Agdex 075-1

Protection Against Frost Damage

Frost risk is an important fact of life for agriculture. Freezing temperatures restrict the length of the growing season and are responsible for reductions in yield and quality of agricultural crops. Sensitive crops can suffer serious damage at temperatures above freezing as well. In either case, the minimum temperature is critical.

Of all the weather factors affecting agriculture, minimum temperature is among the most variable from place to place. Adjacent fields and garden sites can have very different frost-free periods, and are therefore suited to different uses. Risk can be reduced by careful management of the land and effective reaction to forecasts. Late spring and early fall frosts usually involve minimum temperatures just slightly below freezing, It is in these situations that preventive measures can be most effective. By successfully averting a single freezing situation, the growing season may be extended by weeks.

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Minimum temperature

The stage is set when cool air floods over an area, usually in the wake of a cold front, Daytime temperatures may still be well above 10°C with the coldest overnight minimum temperatures not occurring until a night or more after the cold outbreak. This is because associated wind and cloud cover reduce the cooling rate, as explained later. When the wind abates and cloud cover moves off or dissipates, rapid heat loss at night can lead to freezing.

How heat is lost

The primary heat loss that can lead to freezing takes place at the earth's surface - from the soil, water, plant cover, and so on. Heat is removed from the surface by outgoing invisible radiation that escapes to space, At night there is little incoming radiation to offset this heat loss, which continues until after sunrise. For this reason, minimum temperatures usually occur in the early morning.

Cloud cover reduces the cooling rate at night because clouds absorb part of the escaping invisible radiation and re-radiate some of it back to earth.

Air is cooled from below

When the earth's surface cools, the adjacent air is cooled in turn by conduction. The condition of the soil is very important in determining how much the air is cooled. Moist, firmly-packed soil will cool slowly because heat removed at the surface by radiation is replaced in part by heat conducted upwards from the warmer soil below. The soil acts as a reservoir of heat, stabilizing temperature. If the soil is dry or loose, it is a poorer conductor of heat. This means that the surface can cool off drastically, more or less insulated from warmer soil below. Accordingly, frost risk is greater on dry, loose soils. This is true also of soils that are peaty or heavily manured. A blanket of crop residues or dense plant cover has a similar effect. A common illustration is the frost buildup that occurs on grass during clear nights while adjacent bare soil remains frost-free. A later section describes soil management techniques for maximum frost prevention.

Wind speed is important in determining minimum temperature. In general, the lighter the wind the lower the overnight temperature. Under calm or nearly calm conditions, a very shallow layer of air next to the ground is strongly cooled from below. This condition of colder air underlying warmer air is called an inversion. However, when there is wind, turbulent mixing tends to diminish the intensity of the cooling by spreading the effect through a deeper layer of air. The lowest nighttime temperatures are favoured under clear, calm conditions.

Cold air drainage

On calm nights, the shallow layer of cold dense air that forms near the ground surface will tend to flow downslope if the ground is not completely level. This phenomenon is known as cold air drainage. It has a major influence on the distribution of minimum

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temperature, rendering some areas much more frost-prone than others nearby. The coldest air settles in depressions commonly called frost hollows or frost pockets, or it collects in other areas where cold air drainage is obstructed by some kind of barrier.

On a small scale, the effects of cold air drainage may be visible in the widely variable frost damage observed within a medium sized garden. The lowest areas are hardest hit while higher portions may escape all frost damage. This underlines the importance of considering topography when choosing garden sites. On a larger scale, entire fields may be affected. Even if the slopes involved are very gradual, some fields are much more suited to cold-sensitive and long-season crops than others nearby.

A site to site difference in average minimum temperature of 1°C corresponds to a difference of one to three weeks in growing season length, depending on location. See the following two examples.

Situation A – shallow valley, several miles wide, 100–150 feet deep; average slope less than 1:300 (barely noticeable), clear calm nights

Temperature – decrease of about 2°C per mile moving towards the lowest part of the valley, or about 1/2°C for every 10 feet of vertical descent.

This frost hollow nearly one mile across has an average frost-free period some 20-30 days shorter than areas a mile away with better cold air drainage.

Situation B – ridge sloping downward uniformly to a basin about one mile across, height difference of some 135 feet over a horizontal distance of 3500 feet (about 1:26 slope)

Temperature – frost-free period in the basin is about 75 days shorter than at the crest of the ridge only two-thirds of a mile away.

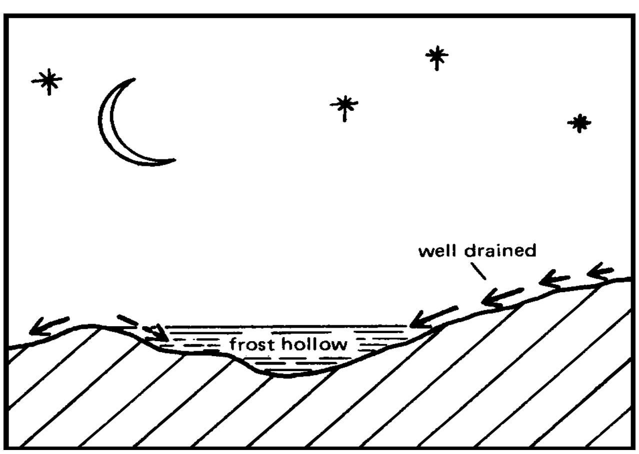


Figure 1. Cold air collects in frost hollows, seriously affecting the length of season. Slopes may be much more gradual than shown.

Measuring minimum temperature

Standard temperatures are measured in a ventilated instrument shelter perched some 4 1/2 feet above ground, and are an accurate reflection of air temperature at that height. But on calm nights minimum temperatures near ground level are often from 1 to 6°C colder than values in the shelter, depending on cloud cover. This difference is significant because a large proportion of damaging frosts occur during clear calm nights. A standard minimum reading of 0°C can correspond to a killing frost in a crop.

Killing frost

The term **killing frost** identifies freezing situations lethal to plants, and recognizes the fact that for many crops, temperatures can drop below 0°C without killing them. However, when assessing a situation on the basis of standard temperature information (data or forecasts) it is important to bear in mind differences between standard readings and temperatures in the crop, especially under clear and calm conditions. The specific temperature for killing frost varies according to the crop and stage of maturity. Cucumber plants suffer at temperatures below 3°C while grain crops may withstand sub-zero values. Plant tissue will generally be a little colder than the surrounding air since plants lose heat by radiation. The duration of cold temperatures is also a factor.

Reducing the hazards

The microclimate of each field or garden site is unique from the standpoint of minimum temperature. The principles described above apply generally, however, and should be helpful in adapting the following guidelines to individual situations.

Site selection

The best sites for cold-sensitive crops are those with good cold air drainage: situated above areas into which cold air can flow freely at night. Sloping land encourages cold air drainage; south-facing slopes have the added advantage of generally warmer soils and in turn warmer air near ground level. It has been noted too that convex (rounded) slopes are generally less frost prone than concave (dished) slopes. This is related to the effect of slope on the rate of cold air movement.

It is especially important to avoid basins, depressions, and other poorly drained areas when growing crops sensitive to cold temperatures and freezing. This is also true of sites where cold air drainage is obstructed by some kind of barrier. Barriers can be natural or man-made, comprising such things as ridges, trees, hedges, fences and buildings. Sometimes these can be modified or removed with good results.

Woodland strips or other barriers can be useful if they are positioned so as to hold back and turn aside influxes of cold air.

Areas of organic (peaty) soils are vulnerable to temperature extremes. This is because the exposed soil surface is thermally insulated from lower portions of the soil, and because these soils are generally found in areas with poor cold air drainage.

Sandy soils dry out more quickly than clay soils and can be more frost-prone as a result.

The risk of frost is generally reduced in urban areas because of associated heating.

Large bodies of water (lakes, reservoirs, rivers) tend to reduce temperature extremes on nearby land. This effect diminishes with increasing distance from the water; it may also be offset by cold air draining into the area at night.

Crop selection

Risk of cold temperature damage can be minimized by weighing the degree of hardiness of available crops against the relative level of risk at available locations. The most favored locations are reserved for the most cold-sensitive or long-season crops. This applies to both gardens and field crops.

Taller plants have an advantage in that the tender flowering or fruit-bearing parts of the plant are kept above the cold air near the ground.

Managing soil and soil cover

The key to moderating overnight temperature extremes lies in promoting the upward movement of heat in the soil to help counteract surface cooling. This is most readily achieved with **bare, moist, packed, mineral soils.**

When adding manure or peat as soil improvers, these materials should be well-mixed into the soil. Excess quantities should be avoided.

Organic soils can sometimes be modified to improve minimum temperature characteristics. It helps if these soils (and others) are firmly packed. Mixing in sand has also been effective, though it is not always practicable on a field scale.

Soil loosening should be avoided whenever frost is expected. Disturbing bare soil to a depth of only 2 cm for example, lowers the overnight minimum temperature at the surface by about 1 to 3°C in typical situations. During the critical spring and fall periods, this can easily mean the difference between extensive damage and none at all. The timing of spring and fall tillage operations, hilling of potatoes, and so on, is best decided in light of the latest weather forecast.

Packing the soil has a positive effect. Watering is another way to consolidate a loosened soil and improve its ability to store and conduct heat.

Soil cover tends to increase the risk of cold temperature damage to crops. This is true whether the covering consists of living plants such as grass or weeds, or of a mulch of organic matter such as peat or crop residues.

Weed cover should therefore be kept to a minimum, provided cultivation is avoided when there is a risk of dangerously low temperatures.

Active crop protection

Forced harvest - Given a frost forecast, available time before frost occurrence can be used in harvesting crops that are sufficiently mature. If the warning comes far enough in advance, savings can be considerable.

Hastening the maturity of cereal grains by timely swathing is a means of reducing risk. Wheat and barley can be swathed at a kernel moisture content of 35 percent without seriously affecting volume or weight. Grain intended for seed should be tested for germination level.

When using general frost forecasts and data, a knowledge of the site factors affecting frost risk, as described earlier, is useful in assessing the risk at specific locations; for instance, when applying a forecast of “frost in low-lying areas” to a particular site.

The following methods of crop protection are generally confined to valuable crops like fruit and vegetables because of the costs involved. They are described only briefly:

Heating — heaters or open fires to counteract radiation heat loss; a large number of small heaters works better that a few large ones.

Covering — of individual plants or larger areas, preferably with insulating materials; any heat source is more effective under such cover.

Air circulation — fans to mix air near the ground with warmer air above.

Sprinkling — maintaining a thin film of water on plants prevents temperatures beneath the film from dropping below freezing, even though ice may form.

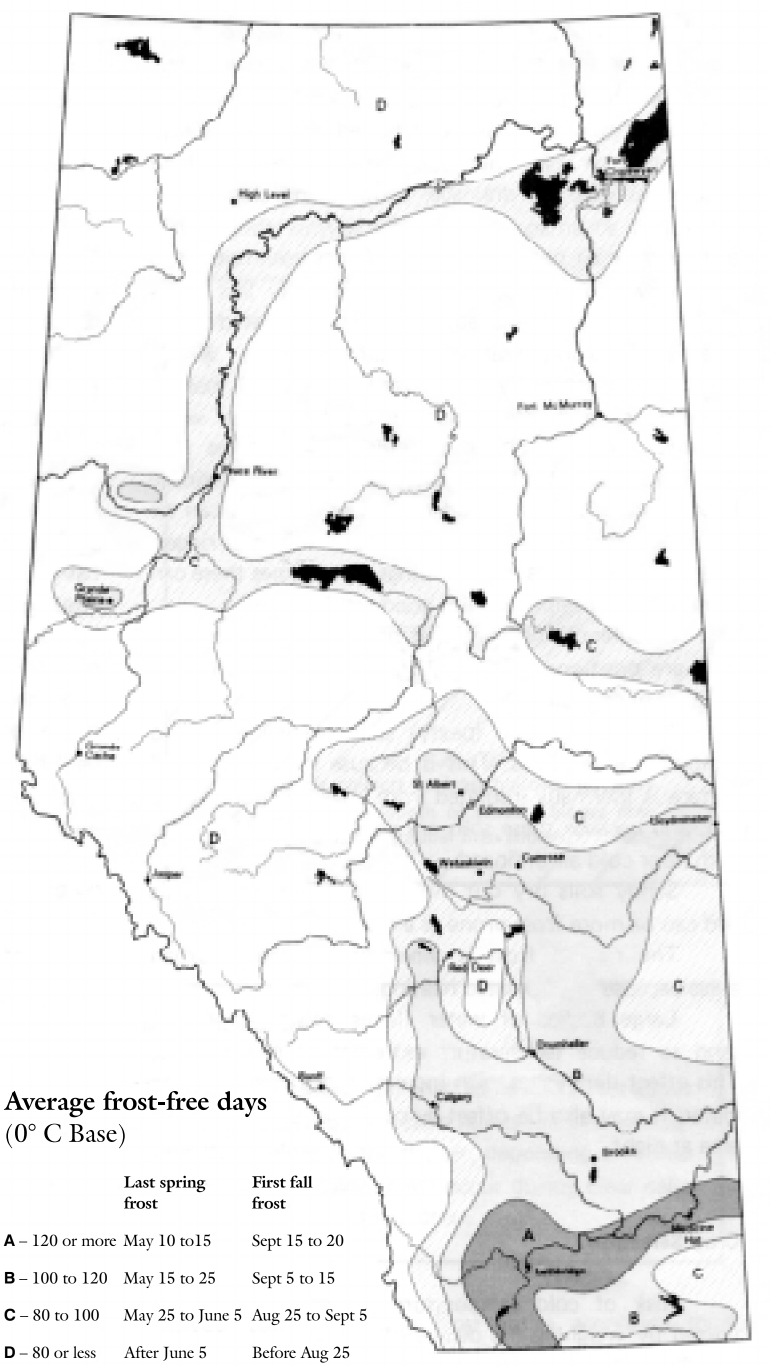
Cold tolerance of some specific crops

A number of crops are listed below according to approximate lethal minimum air temperature. Plant response to cold temperature is complex, and actual hardiness is affected by variety, stage of growth, past weather and general health of the plants. Duration of temperatures is also important. Damage begins at temperatures above lethal values.

Lethal minimum temperature	Crop
0 to +3°C	cucumbers, tomatoes (most sensitive during and after flowering)
0°C	beans, potatoes
-1°C	corn (sweet), asparagus
-2°C	wheat – heading and filling
-6°C	wheat – vegetative growth
-9°C	barley – vegetative growth

Other sensitive crops:
squash, pumpkin, eggplant, pepper.

Other tolerant crops:
legumes, grasses, oats, canola (most sensitive early fall), cabbage, cauliflower, broccoli, Brussels sprouts, lettuce, carrots, peas, radishes.



Average frost-free days
(0° C Base)

	Last spring frost	First fall frost
A – 120 or more	May 10 to15	Sept 15 to 20
B – 100 to 120	May 15 to 25	Sept 5 to 15
C – 80 to 100	May 25 to June 5	Aug 25 to Sept 5
D – 80 or less	After June 5	Before Aug 25

The map is based on standard climatic normals and shows the general distribution of the frost free period; on a more localized scale topography exerts a strong influence.

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