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Frost injury to cereals in W.A.

By M. W. Perry, Research Officer, Plant Research Division, and A. G. P. Brown, Plant Pathologist, Biological Services Division

Late spring frosts commonly reduce yields and affect the quality of grain in wheat crops, especially in the southern, eastern and north-eastern districts. The damage is usually localised on individual farms, but is sometimes widespread.

Barley, and oats to a lesser extent, are also affected. Average losses of wheat in Western Australia have been estimated at 3 to 5 per cent. per year, or about 2 million bushels on current production figures.

Radiation frosts

Frosts in W.A. are caused by radiative cooling of the ground. Heat absorbed during the day is lost from the ground surface at night as long-wave radiation leading to a fall in surface temperatures.

Cloud cover and the water vapour content of the atmosphere are the main factors controlling the heat loss. Water vapour traps the long-wave radiation emitted by the soil and, with the clouds, reflects much of the heat back toward the ground. But when skies are clear and the air cool and relatively dry, most of the radiation is lost into space and surface temperatures fall rapidly. In W.A., ideal conditions for radiation frosts follow immediately after the passage of a depression and its associated cold front. The following anticyclone establishes a ridge of cool air and frosts are likely as the skies clear and the wind drops.

As the ground surface cools at night, air above it is chilled by contact and a temperature gradient is formed with the coldest air close to the ground. Vegetation surrounded by cold air and frosts are likely as the skies clear and the wind drops.

When is damage likely?

Minimum temperatures are lowest in July and August (Fig. 1). During these months young crops may suffer leaf damage but yields are unlikely to be affected. Later, when tillers are elongating, the plant appears resistant enough to withstand the mild frosts which are most common in W.A. There is some stem frosting every year but experience suggests that it does not cause much yield reduction.

Frosts may cause serious losses just before, at and after ear emergence (late September to early October). The newly emerged ear is composed of delicate flower tissue which is susceptible to injury by even light frosts. There is evidence from Japan that pollen formation may be adversely affected by temperatures close to though not below 0°C. Such damage, however, has not been recorded in Australia.

Frosts after grain formation cause varying degrees of shrivelling but resistance increases as the grain matures.

Meteorological records indicate that the northern wheatbelt is virtually free of frosts from the end of August onward. In the southern and eastern wheatbelt a number of September frosts can be expected and, as in 1971, may occasionally extend into late October. It is these abnormally late frosts which cause widespread losses in W.A.

Symptoms in young crops

Damage to crops after emergence and before tiller extension is usually confined to leaf blighting. Several days after a frost, affected parts appear water soaked and wilted. After a week they become a straw brown colour and the leaf margins tend to roll in from the under surface (see photographs). Severe cooled below 0°C (32°F) without freezing. That such parts remain undamaged demonstrates that ice formation rather than low temperature is the cause of frost damage.

Hoar frosts, which cover vegetation with a white layer of ice, are caused by freezing of dew formed as moist air cools. These are a more dramatic sight than normal "dry" frosts, but ice formation on the outside of the plant actually releases a little heat which often prevents the sap freezing.

Parts of the plant differ in their tolerance to frost. Leaves, and stems to a lesser extent, may suffer only minor damage from repeated frosts. In contrast, the soft young tissues of the head and rapidly elongating sections of the stem are highly susceptible and easily killed by frostig.

Causes of frost damage

Frost injury at any stage of plant growth is essentially due to the freezing of water within the plant tissues. Freezing starts in the coldest leaves and spreads along the leaf into the stem. As the ice crystals form and grow they withdraw water from the plant cells, damaging them by dehydration and rupturing cell membranes.

The whole plant may not freeze; often ears or sections of the ear may be super-
Leaf blighting—
death of frosted leaf tips. The dead tissue is a clear straw colour.

Blistering of the stem immediately above the nodes.

Bending of the stem as a result of frost damage to the nodes. Healthy stem on the left.

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Blistering of the stem immediately above the nodes.

Bending of the stem as a result of frost damage to the nodes. Healthy stem on the left.

Frosts can kill the growing point and subsequently the tiller or the entire plant, but these frosts are rare in W.A.

After stem extension has begun, damage may include leaf blighting and also various effects on the stem. Stem damage is rarely noticed until much later when the crop is in ear. At this time symptoms appear as browning of the nodes and internodes at the base of the stem, node swelling and bending, and cracking and blistering of the stem above the node. Stem injuries can lead to lodging. Injuries to the young crop rarely result in reduced yield.

Symptoms in older crops

Just before heading the plant becomes increasingly frost sensitive. A moderate frost at this stage often results in a white ring around the stem just below the ear, usually accompanied by blasting of the lower florets.

Just after ear emergence the crop is very sensitive and remains so until grain has formed. Frost before grain set can cause affected florets to fall off, leaving a bare stem. The bottom of the ear is the part most commonly lost, but middle or upper sections may also be taken.

Often frost kills the newly formed grain and leaves the rest of the ear normal. These plants may later appear purplish and the ears remain stiffly erect without the weight of grain to bend the stems. With sufficient soil moisture there is often profuse re-stooling of frosted plants.

Frost after grain formation results in varying degrees of shrivelling, depending on the water content of the grain. Milky ripe grain is badly affected but hard ripe grain hardly at all.
"White ring" symptom of frost injury on green stems just below the ear.

Tip, central and basal blighting of ears.

Discoloured, stiffly erect ears caused by frost blasting during grain formation. Healthy ears on the left are drooping with the weight of grain.

**Can frost damage be prevented?**

Due to the random and uncontrollable nature of weather it is difficult to recommend practices which could control frost damage. Work is under way in W.A. and N.S.W. on varieties which incorporate increased resistance to stem frosting but most frost damage in W.A. happens after ear emergence and at present there are no prospects of varieties resistant at this stage of growth.

An individual farmer's local knowledge may help to reduce the risk of frost losses. Areas where crops are often frosted could be left uncropped. These areas are likely to be on the lower slopes and valley floors where cold air gathers after flowing from higher ground. Tree belts across slopes may also trap cold air and result in local frost patches.

Crops on some soil types are more susceptible to frost damage. Heat conducted to the surface from deeper layers in the soil normally reduces the amount of surface cooling. Dry, fluffy soils or soils with an organic surface cover are poor conductors and the surface cools rapidly. Wet or well compacted soils conduct heat readily and are less likely to promote frosts.

The relative susceptibility of different cereals is not clear but barley and oats appear to be slightly more tolerant than wheat in the field.

Farmers in susceptible areas could reduce the risk of frost damage to crops by—

- avoiding sites known from experience to be frost liable;
- using varieties recommended for the area, not very early varieties which may ear when there is still a high risk of frost;
- sowing at the correct time into a well prepared, well compacted seedbed.

**The future**

Although plant breeding cannot provide a complete answer to frost damage, some highly frost resistant cereals have been imported into W.A. and may be included in future breeding programmes.

Little is yet known of the temperatures within crops; most temperature records at present come from meteorological stations in towns. Department of Agriculture trials this year will record ground and crop temperatures in an attempt to relate them to existing records and to any frost damage observed.

Although wheat is the main crop under study, lupins and rapeseed will be included in order to assess any risk to production of these crops.
Figure 1—Mean monthly minimum temperatures for July, August, September and October.