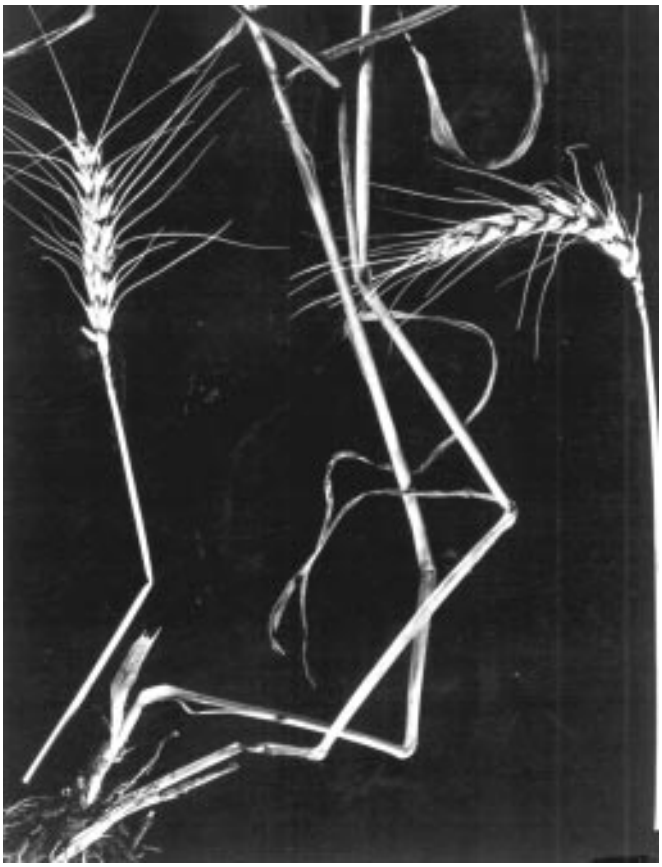
1994

EC94-132 Freeze Injury to Nebraska Wheat

Robert N. Klein
University of Nebraska - Lincoln, robert.klein@unl.edu

Drew J. Lyon
University of Nebraska-Lincoln, drew.lyon@wsu.edu

John E. Watkins
University of Nebraska - Lincoln, jwatkins1@unl.edu



Nebraska Cooperative Extension EC 94-132-S

The Nebraska Wheat Board contributed funds to support the printing of this publication.

Freeze Injury to Nebraska Wheat

Robert N. Klein, Extension Cropping Systems Specialist
Drew J. Lyon, Extension Dryland Cropping Systems Specialist
John E. Watkins, Extension Plant Pathologist

Nebraska's adverse weather conditions affect winter wheat during much of its growth. The newer varieties of wheat have increased winter hardiness, and better management practices have reduced winter injury of winter wheat, yet low temperature injury during winter and spring can be destructive.

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 winter injury, symptoms of injury at different spring growth stages, and management practices to use when wheat is injured.

Winter Injury

Low temperatures kill winter wheat plants by injuring the crown. When adequately hardened, crowns can tolerate temperatures down to -9 to -11 degree Fahrenheit. Plants in the three-leaf to four-leaf stage with good root systems are in the best position to survive the winter in the Central Great Plains. The hardening process is the key to a plant's ability to withstand low temperatures. Plants that develop several tillers because of early seeding remain more vulnerable to low temperatures than those seeded later. Larger plants are more subject to desiccation due to cold, dry winds and a lack of adequate snow cover. Soil and seed-inhabiting fungi parasitize weakened plants and cause root and crown rot.

Plants killed by low temperatures will normally fail to green-up in the spring and will have a bleached tan color. Typically, these symptoms will be most apparent on exposed ridges or hilltops. Very dry conditions in the fall through winter, which prevents secondary root development, often predisposes the plants to direct low temperature winter kill, or a combination of winter injury and root/crown rot.

Wheat that has suffered from winter injury will often green-up in the spring only to decline and eventually die. The crown tissue of plants suffering from winter injury will be soft, brown and mushy and secondary roots will be rotted off. Healthy plants have firm, pale green crowns and white roots. If you suspect winter injury before spring green-up you can dig up wheat plants in the field and bring them indoors. If the crown tissue is still alive, new growth should be visible within three days on plants clipped at 1/2 to 3/4 inch above the crown.

This publication is based on *SPRING FREEZE INJURY TO KANSAS WHEAT*, written by Gary M. Paulsen, Elmer G. Heyne, and Howard D. Wilkins and published by Agricultural Experiment Station and Cooperative Extension Service, Kansas State University, Manhattan, Kansas, 1982. The University of Nebraska authors Robert N. Klein, Drew J. Lyon, and John E. Watkins adapted and revised the material for Nebraska growing conditions.

When and Where Spring Freeze Injury Occurs

Significant spring freeze injury to wheat in Nebraska has occurred several times in the past with the area of the state involved and the extent of injury varying. One of the most severe instances of winter wheat injury in Nebraska occurred in 1992.

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

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 at the time of the freeze. There is little difference among wheat varieties at the same growth stage and, therefore, little opportunity to increase freezing resistance in improved varieties.

When growing conditions are favorable and there is high soil fertility, particularly soil nitrogen enriched, wheat is more sensitive to freeze injury because of its lush growth and high moisture content. Conversely, drought stress tends to harden plants to cold and decreases their water content, thus reducing the severity of freeze injury. However, ample soil moisture, cool temperatures, and high soil fertility slow plant maturity, so injury is sometimes less severe than in plants that have had less favorable growing conditions and are at a more advanced growth stage when freezing occurs.

Temperatures Causing Spring Freeze Injury

Winter wheat goes through a complex process of cold hardening during fall that increases its resistance to cold winter temperatures. Its cold hardiness is quickly lost when growth resumes during spring leaving it little resistance to freezing.

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 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 are shown in *Figure 1* and *Table I*, and 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.

The many factors influencing freeze injury to wheat—plant growth stage, plant moisture content, and duration of exposure—make it difficult to predict the extent of the injury. This is complicated further by differences in elevation and topography among wheat fields and between the 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.

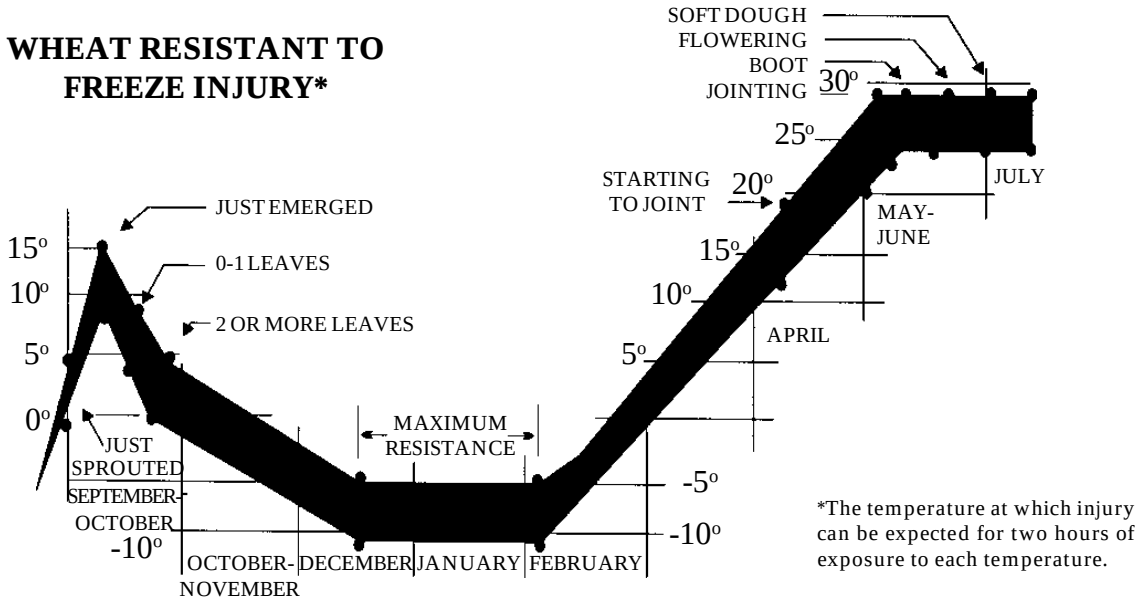


Figure 1. The severity of freeze injury to winter wheat depends on the temperature, the length of exposure and the growth stage of the plant.

Table I. Temperatures that cause 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	Leaf chlorosis; burning of leaf tips; silage odor; blue cast to fields	Slight to moderate
Jointing	24 F	Death of growing point; leaf yellowing or burning; lesions, splitting, or bending of lower stem; odor	Moderate to severe
Boot	28 F	Floret sterility; head trapped in boot; damage to lower stem; leaf discoloration; odor	Moderate to severe
Heading	30 F	Floret sterility; white awns or white heads; damage to lower stem; leaf discoloration	Severe
Flowering	30 F	Floret sterility; white awns or white heads; damage to lower stem; leaf discoloration	Severe
Milk	28 F	White awns or white heads; damage to lower stems; leaf discoloration; shrunken, roughened, or discolored kernels	Moderate to severe
Dough	28 F	Shriveled, discolored kernels; poor germination	Slight to moderate

Symptoms of Spring Freeze Injury

Knowing the symptoms of freeze injury enables an early assessment of the extent of the injury. 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 which plant parts are most vulnerable at each growth stage, where they are located on the plant, and their appearance when they are normal as well as after injury has occurred.

Figure 2 illustrates several stages of growth of the wheat plant. *Figure 3* shows the wheat inflorescence and *Figure 4* a portion of the spike of common wheat.

Tillering Stage

Spring tillering of wheat in Nebraska usually begins during March and continues through mid-April. The growing point is just below 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 (Figure 5). 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 is when the internodes (stem segments between joints or nodes) are elongating in the wheat stem and the embryonic head is moving up through the stems. This stage usually occurs from early April through early May. Leaves of freeze-injured plants show the same symptoms as at the tillering stage (Figure 5), but the most serious injury occurs to the growing points (Figure 6).

The growing points can be located by splitting stems lengthwise with a sharp knife. A normal, uninjured growing point is bright yellow-green and turgid; freeze injury causes it to become white or brown and water-soaked in appearance. 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.

Stem growth stops immediately when the growing points are injured, but growth from later 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, splitting, collapse of internodes, and enlargement of nodes frequently occurs at the jointing stage and the following stages after freezing (see cover photo). 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 the 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, however, which can cause further stem

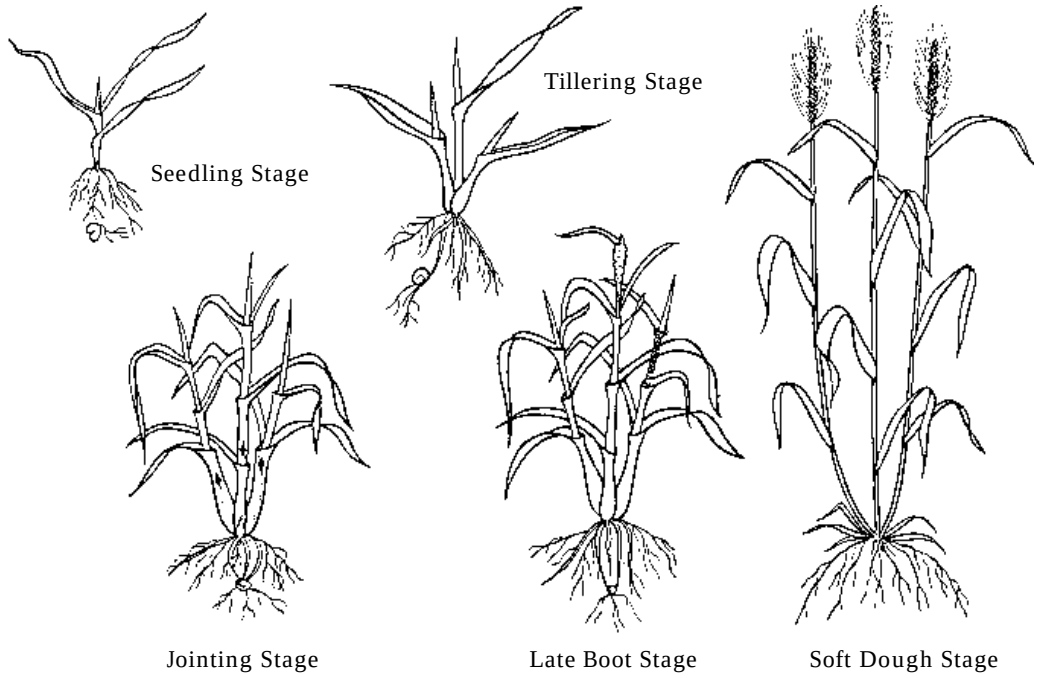


Figure 2. Growth stages of the wheat plant.

Seedling Stage is the growth stage from wheat emergence until the plants begin to tiller. Tillering usually starts at about the 4- to 5-leaf stage.
Tillering Stage usually starts in the fall.
Jointing Stage is when the internodes (stem segments between joints or nodes) are elongating in the wheat stems and the embrionic head is moving up through the stems. This stage usually starts in April.
Boot Stage is the growth stage from the time the head passes the third joint until the head emerges through the flag leaf.
Soft Dough Stage is the stage of the seed formation after the milk stage where the seed begins to harden.

deterioration. Lodging, or falling over, of plants is the most serious problem following stem injury. Wind or hard rain will easily lodge the plants, decreasing grain yields and slowing harvest.

Boot Stage

The boot stage is the stage of growth from the time the head passes the third joint until the head emerges through the flag leaf.

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

Heads sometimes emerge normally from the boots after freezing, but remain yellow or even white instead of their usual green color. When this happens, the heads have been killed (Figure 7).

Frequently, only the male parts (anthers) of the flowers in the heads are killed. Since wheat is mostly self-pollinated, sterility caused by freeze injury causes poor kernel set and a 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 flowering (anthesis). Freeze injury causes anthers to be white and shriveled and might prevent them from being extruded from the florets.

Many symptoms of freeze injury that occur at early stages might also be present at the boot stage. 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 mid-May to early June. Most symptoms of freeze injury at this stage—sterility, leaf desiccation or drying, and lesions on the 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 that they are white instead of the normal green color. Freezing temperatures that injure the awns also usually kill the male flower parts.

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 (cover). This area of yellowed chlorotic tissue marks the juncture of the stems and the flag leaves at the time that

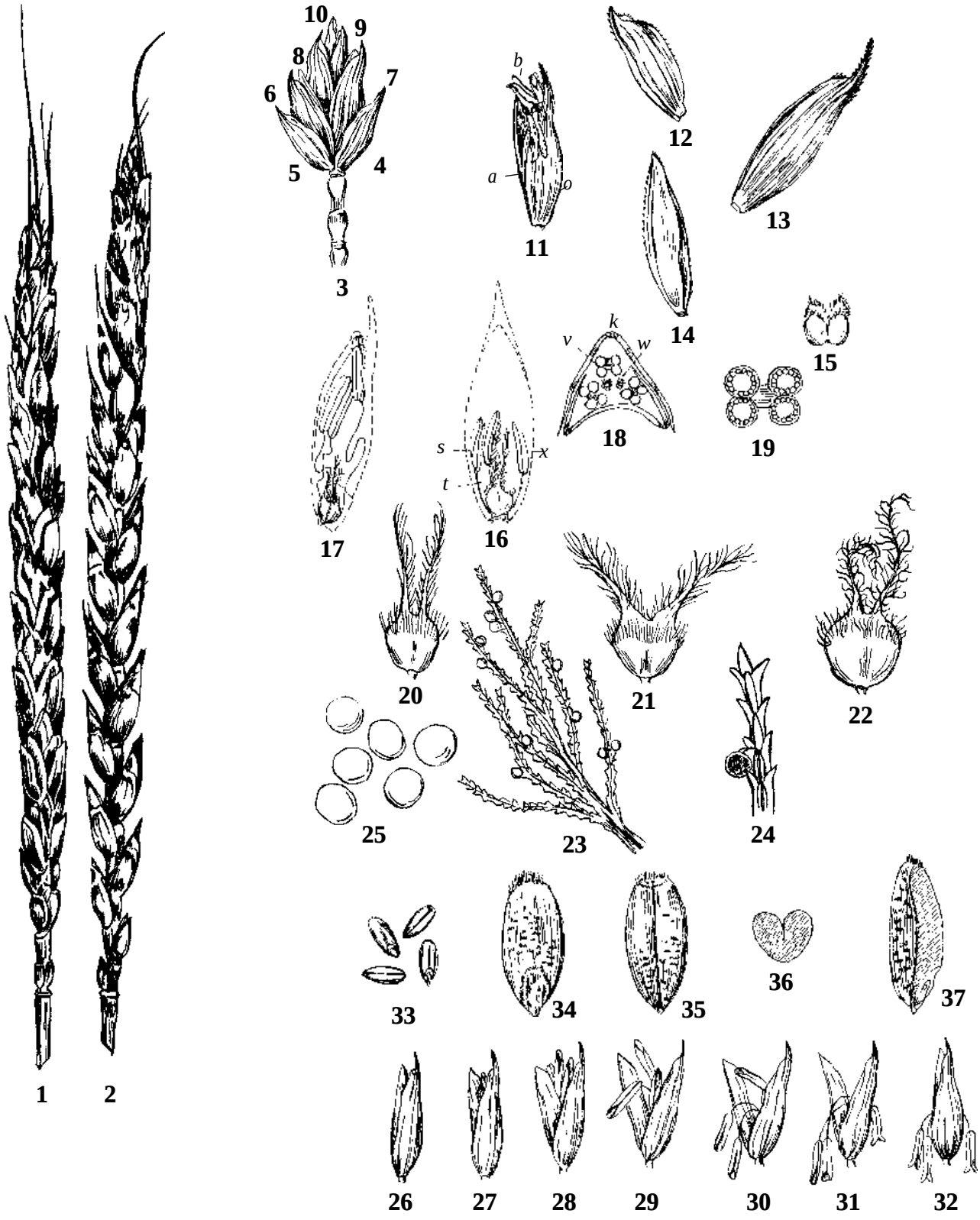


Figure 3. **The wheat inflorescence. 1. Spike dorso-ventral view. 2. Spike lateral view. 3. Spikelet, lateral view and subtending rachis. 4. Upper glume. 5. Lower glume. 6, 7, 8, 9 and 10. Florets: No. 6 and No. 7 are largest, while Nos. 8, 9, and 10 are progressively smaller. 11. Floret, lateral view, opening in athesis. 12. Glume, lateral view. 13. Lemma, lateral view. 14. Palea, lateral view. 15. Lodicules, which swell to open the glumes. 16. Floret before anthesis, showing position of pistil (u) and the elongating filaments of the stamens. 18. Cross section of floret (c) palea, (k) lemma, (v) stamen, and (w) stigma. 19. Cross section of anther. 20. Pistil before anthesis. 21. Pistil of stigma (greatly enlarged) showing adhering pollen grains. 24. Tip of stigma hair (greatly enlarged) penetrated by germinating pollen grain. 25. Pollen grains, enormously enlarged. 26-32. Florets during successive stages of blooming and anthesis. Time required for stages 26-31 is about 2 to 5 minutes, for stages 26 to 32 about 15 to 40 minutes. 33. Kernels (Caryopses). 34. Kernel, dorsal view. 35. Kernel, ventral view. 36. Kernel, cross section. 37. Lateral view, with one-half the kernel in longitudinal section. (34 through 37, greatly enlarged.) Redrawn from Technical Bulletin No. 1278, *Classification of Triticum Species and of Wheat Varieties Grown in the United States*, Figure 2. USDA. 1963.**

Figure 4. Portion of spike of common wheat. Redrawn from Technical Bulletin No. 1278, *Classification of Triticum Species and of Wheat Varieties Grown in the United States*, Figure 2. USDA. 1963.

Figure 5. Freeze injured winter wheat at the tillering and jointing stages.

the freeze occurred. The frost ring may be present on injured plants as well as on plants that show no other symptom of injury. It does not seem to interfere with the movement of nutrients from the plant to the developing grain. As the plants mature, however, 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 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 the 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 (Figure 8).

Freeze injury at the flowering stages causes either complete or partial sterility and void or partially filled heads because of the extreme sensitivity of the flower parts (Figure 9).

Flowering proceeds from florets near the center of the wheat heads to florets at the top and bottom of the heads over a 2- to 4-day period. This small difference in the flowering stage when freezing occurs produces effects shown in *Figure 7*. The center, or one or both ends of the heads, might be void of grain because the male flowers in those florets were at a sensitive stage when they were frozen. Grain might develop in other parts of the heads, however, because flowering hadn't started or was already completed in those florets at the time of the freeze.

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. If young kernels fail to develop after freezing temperatures occur, they likely have been injured. Injured kernels also may be white or gray and have a rough, shriveled appearance instead of their normal light green, plump appearance. Cool weather frequently delays these other symptoms, however, so that 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 (Figure 10). Examination of these kernels before maturity, as 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. The interior of the rachille, 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 the gradual deterioration of tissues and usually do not show up for a week or more after freezing occurs.

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.

Dough Stage

Wheat kernels reach full size and nearly full weight by mid-dough stage in early to late June. Because kernel development is nearly complete and kernel moisture content may have decreased, wheat is usually more

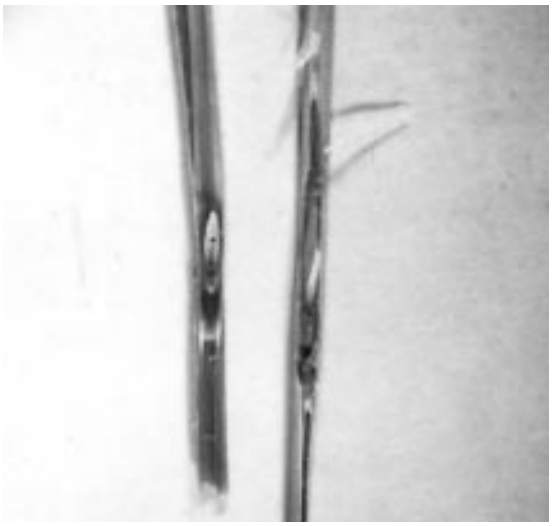


Figure 6. Injured growing points at the jointing stage on a normal plant.

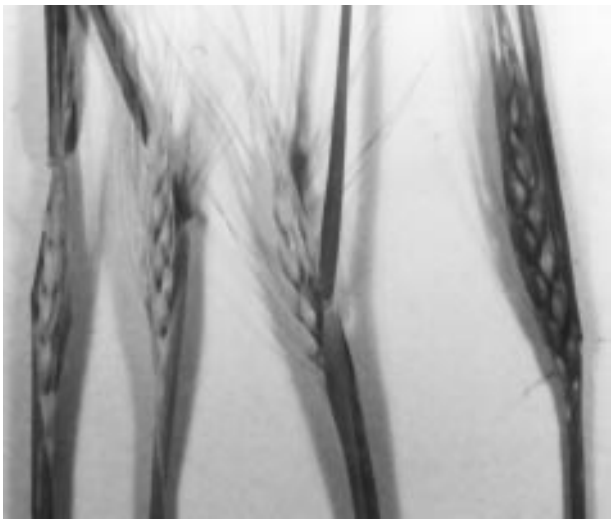


Figure 7. Damage to heads to boot and early heading stages.

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 consequences 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 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. After freezes at late spring growth stages, however, hot and dry conditions usually prevent later tillers from producing worthwhile yields.

When freeze injury is only partial, when alternate management practices might disrupt established rotation systems, or when good alternate uses or crops are not available, 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. However, this might be offset somewhat 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 frequently is of poorer quality than usual. Test

Figure 8. Freeze injured anthers.

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 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 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. 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

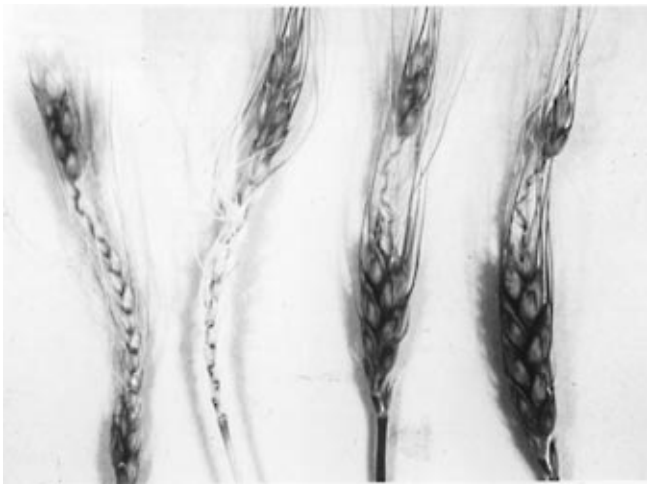


Figure 9. Partially filled heads after injury at the flowering stage.

Figure 10. Injured wheat kernels (top).

grain than seedlings from good quality wheat seed.

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 and, in no case, should it constitute more than one-third to one-half of the total grain in the ration.

Hay on Ensilage

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. 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 moisture loss.

The nitrate content of wheat 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 head and rarely kills the 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 rather than when it is fed as hay.

Alternate Crops

Ample time is usually available after early assessment of spring freeze injury to wheat to replant the land to other crops. The most likely alternate crop possibilities are soybeans and sorghum in eastern Nebraska and sorghum, proso millet, and sunflowers in western Nebraska. Soil moisture should be considered when choosing the alternate crop. In many situations the summer fallow land will have more soil moisture than the land on which the wheat has grown and, therefore the summer fallow land should be planted to the alternate crop. 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 alternate crop and for the wheat in the fall.

Freeze-injured wheat might need to be killed with herbicides 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 not removed or killed with herbicides, it should be chopped or worked thoroughly to prevent rapid drying of the soil.

The injured wheat could contribute to wheat streak mosaic virus the following year if the plants develop late tillers. These late tillers along with some early volunteer plants could bridge the gaps between crops. See EC89-1871 *Wheat Streak Mosaic Disease* for additional information.

Issued in furtherance of Cooperative Extension work, Acts of May 8 and June 30, 1914, in cooperation with the U.S. Department of Agriculture. Kenneth R. Bolen, Director of Cooperative Extension, University of Nebraska, Institute of Agriculture and Natural Resources.