of stems (Figure 9) and collapse of internodes is common (Figure 10).

Boot Stage

Freeze injury at this stage, when the heads are enclosed in the sheath or the flag leaves, causes a number of symptoms. Freezing may trap the head inside the boots so that they cannot emerge normally. When this happens, the heads will remain in the boots, split out the sides of the boots, or emerge base-first from the boots (Figure 11).

Sometimes spikes emerge normally from the boot after freezing, but remain yellow or even white instead of their usual green color (Figure 12). When this happens, the heads have been killed.

Frequently, only the male parts (anthers) of the flowers in the head are killed. Since wheat is self-pollinated, sterility caused by freeze injury causes poor kernel set and low grain yield. Injury can be detected soon after freezing by examining the anthers inside each floret. Anthers are normally light green and turgid when young and become yellow about the time they are extruded from the florets after anthesis or flowering (Figure 13). The anthers, still green, become twisted and shriveled within 48 hours after a freeze (Figure 14 and

Figure 8. Discoloring and roughening of the lower stem are symptoms of spring freeze damage.



Figure 9. Splitting of stems occurs with severe freeze damage.



Figure 10. Collapse of internodes, which may lead to lodging occurs with severe freeze damage.



Figure 11. 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.



Figure 12. This spike is emerging normally, but the yellow water soaked appearance, instead of the normal crisp, green spike indicates it is damaged.



Figure 13. 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 15), but they turn white to whitish-brown quickly and may not be extruded from the florets (Figure 16). The female parts (stigma, style, and ovary) may be damaged, but if they are, the anther also will be 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 17). Leaves and lower stems might exhibit symptoms described for the jointing stage, but these plant parts are less sensitive than are the male flower parts. 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 heads usually emerge from the boots during the first two weeks of May. Most symptoms of freeze injury at this stage are sterility, leaf desiccation or drying. Lesions on lower stems have symptoms that are similar to those at earlier growth stages. The most apparent symptom, however, is usually chlorosis or bleaching of the awns ("beard") so that they are white instead of the normal green color (Figure 18). Freezing temperatures that injure the awns will usually kill the male flower parts (Figure 19).

A light green or white "frost ring" may encircle the stems one to two inches below the heads several days after exposure to freezing temperatures (Figure 20). This area of yellowed chlorotic tissue marks the juncture of the stems and the flag leaves at the time that 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, the heads may break over at the frost ring. That is most likely to happen to heads that are well-filled, particularly during windy conditions.

Flowering (Anthesis) Stage

Wheat usually flowers about one week after the heads 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 yellow color.

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

Flowering proceeds from florets near the center of wheat heads to florets at the top and bottom of the heads over a 2- to 4- day period. This small difference in flowering stage when freezing occurs may result in no grain being set in the center or one or both ends of the head (Figure 21). This lack of grain set may have resulted from male flowers in those florets being in a sensitive growth stage when the freeze occurred. 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 maximum grain weight is not reached for another two weeks (Figure 22 and Figure 23). If young kernels fail to develop after freezing temperatures occurred, they likely have been injured. Injured kernels may be white or gray and have a rough, shriveled appearance (Figure 24) instead of their normal light green, plump appearance. Cool weather frequently delays these other symptoms and failure of 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 the kernels before maturity, at the early dough stage, may show that their contents are grey and liquid instead of white and viscous as they should be at this stage (Figure 25). 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. Germination percentage of the grain also may be seriously reduced as a result of freeze injury.



Figure 14. 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.

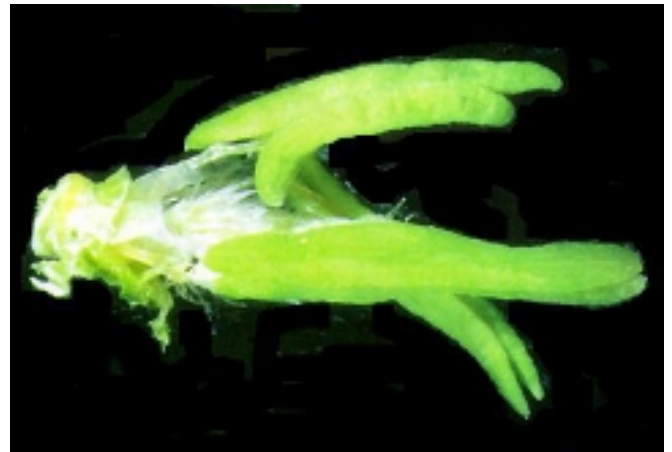


Figure 15. Close-up of twisted anthers and unopened whitish stigma shown in Figure 14.

Figure 16. 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.



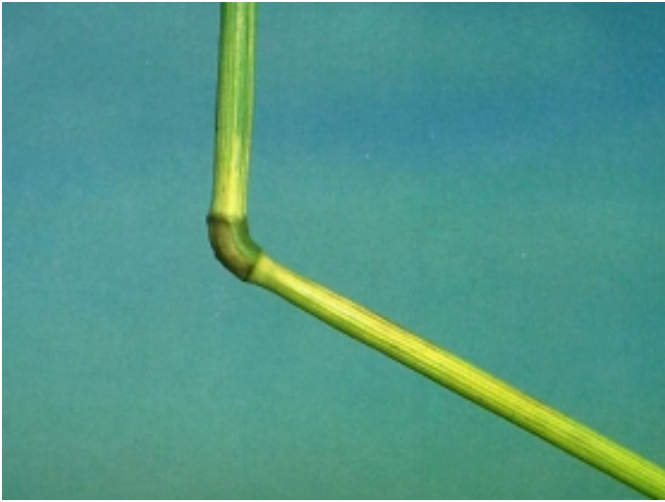


Figure 17. Damage to the lower stem and nodes can occur at the boot and heading stages. Freeze damage causes nodes to become enlarged and the stem to bend or have a crooked appearance.



Figure 18. 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 19. 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.

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 cellular content and structure makes it more vulnerable to freezing.

Management of Freeze-Injured Wheat Harvest for Grain

Freezing frequently injures only part of the wheat head or only plants in certain parts of fields such as depressions and 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 weather conditions following the freeze are suitable. Freezes at late spring growth stages would result in late tiller being developed in hot and dry conditions which usually prevent them from producing worthwhile yields.

When freeze injury is only partial and alternate management practices might disrupt established rotation systems or when good alternate uses of crops are not available, then 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 by the possibility of lodging caused by lower stem damage. Lodged plants slows harvest and increases shattering losses.

Grain produced by wheat injured after the flower stage frequently is of poorer quality than usual. 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.

The germination percentage of grain from a freeze-injured plant 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 for several weeks after harvest. The grain should be given a cold treatment before testing, or germination tests should

be delayed for almost four weeks. If germination is slow and germination percentage is low for 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.

Wheat grain that is shriveled or germinates poorly can still be used as 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 and, in no case, should it constitute more than one-third to one-half of the total grain in the ration.

In order to make the decision to keep or abandon a field of wheat, a farmer needs to estimate potential yield (See publication SCS-1999-21 on yield estimation in wheat).

Hay or Ensilage

Producers should evaluate the field for total freeze loss before abandoning the crop. The degree of freeze injury varies greatly with elevation in a given field. In many cases, low lying areas in a field may have severe injury, while the upper end of the same field may have little apparent injury. Strategic use of a hot wire may allow a significant amount of grain harvest, while utilizing freeze injured wheat as forage. This requires careful scouting.

If damage is wide spread enough that haying is the only option, producers need to harvest as soon as possible to retain the forage quality. Freeze damaged wheat degrades very rapidly. If adequate livestock are not available to utilize forage rapidly, haying may be a better option, if weather will allow.

Cutting freeze-injured wheat for hay or ensilage may be the most economic and practical use if the feed is needed and equipment is available. The feed quality of hay or ensilage is good through the soft dough stage, and salvaging the crop this way gives it a use that it might not otherwise have. Moreover, it might be necessary to kill freeze-injured wheat plants so that 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. Late freezing usually injures only certain parts

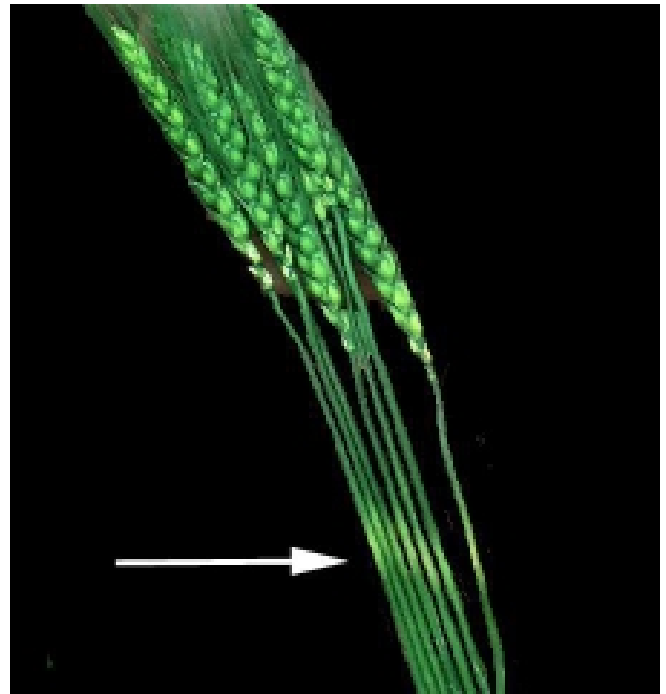


Figure 20. A whitish "frost ring" encircles the stem at the juncture of the stem and flag leaf at the time of the freeze.



Figure 21. 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 22. Shortly after pollination healthy kernels begin to develop and are greenish-white.





Figure 23. As healthy kernels continue to develop, they will contain a clear liquid.



Figure 24. Kernel development stops immediately after freeze damage. Damaged kernels are grayish-white, rough and shriveled.



Figure 25. 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.

of the wheat head and rarely kills the whole plant, plants may continue to absorb nitrate from the soil but do not have 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.

Alternate Crops

Ample time is usually available after early assessment of spring freeze injury in wheat to allow the producer time to replant the land to other crops. The most likely alternate crops for our area would be cotton or grain sorghum (milo). Other possibilities are sunflowers or corn, if damage is assessed early and irrigation is available.

Freeze-injured wheat might need to be killed with an herbicide if it is not cut for hay or ensilage to prevent it from becoming a weed after replanting to another crop. This is necessary because freezing rarely kills the entire plant. If the wheat is killed at a late development stage the stalk will remain standing for several months protecting the alternate crop from wind damage.

With wheat-fallow or wheat-sorghum-fallow rotations, an alternate crop, usually sorghum, might be planted on fallowed land if soil moisture conditions are adequate. The land with injured wheat can be summer-fallowed and replanted to wheat in the fall. This scheme requires better than usual moisture conditions for both the sorghum and for the wheat in the fall.

For additional information see our website at: <http://taexsoilcrop.tamu.edu>

The information concerning freeze injury in wheat was modified from the Kansas State University Cooperative Extension Service publication C-646 revised March 1995. A copy of the KSU publication, C-646, is available in a pdf format at the following website: <http://www.oznet.ksu.edu/library/crps12/C646.PDF>.