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Spring Freeze Injury to Idaho Cereals

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Every year, small grains in Idaho face potential injury from cold temperatures. Injury to spring and winter cereals from low spring and summer temperatures has occurred in all parts of Idaho but is most prevalent in the higher-elevation southeast. Some producers may suffer significant losses to spring freezes each year. Low temperatures during the boot, heading and early seed filling periods can be particularly destructive.

The types of injury described here occur to both spring-seeded crops and to fall-seeded crops after they break dormancy in early spring. Winter barley, winter oats and winter wheat respond similarly to cold springtime temperatures.

Susceptibility to spring freeze injury

In fall, fall-seeded, winter cereal crops go through cold hardening — a complex biochemical process that increases their resistance to winter cold. In spring, when they break dormancy and resume growth, the crops quickly lose their acquired cold hardiness and resistance to freezing (Fig. 1). Many factors influence spring freeze injury. Plant growth stage, plant moisture content, freeze type, duration of exposure and lowest temperature reached are most important.

Plant growth stage

Spring freeze injury occurs whenever freezing temperatures coincide with susceptible plant growth stages. Susceptibility to freezing temperatures in spring steadily increases as maturity progresses through the flowering stage then decreases slightly as seed develops (Fig. 1). All cereals are most sensitive to freeze injury during reproductive growth, beginning at jointing and continuing through the boot, heading and pollination stages (Zadoks stages 31-69). A light freeze (28°-32°F) can severely injure cereals at these stages and greatly reduce grain yields.

Spring and winter crops behave similarly to springtime subfreezing temperatures. They differ mainly in being at different stages of growth when the freeze occurs.

Cover: Random head sterility on spring wheat due to spring freeze damage at flowering. Thin parts of the heads are sterile, and seed is not developing.

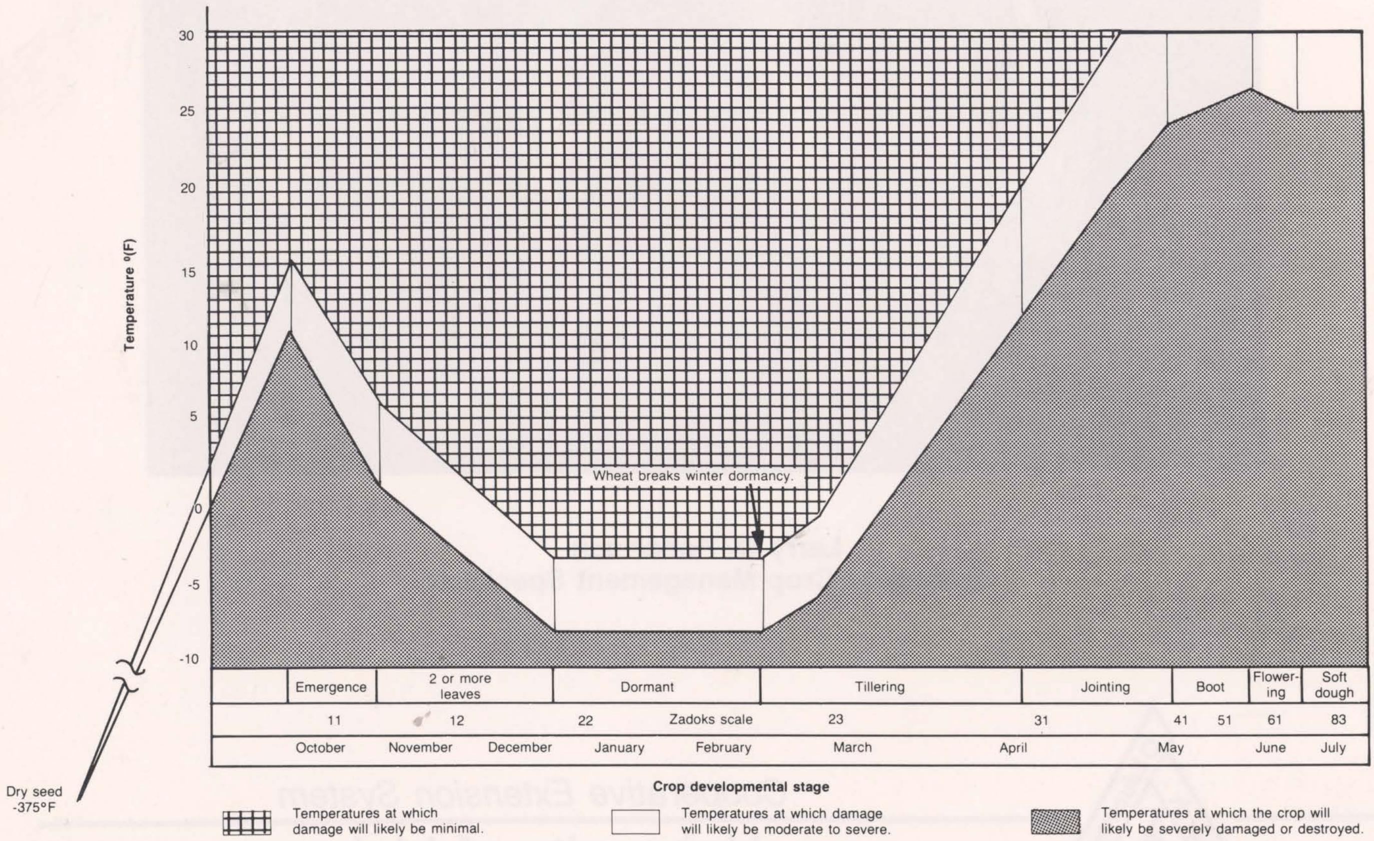

Fig. 1. Temperatures that cause freeze injury to winter wheat when exposure duration is 2 or more hours. (Adapted from Paulsen, G. M., E. G. Heyne and H. D. Wilkins. 1982. Spring freeze injury to Kansas wheat. Kansas State University Cooperative Extension Service C-646.)

Early plantings and early-maturing varieties are more likely to be injured by spring freezes than are later plantings and late-maturing varieties. However, in areas where early fall freezes are likely, late-spring plantings and late-maturing varieties may be injured by freezes that occur late in crop maturation.

Minor varietal differences in susceptibility to spring freeze injury have been reported, but they result primarily from differences in plant growth stage when the freeze occurs. Spring freeze resistance among cereal varieties at the same growth stage is similar. Therefore, little opportunity exists to increase freeze resistance through varietal selection.

Plant moisture content

Damage results from mechanical disruption of cells by ice crystals that enlarge both within and between cells. Cereals grown under good growing conditions and high soil-test nitrogen levels are more susceptible to freeze injury because of their lush growth and high moisture content. Drought and other stresses tend to harden plants to cold by decreasing plant water content, thereby reducing the severity of freeze injury at a given temperature.

It is also possible that ample soil moisture, cool temperatures and high soil-test nitrogen levels may result in less-severe injury. This could occur if the favorable conditions slow plant maturity, resulting in plants at an earlier, less-susceptible growth stage when the freeze occurs.

Temperature

Degree of injury is influenced by the duration of low temperatures as well as by the lowest temperature reached. Prolonged exposure to a given temperature can cause much more severe damage than brief exposures.

The extent of injury from a given temperature report is difficult to predict. Predicting is complicated by differences in elevation and topography among and within fields and between fields and official weather reporting stations. Growers' fields may have temperatures several degrees higher or lower than that recorded at the nearest official weather station. Field pockets may have temperatures several degrees lower than occur at higher elevations or on open slopes. Also, temperature reports fail to provide duration of critical temperatures.

Types of freezes

A freeze is defined as an occurrence of a temperature of 32°F or lower in a thermometer shelter at about the 5-foot level. It may or may not be accompanied by frost. The National Weather Service has described three classes of freeze:

Light freeze — the air temperature in a standard instrument shelter ranges between 28° and 32°F.

Moderate freeze — the air temperature in a standard instrument shelter ranges between 24° and 28°F.

Severe freeze — the air temperature in a standard instrument shelter is less than 24°F.

Radiation freezes occur when the air mass over an area is cool, the winds are light and the sky is clear or nearly so. Under these conditions, the soil surface cools rapidly as heat radiates outward. Air in contact with the soil surface gives up its heat to the cooler surface. As this cooling process continues, the temperature of the layer of air next to the soil surface decreases. If heat loss by outward radiation continues throughout the night, the minimum temperature will occur near sunrise. Under these conditions, the temperature near the soil surface can be 1 or more degrees lower than that recorded in the temperature shelter. If a layer of clouds interrupts the outward flow of heat, the temperature will often be prevented from falling below the freezing point. The lowest temperatures in a field will generally occur in low areas.

Advection freezes occur when a mass of air whose temperature is below freezing moves over an area. Under this condition, the temperature steadily decreases with increasing height above ground — the reverse of radiation freezes. Advection freezes usually are accompanied by winds. They are not associated with the low-level temperature inversion found in radiation freezes. Lowest temperatures during advection freezes generally occur on slopes or near the tops of ridges and hills.

A combination **radiation-advection freeze** occurs occasionally when a cold air mass and strong winds move in during the day and the winds subside at night. If nighttime skies are clear, radiational cooling further decreases the temperature and may result in a severe freeze.

See University of Idaho bulletin 494, *Spring and Fall Freezing Temperatures and Growing Seasons in Idaho*, for tables of probability of spring and fall freezing temperatures for many locations in Idaho.

Spring freeze injury symptoms

Knowing the symptoms of freeze injury may enable early assessment of damage, giving you a greater selection of uses for the damaged crop and of alternative crops to plant. Waiting until harvest to assess damage may decrease the value of the damaged crop for some uses and limits management alternatives.

Several characteristic symptoms of freeze injury develop at each growth stage (Table 1). Although continued cold weather after freeze damage may delay symptom development, moderate to severe damage can usually be identified by careful examination of the vital plant parts. For proper diagnosis, you must know the plant parts that are most vulnerable at each growth stage, their location and their appearance when they are normal as well as when they are injured. See Fig. 2 for the growth stages of cereal grain.

Table 1. Spring freeze injury to cereals at various growth stages.

Growth stage	Primary symptoms	Yield effect
Tillering (Zadoks 12-25)	Leaf chlorosis, burning of leaf tips, silage odor, blue cast to fields	Slight to moderate
Jointing (Zadoks 31-39)	Death of growing point; leaf yellowing or burning; lesions, splitting or bending of lower stem; odor	Moderate to severe
Boot (Zadoks 41-49)	Floret sterility, head trapped in boot, damage to lower stem, leaf discoloration, odor	Moderate to severe
Heading (Zadoks 51-59)	Floret sterility, white awns or white heads, damage to lower stem, leaf discoloration	Severe
Flowering (Zadoks 61-69)	Floret sterility, white awns or white heads, damage to lower stem, leaf discoloration	Severe
Milk (Zadoks 71-77)	White awns or white heads; damage to lower stems; leaf discoloration; shrunken, roughened or discolored kernels	Moderate to severe
Dough (Zadoks 83-89)	Shriveled, discolored kernels; poor germination	Slight to moderate

Source: Paulsen, G. M., E. G. Heyne and H. D. Wilkins. 1982. Spring freeze injury to Kansas wheat. Kansas State University Cooperative Extension Service C-646.

Emergence to tillering — Zadoks scale 10-25

During the seedling and early tillering stages, the growing point is below the soil surface and protected from freeze injury. The growing points of wheat and barley are generally located deeper in the soil than the growing point of oats.

Most damage occurs to leaves, which may have distinct light-yellow bands and which become chlorotic or necrotic and usually twisted. Banding usually appears on smaller plants and reflects the pattern of daily growth and nighttime freezing (Fig. 3). Leaf tips and occasionally whole leaves may die within 1 to 2 days after freezing. A strong odor of dehydrating vegetation may develop several days after severe freezes.

Plants in these stages are rarely completely killed although individual tillers may be killed and total tiller numbers may be reduced. Most often injury only slows leaf growth. Generally, growth of new leaves and tillers resumes with warmer temperatures.

Jointing — Zadoks scale 31-39

Leaves of freeze-injured plants develop damage symptoms similar to those of the tillering stage. The most serious injury can occur to the growing points,

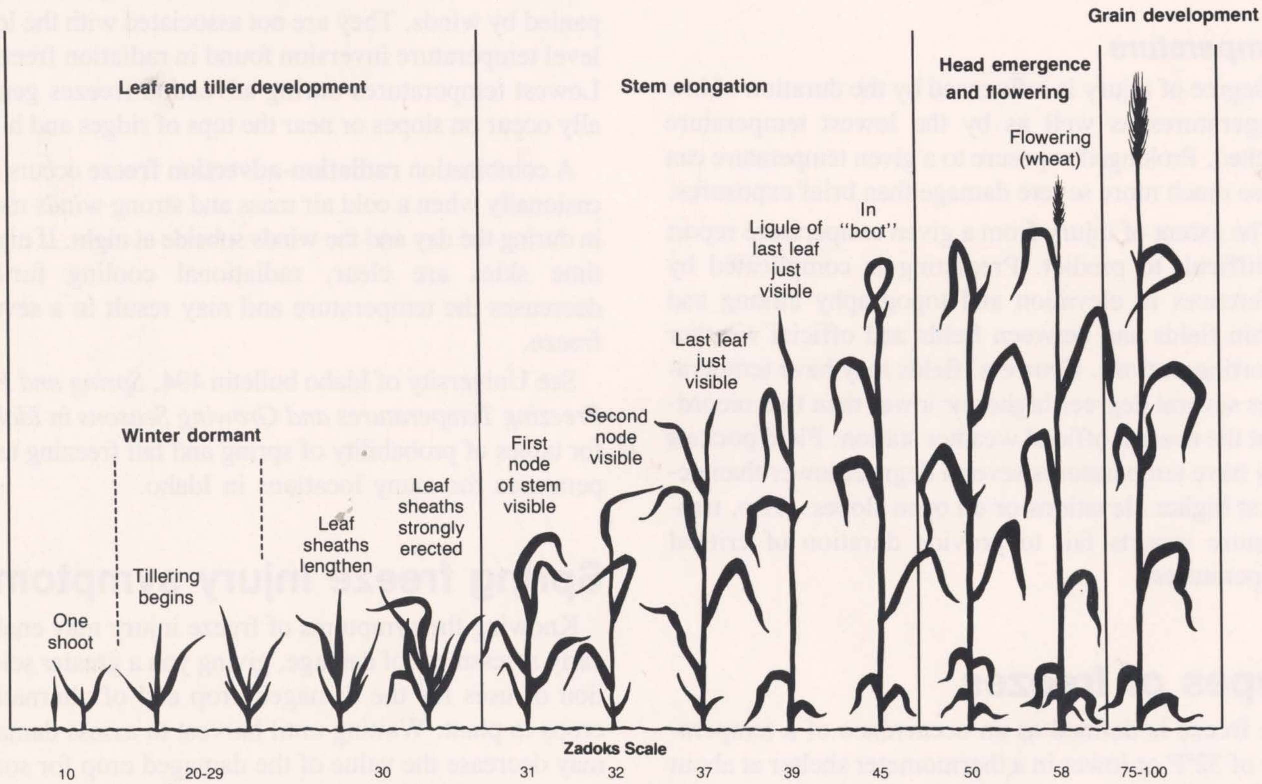

Fig. 2. Zadoks scale for cereal grain development.

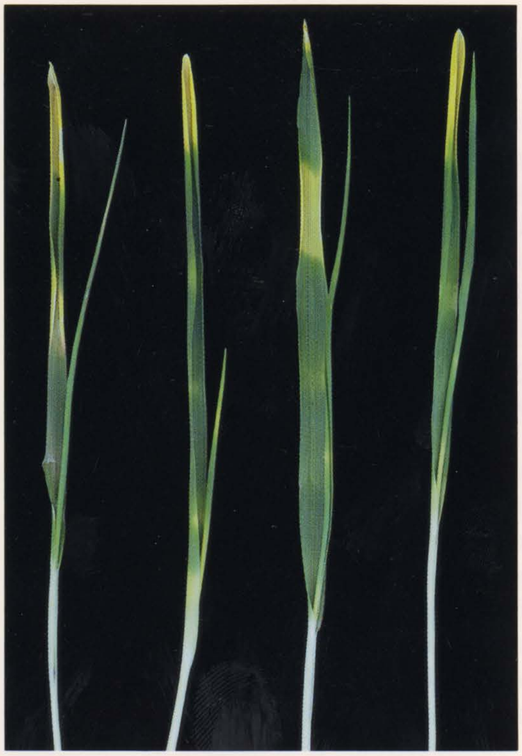

Fig. 3. Freeze bands on spring barley seedlings.

Fig. 4. Spring-freeze-damaged winter wheat stems showing discoloration below the nodes.

Fig. 5. Distorted heads of winter barley caused by spring-freeze-induced "trapping."

Fig. 6. Freeze ring on winter wheat stem shows junction of stem and leaf sheath collar at time of freeze.

Fig. 7. Sterile wheat heads have awns bent at 90 degrees to the rachis.

which are now 1 to several inches above the soil surface. The growing point in a stem is located just above the uppermost node you can feel when you run the stem between your thumb and forefinger. To observe the growing point, split the stem lengthwise with a sharp blade to expose the developing head.

A normal, uninjured growing point is bright pearl white to yellow green and turgid. Freeze injury causes the growing point to turn dull white or brownish and water soaked. Injury to the growing point can occur in plants that appear to be otherwise normal because the growing point is most sensitive to cold.

When a growing point has been injured, stem elongation stops, but later, uninjured tillers continue to grow and may mask the damage. Injury at this stage usually results in a mixture of normal and late tillers, uneven maturity and a corresponding decrease in grain yield.

Lower-stem injury at this and later stages can result in stem discoloration, roughness, lesions, splitting, collapse of internodes or enlargement of nodes. Stem damage is often not visible until after the boot or later stages.

Stem discoloration is associated with reduced metabolite transport through the nodes (Fig. 4). Metabolites collecting under the nodes cause the discoloration. Injured stems often break over at affected areas so that one or more internodes may be parallel to the soil surface. In stems with no discoloration, injury does not appear to interfere with the plant's ability to take up nutrients from the soil and translocate them to the developing grain. Injured areas are more likely than healthy tissue to become infected with microorganisms, which also may cause stem discoloration and deterioration. Wind or hard rain will easily lodge these plants, decreasing grain yields and slowing harvest.

Boot — Zadoks scale 41-49

During the boot stage, the heads are enclosed in the sheaths of the flag leaves. Freezing causes varied symptoms. Freezing may cause heads to be trapped inside the boot so that they cannot emerge normally (Fig. 5). The heads may remain in the boot, split out the side of the boot or emerge from the boot base first. Often the ''peduncle'' or stem supporting the head continues to elongate normally, causing crimps in the stem that can inhibit normal transfer of photosynthates. The result is light test weight grain.

Heads that emerge normally from the boot may turn yellow or white instead of their normal green. These heads have been killed, and grain will not form.

Often, the head appears normal from the outside even though the male parts of the flower (anthers) are dead. Because wheat, barley and oats are mostly self-pollinated, male sterility causes poor seed set and low grain yield. Anthers are more sensitive to freezing temperatures than are the female flower parts.

Injury to the anthers can be detected soon after the freeze. Normal anthers are light green, full of developing pollen grains and turgid. They turn yellow when they mature and shed pollen. There is also some degree of anther extrusion from the floret, especially in wheat and oats. Freeze injury causes anthers to turn white and shrivel. It usually prevents them from shedding pollen and from extruding.

Freeze symptoms described for earlier stages of growth may also appear at this time. Leaves and lower stems may exhibit symptoms described for the tillering and jointing stages. However, these plant parts are more resistant to freezing temperatures than are the floral parts. Freezing temperatures that are severe enough to injure leaves and lower stems are nearly always fatal to male flower parts. Less-severe freezing may sterilize the male part of the flower without producing any symptoms on the leaves and stems. It is important, therefore, to examine the anthers.

Heading — Zadoks scale 51-59

Most symptoms of freeze injury at this stage are similar to those of earlier growth stages — sterility, leaf burn and stem lesions. The most apparent symptom, however, is chlorosis or bleaching of awn tips. White-tipped awns (beards) usually indicate that floral parts have been injured. Awn tips may have a purple cast before turning white.

A light-green or white freeze ring may encircle the stem below the head several days after exposure to freezing temperatures (Fig. 6). This ring marks the juncture of the stem and flag leaf at the time of the freeze. The freeze ring may appear on plants that show no other symptoms of freeze injury. The freeze ring may impede movement of metabolites from the plant to the developing grain. As plants mature the straw may break at the freeze ring. Breaking is more likely when heads are well filled, particularly during windy conditions.

Sterility in a head may be complete or localized in a seemingly random pattern (see cover). This sterility pattern probably is due to differential maturity of individual florets within a head. Floret maturity proceeds from near the middle of a head to the top and bottom of the head over 2 to 4 days. Maturity also proceeds from the primary spikelet of a floret to its tertiary and quaternary spikelets. More-mature florets are more likely to be damaged. Even slight differences in maturity of individual florets will result in some being damaged and others left intact.

Flowering (Anthesis) — Zadoks scale 61-69

Wheat and oats flower several days after the heads or panicles appear. Barley flowers more nearly at the time of head emergence. Symptoms of freeze injury at heading and flowering are nearly identical.

The flowering stage is the most temperature sensitive. Small differences in temperature, duration of exposure or other conditions can cause large differences in amount of injury. Usually, light freezes at this stage will result in an appearance of more-random damage than at other stages. More-severe freezes usually cause the entire head to be sterile. It is common for the awns to bend at nearly 90-degree angles from the rachis as they mature (Fig. 7).

Milk — Zadoks scale 71-77

Developing cereal kernels normally grow to full size about 2 weeks after flowering. Maximum grain weight, however, is not reached until 3 to 5 weeks after flowering, the length of time depending on temperature and variety.

If young kernels fail to develop after freezing temperatures, they likely have been injured. Injured kernels may be white or gray and appear rough and shriveled instead of light green and plump. If the freeze is followed by cool weather, symptom appearance may be delayed a week or more.

Injured kernels may initially grow to normal size, but they produce light, shriveled grain at maturity. Their contents may be off-color and liquid instead of viscous. The rachilla or short stems that hold the florets in the head may also be darkened. Often, damaged forets are easily stripped from the rachillas.

Cereals frozen at the milk stage often shatter easily at maturity, and the shriveled kernels produce low test weight grain. Germination percentage is usually reduced as a result of freeze injury.

Dough — Zadoks scale 83-89

Kernel development is completed during this stage. Cereal kernels frozen at this stage are likely to have slightly reduced test weights and to appear shriveled or wrinkled. Yield reductions are usually minor. The embryo (germ) has a higher moisture content than other kernel parts, and its complex of cellular contents and structures makes it more vulnerable to freeze damage. Seed germination and barley malt quality may be reduced.

Management of freeze-injured cereals

Making the best decisions concerning the crop requires accurate assessment of damage. Except in rare cases, freezing in any given field usually injures only a part of the cereal crop. Damage may be worse in low areas or on a slope where the crop is at a more-susceptible stage of maturity.

Late tillers that may not normally produce grain often develop rapidly after main tillers are killed by a freeze, particularly when damage occurs in early growth stages. If after-freeze conditions are favorable, these tillers can account for appreciable yield. Most often, however, late tillers have significantly reduced yields and the grain is poorly filled, giving low test weights.

Efforts to force wheat to retiller after the initial crop was cut due to freeze or hail damage have been generally unsuccessful if the crop was in the boot or later stages of growth. Barley and oats may retiller more than wheat.

Harvest for grain

When damage assessments indicate that adequate yields can be obtained, leaving the crop for grain harvest is often the producer's best choice. Freeze damage that occurs before heading and flowering usually does not adversely affect the development of individual kernels. However, low test weight may result from stem damage. Freeze injury after the flowering stage usually leads to shriveled, poorly filled grain. Germination percentage is also often affected.

Grain that has been frozen after flowering should not be used for seed unless the seed has normal test weight and thorough germination tests indicate normal germination. Numerous tests have indicated that normally germinating seed with low test weight will produce weaker seedlings and lower yields than seed of good test weight. Because of a natural seed dormancy in cereal varieties after harvest, germination tests should be conducted only by a qualified laboratory, and seed should be pre-chilled.

Most wheat from freeze-injured fields is suitable for normal milling and baking. Crops that are badly shriveled are usually poor in quality due to their low test weight; discolored, chalky endosperm; and mixture of different kernel sizes and maturities. Grain this badly damaged should not be used for milling and baking. Malt barley that has been freeze injured after the heading or flowering stages will probably not pass the requirements of brewing companies.

Severely shriveled grain is best used as a livestock feed. Protein in shriveled grain is usually high. Freeze-injured grain should be gradually incorporated into feed rations.

Hay, silage or grazed forage

If the field inspection indicates low grain yields, cutting a freeze-injured cereal for hay or silage may be the most economical and practical use if feed is needed and harvesting equipment is available. Feed quality of cereals harvested up to the soft dough stage is generally excellent.

If the crop is to be used for hay, silage or grazed forage, check its nitrate content to be sure it is not toxic to livestock. Freezing normally does not kill the entire plant, and the roots may continue to absorb nitrates from the soil. With no grain to use the nitrates, they may accumulate in the forage. If the crop contains high nitrate levels, do not use it for hay, silage or grazed forage unless you can adequately dilute it with low-nitrate feeds.

When ensiling a cereal crop, take extra care to ensure tight packing. Proper packing of cereals is difficult because of their round, hollow stems. As the crop develops toward maturity, proper packing becomes increasingly difficult.

Harvesting for hay or silage removes a crop faster than is generally possible by grazing. This earlier harvest may be important if another crop is to be planted in the field in the same crop year. Harvesting for hay or silage also makes it possible to avoid working the vegetation into the soil, which can cause excessive soil moisture loss on dryland fields.

Wheat and barley awns in crops cut after flowering can cause actinomycosis, commonly known as "big jaw" or "lumpy jaw," in cattle. Actinomycosis is much less likely to occur when the crop is harvested before flowering or ensiled than when it is harvested at a later growth stage or fed as hay.

Alternative crops

Some areas of the state have much more flexibility with alternative crops than other areas. Parts of the state with irrigation water and a relatively long growing season have available numerous alternative crops if freeze damage occurs before or at heading. In higher elevation areas where the growing season is short, replanting to another shorter-season cereal may be possible. If you decide to replant to another crop, kill the freeze-damaged crop either with chemicals or tillage to prevent it from becoming a weed in the new crop.

Before deciding to plant an alternative crop, be sure that your evaluation includes all costs of removing the freeze-injured crop and reseeding the new crop. Yield potential falls with later-than-optimum seeding dates. For example, at the University of Idaho Research and Extension Center at Aberdeen, yields of spring barley were reduced about 10 bushels for each week planting was delayed between mid-April and early June. Other crops and areas may differ in their response. Always consider yield reductions and reseeding costs before making final decisions.

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