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.

Issued in furtherance of cooperative extension work in agriculture and home economics, Acts of May 8 and June 30, 1914, in cooperation with the U.S. Department of Agriculture, LeRoy D. Luft, Director of Cooperative Extension System, University of Idaho, Moscow, Idaho 83843. We offer educational programs, activities and materials without regard to race, color, religion, national origin, sex, age or disability, in accordance with state and federal laws.

2M, March 1991

$1.25 per copy