Department of
Primary Industries and Regional Development

GOVERNMENT OF WESTERN AUSTRALIA

GRDC
GRAINS RESEARCH & DEVELOPMENT CORPORATION

Frost Identification Guide for Cereals

How to use this guide

This field guide will help you identify the common symptoms of frost damage in cereal crops. A frost event is defined as when the temperature drops to 2°C or below recorded by a Stevenson screen. Look for frost damage in your cereal crop 5–10 days after a frost event.

Acknowledgments
Images supplied by Kelly Angel (Birchip Cropping Group), Figures 4C and D.

Accessibility
Copies of this document may be available in alternative formats upon request.

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Contents

Glossary of terms used in this guide

Awn	Whisker
Anther	A sac like structure of the male part of the flower in which pollen is formed
Anthesis	The period of flowering whereby pollen is shed from the anther
Carpel	The female reproductive organ, in wheat consists of the ovary and two feathery stigmas.
Ear/ head	The grain bearing tip of the stem of a cereal plant
Floret	The individual flower of a cereal. Each floret has three anthers containing pollen and an ovary which, when fertilised may form a grain.
Glume	The outer chaffy bract that encloses the wheat spikelet and grain
Lemma	One of the thin bracts of a floret below the anthers, ovaries and stamens, later enclosing the grain
Ovary	The female part of the flower that contains the ovule
Ovule	The structure within the ovary of the flower that becomes the grain following fertilisation
Palea	One of the thin bracts of a floret above the anthers, ovaries and stamens, later enclosing the grain
Panicle	The inflorescence (complete flowering head) of oats
Peduncle	The uppermost internode of the stem
Rachis	The main axis of the grass flower, in wheat provides the attachment of many spikelets to the peduncle
Spikelet	The structural unit of a grass flower that includes two basal glumes, consisting of one to several florets
Stigma	The female part of the carpel which traps the pollen from the anther transporting it to the ovary
Style	The stalk between the stigma and the ovary

Structure of a healthy wheat head

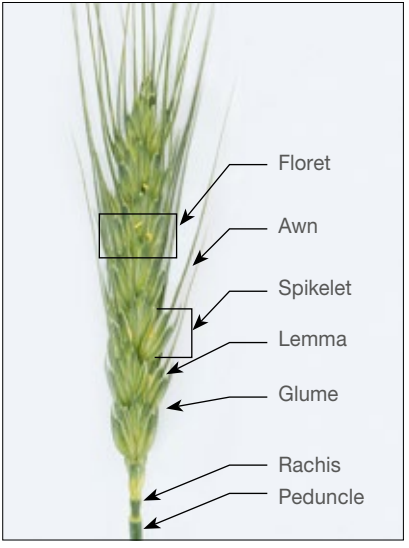


Figure 1 Structure of a wheat head

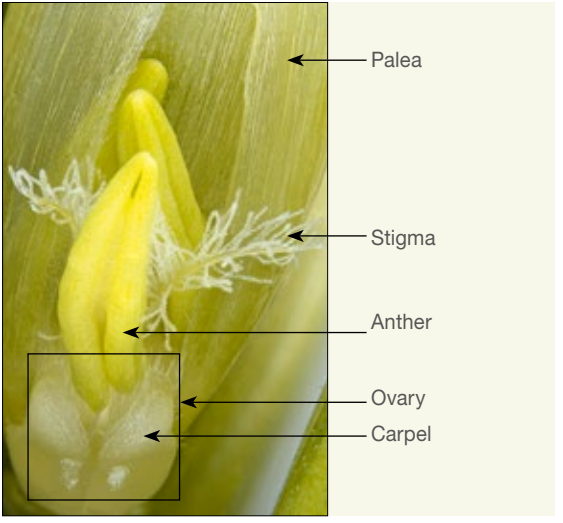


Figure 2 The inside of a wheat floret, (lemma and glume removed), showing palea, stigma, anther, ovary, and carpel

Susceptibility of wheat to frost damage

Factors affecting frost damage

Visible frost damage within a paddock is variable and can be caused by many factors including: temperature, soil type, soil moisture, cloud cover, wind speed, position in the landscape, crop species, crop nutrition and crop density.

Period of risk for wheat

Cereal crops are most susceptible to frost damage during flowering, however, are also susceptible at the early booting and grain filling stages (Fig. 3).

Which parts are susceptible?

Leaves, stems, anthers, ovaries and grain can all be affected by frost. A plant may suffer stem, flowering and grain frost, especially if a series of frost events occur throughout development.

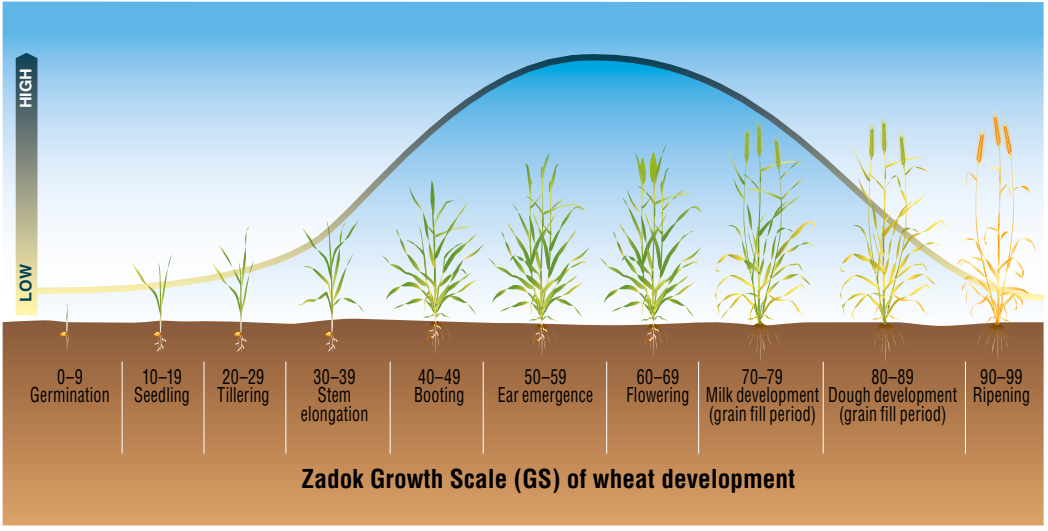


Figure 3 Susceptibility of wheat to frost damage during each stage of development (Zadok Growth Scale)

How to identify stem frost (Z31–49)

To check for early head and stem damage, peel the flag leaf away from the stem down to the node (Fig. 4). Carefully, roll the leaves away from the stem until two nodes appear. Using a nail or scalpel, slice open the sheath within to expose the head. If the head is a pale green, it is healthy. If it is white, it has been frosted. Keep inspecting the stem further down for cracking or bleached appearance of the stem. To check for peduncle damage, pull the head and the peduncle from the plant, peel away the flag leaf sheath from the peduncle.

Figure 4 How to dissect primary tiller to inspect for early head and stem damage

Stem frost

Water can settle inside the leaf sheath and freeze, causing damage to the peduncle or the internodes of the stem (Fig. 5). Peduncle damage can result in either head loss, or severe head damage and death of the primary tiller, causing re-tillering. Stem frosted plants are more prone to lodging. Physical damage can be seen as discoloured or bleached flattened peduncle or felt by the stem having a rough texture.

Figure 5 (A) Frost damage of the peduncle showing pale green rings with leaf sheath removed; (B) Rough texture of the peduncle; (C) Brown discolouring between 1st and 3rd nodes (left) compared to healthy stem; (D) Re-tillering after primary tiller has been frost damaged

Frost damage in wheat prior to head emergence (Z39 – 45)

When the head is emerging from the boot, frost damages the sensitive tissues. This can cause complete (Fig. 6A) or partial (Fig. 6B) pollen abortion, resulting in underdeveloped or bleached florets (Fig 6C and D).

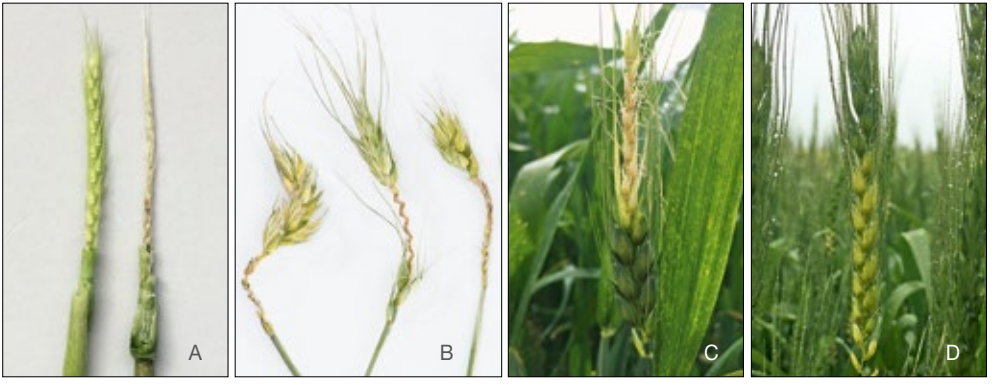


Figure 6 Symptoms of damage when frost occurs between Z39–45. (A) Comparison of healthy (left) and frosted (right) heads after dissection prior to head emergence; (B–D) Visible symptoms after head emergence seen as missing or bleached florets

How to identify flowering frost damage

To check for floret sterility, the floret must be opened. To do this, peel back the lemma and glume, exposing the reproductive structures and or developing grain (Fig. 7).

Figure 7 Peeling back the glume and lemma to reveal the anthers and ovary

Frost damage during flowering (Z65)

Wheat begins flowering in the centre of the head and extends to the top and bottom over time. A frost event during flowering can cause sterilisation of the spikelet, as the pollen, ovary or both can be affected, preventing grain development in that floret (Fig. 8).

Figure 8 (A) Healthy flowering wheat head; (B) Frosted flowering wheat head; (C) Missing grain observed during grain development (arrow)

Flowering frost damage of male reproductive parts

Before flowering, healthy anthers are green to yellow in colour. During flowering (anthesis), they are yellow, turning white with age (Fig. 9A). Frost affected anthers are white and distorted (banana shaped) and become a dull brown in colour (Fig. 9B).

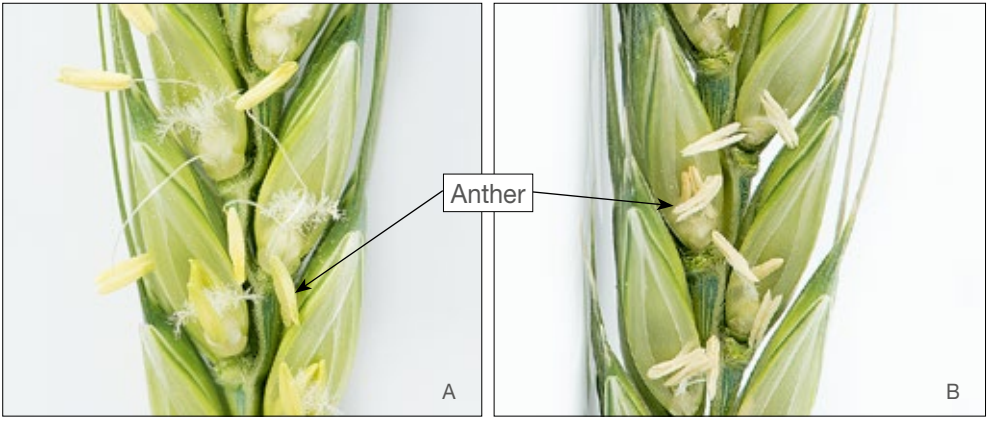


Figure 9 (A) Healthy anthers during flowering; (B) Frost affected anthers

Flowering frost damage of female reproductive parts

A healthy stigma remains white and feathery until after pollination, and a healthy ovary is bright white in colour, and as the grain develops it turns green, and begins to fill the floret (Fig. 10A). A frost affected stigma takes on a crumpled, distorted appearance and a frost affected ovary turns dull brown, and begins to shrivel as no grain develops (Fig. 10B).

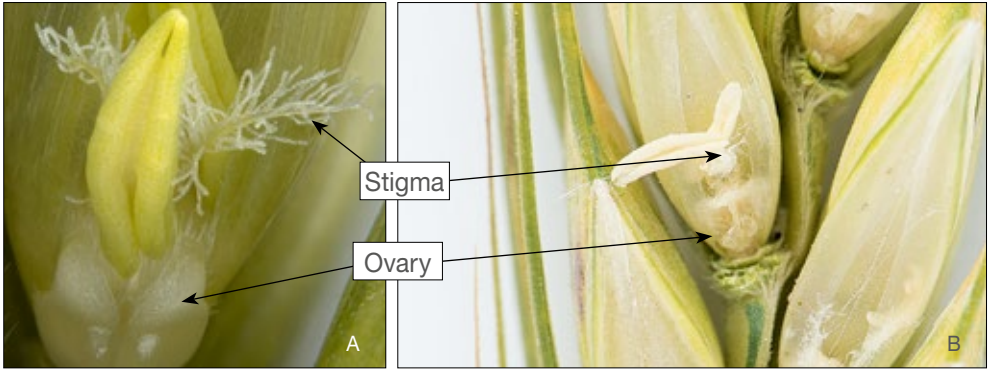


Figure 10 (A) Healthy stigma and ovaries; (B) Frost affected stigma and ovaries

Frost damage during grain development (Z70.2–79)

As the grain develops within the head, it can still continue to be affected by frost. Healthy grain are white and hairy, gradually turning dark green with a plump appearance. When squeezed they exude a white milk/ dough. Affected grain are white and shrunken, turning brown with a dimpled, crimped appearance. When squeezed they are spongy and does not exude milk/ dough, but rather a clear or straw coloured liquid. Depending on the severity of the frost there will be some healthy and unhealthy grains in the same head (Fig. 11).

Figure 11 (A) Healthy grain Z70.5; (B) Healthy grain Z70.8; (C) Healthy grain Z79 (bottom) and frosted at Z70.8 (top); (D) Healthy and frosted grain Z79 (arrows show dimpled appearance of frost damage)

Frost damage during dough development (Z81–89)

Healthy grain during early dough becomes more solid. Healthy dough is soft, firm and crumbles when squeezed. It is a light green colour turning yellow brown (Fig. 12A).

Frost affected grain are yellow and shrunken with a dimpled, crimped appearance (Fig. 12B). Depending on the severity of the frost there will be some healthy and unhealthy grains in the same head.

Figure 12 (A) Healthy grain at Z81; (B) Frosted grain at Z81; (C) Healthy mature grain

Frost damage observed at harvest (Z91–93)

Frost affected grains at harvest can impact on market end-use and seed quality. Grains are normally visually inspected at delivery for frost damage (Fig 13 B and C)

Figure 13 (A) Healthy grain at maturity; (B) Grain frosted at Z81–83; (C) Grain frosted at 83–87

How to diagnose frost damage in barley

In barley, flowering generally occurs within the boot, which offers protection against frost exposure. Floret sterility can be determined by raising the head towards the sun, allowing light to come through florets where grain is absent (Fig. 14A). Anthers may be seen protruding from unfertilised florets to increase chances of pollination. As grain develops, the unfertilised florets remain closed (Figs 14B and C). At harvest frosted grain can take on a discoloured appearance cause by fungi. Stem frost in barley is not as common as in wheat but when it does occur it has similar symptoms.

Figure 14 (A) Frosted barley head note the light coming through non pollinated florets with anthers protruding; (B) Healthy barley head (left) and frosted barley head with some developing grain (right); (C) Matured barley head with missing grain; (D) Discoloured grain due to frost damage

How to diagnose frost damage in oats

Oats are less susceptible to frost compared to wheat and barley, however they can still be affected at similar growth stages (Figs 15A and B). Sterility of florets sometimes occurs as the panicle is emerging (Fig. 15C)

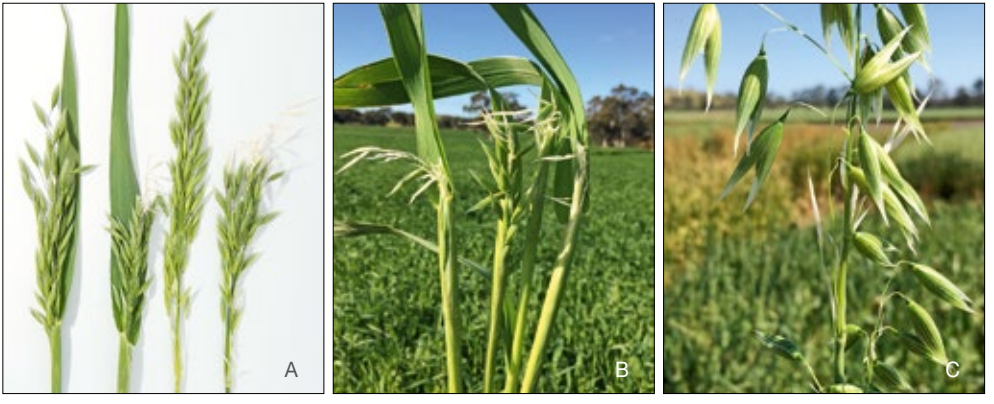


Figure 15 (A) Healthy oat head (left) with a range of frost affected oat panicles (right); (B) Frosted oat spikelets at heading; (C) Frosted oat spikelet at grain fill

When to inspect your crop for frost damage

Inspect crops 5–10 days after a frost event, particularly when they are between early ear-emergence and grain-filling, and when temperatures fall below 2°C at your nearest weather station.

Examine the crop in the more susceptible low parts of the landscape first and if you find frost damage, proceed to higher ground.

Walk through the crop and examine a whole plant every 20–30 paces.

Peel back the leaves and look for stem damage and damage to the developing head.

If the crop is at Z51 (head emergence) or beyond, open the florets on the head to check that the grain is developing.

What else could it be – abiotic factors?

The symptoms of frost damage are similar to many other constraints often leading to misdiagnosis. Below is a list of the most common points of misdiagnosis in cereals. For images and further information see the MyCrop page or download the app from the DPIRD website.

Copper deficiency

Similarities - White rat-tail heads, shrivelled grain and delayed maturity
Differences - Paler plants with distorted flag leaves. Plants with grain also have weak straw

Herbicide damage

Similarities - Necrosis in leaves particularly the tips, distortion of heads
Differences - Symptoms will appear within 4 days rather then 5–10 days with frost, not associated with landscape

Heat or water stress damage

Similarities - White rat-tail heads and shrivelled grain
Differences - uniform across landscape and damage normally confined to tops of heads. Damage often seen after high temps and strong winds

What else could it be – biotic factors?

Take All

Similarities – White rat-tail heads, shrivelled, pinched grain
Differences – Blackening of roots and stem base, reduced root system, early hay-off. Distinct patches of white heads

Fusarium blight

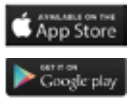
Similarities – White heads scattered throughout the crop, shrivelled or no grain in heads
Differences – All tillers affected with honey-brown discolouration at stem bases, reduced root system, not associated with landscape

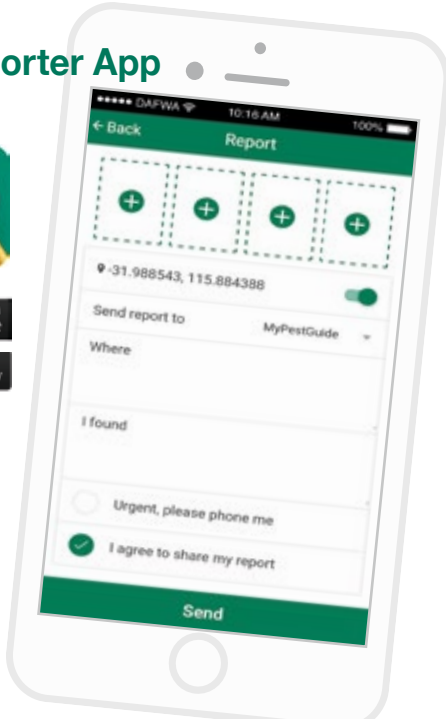
Bacterial oat blight

Similarities – Dark brown rings on stem, death of panicle or no grain development. Death of leaves
Differences – Stems can be slimy and wet. Large areas can be affected

How to use the MyPestGuide™ Reporter App

- → Download the MyPestGuide™ Reporter to your mobile device
- → Check your device location services are turned ON
- → Click on the plus sign in the top right hand corner, check latitude and longitude is running
- → Press camera icon to either attach a photo or take a photo of frost symptoms
- → Send report to 'Frost survey'
- → Populate the "Where" and "I found" field
- → Press Continue
- → Select State, add your email and phone details
- → Press Send
- → Your report will be reviewed by the Frost team at DPIRD and you will receive a response





Further Information

DPIRD Frost frequently asked questions brochure goo.gl/SWdCd8

DPIRD weather stations: agric.wa.gov.au/weather-stations-and-radar

DPIRD Extreme Weather Events Tool: agric.wa.gov.au/n/5766_

DPIRD MyCrop application: agric.wa.gov.au/mycrop

DPIRD MyPestGuide Reporter App: agric.wa.gov.au/apps/mypestguide-reporter

Search “Frost” on the DPIRD website agric.wa.gov.au

GRDC Frost management tip and tactics: grdc.com.au/ManagingFrostRisk