



Department of
**Primary Industries and
Regional Development**



Frost Identification Guide

for *Cereals*



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Images

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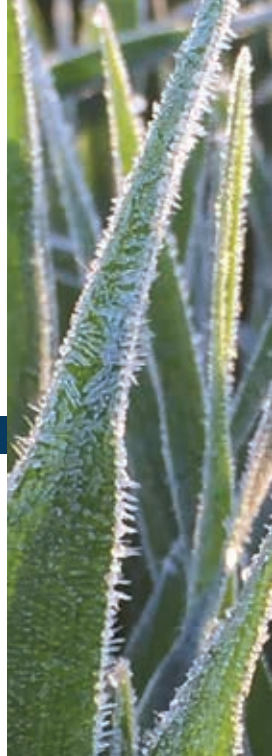
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Frost overview

Frost damage reduces crop yield and grain quality. Early identification of symptoms allows timely crop salvage decisions to be made.

To identify frost damage:

- Inspect cereal crops between stem elongation and grain-fill, if night air temperature falls below 2°C and there is likely to have been a frost.
- Check low-lying, light-coloured soil types and known frost-prone areas first. Then check other areas. Walk a machinery width into the paddock as crop on outside edge may have less damage.
- Frost damage can occur randomly, resulting in high variability within paddocks and even on individual plants.
- Monitor reproductive parts and seed-set following a frost event by tagging reference plants and checking these a few days later for signs of senescence (death) or continued development.

Monitoring for frost



Inspect crops after frosts when they are between stem elongation, ear-emergence and grain filling. Symptoms may not be obvious for 5–7 days after the frost.



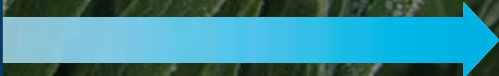
Check developing heads for wilting and/or discolouration. Check stems for blistering, distorted shape and/or discolouration. Check flowers for abnormal development.



Open developing grain heads. Check for mushy, shrivelled or abnormal seed.



A magnifying glass and sharp knife can be useful when inspecting developing heads and florets.



For more detailed information on monitoring frost damage, visit www.agric.wa.gov.au/climate-land-water/climate-weather/frost



Susceptibility of cereals to frost damage

Factors affecting frost damage

Visible frost damage will vary within a paddock due to many factors including: temperature, soil type, soil moisture, wind speed, position in the landscape, crop species, crop development stage, crop nutrition and/or crop density.

Period of risk

Wheat crops are most susceptible to frost damage during flowering, however, they are also susceptible during stem elongation, at early booting and grain filling stages (Fig. 1). Final damage and impact on grain yield is an accumulation of damage through all of these periods.

In barley flowering generally occurs within the boot, which offers some protection against frost exposure. Barley, however, can be quite susceptible at early grain development.

Oats are less susceptible to frost during reproductive stages than wheat and barley, however they can still be severely frosted before flowering during stem elongation and panicle emergence.





Which parts are susceptible?

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

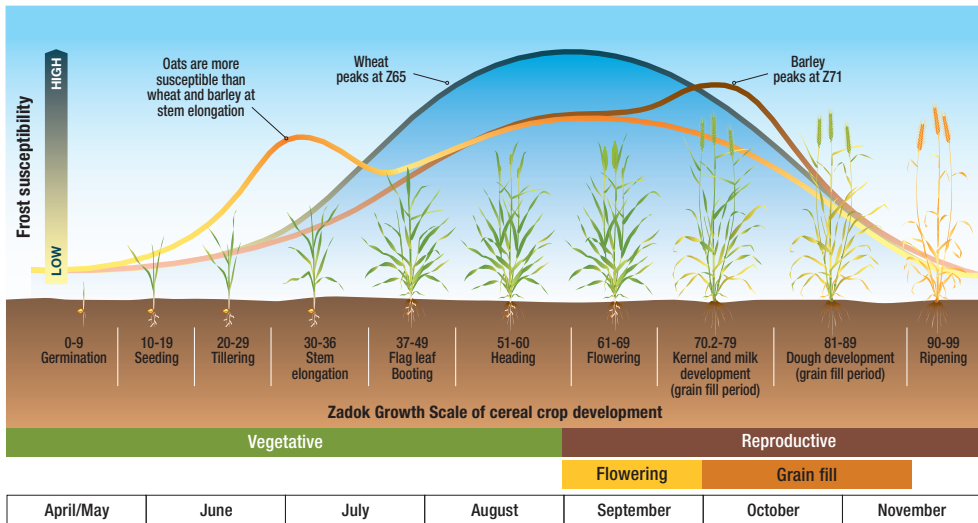


Figure 1. Susceptibility of wheat, barley and oats to frost damage during each stage of development (Zadok Growth Scale).

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 and fertilises the ovary
Bract	A modified leaf associated with a floret
Carpel	The female reproductive organ, which in wheat consists of the ovary and two feathery stigmas
Ear/head	The grain-bearing tip of the stem of a cereal plant
Filament	The stalk on which the anther is attached
Flag leaf	The final leaf to develop before ear emergence. The uppermost leaf on the stem
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	Thin outer bract of a floret below the anthers, ovaries and stamens, later enclosing the grain. The lemma is relatively larger than the palea
Node	Joints on the stem where other structures such as leaves, roots, tillers and spikelets join the stem
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	Thin inner bract of a floret below the anthers, ovaries and stamens, later enclosing the grain
Panicle	A loose, branching cluster of spikelets that makes up the complete flowering head of oats
Peduncle	The uppermost internode of the stem between the head/panicle and last node
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

Basic structure of a healthy wheat/barley and oat plant

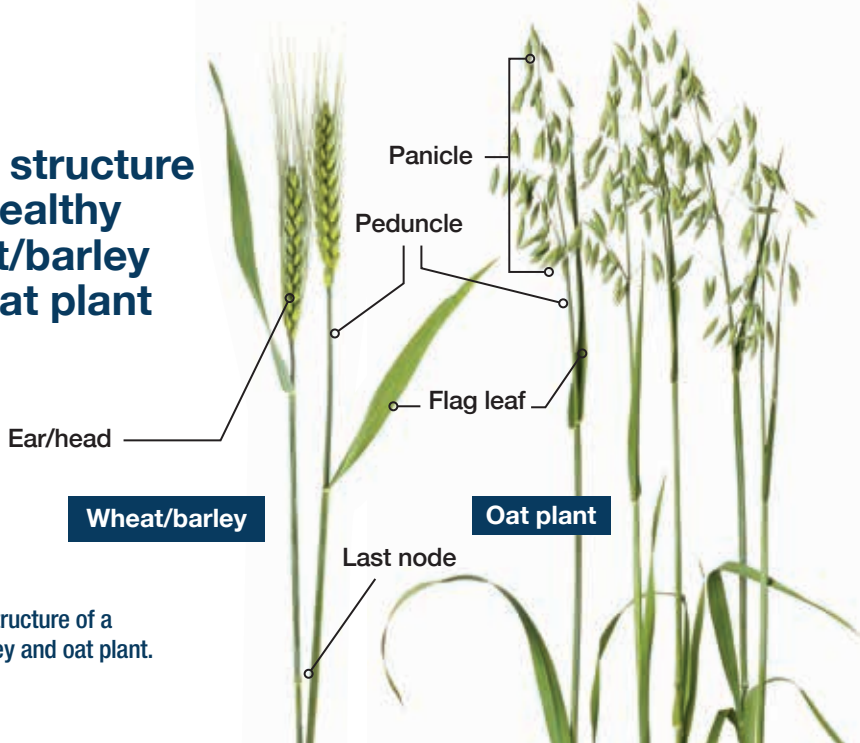


Figure 2. Structure of a wheat/barley and oat plant.

Wheat



Structure of a dissected healthy wheat head

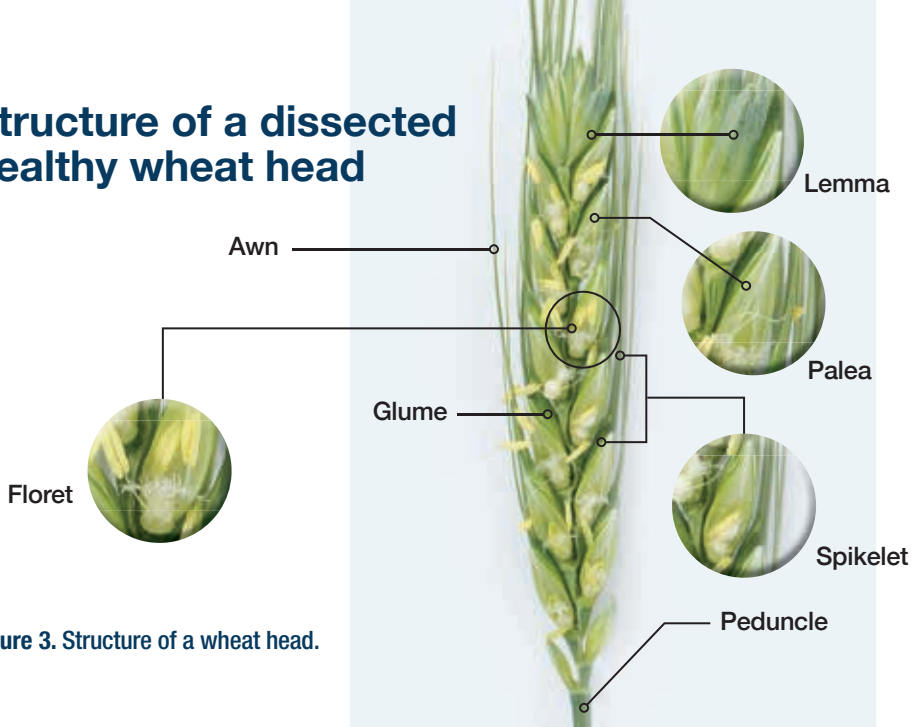
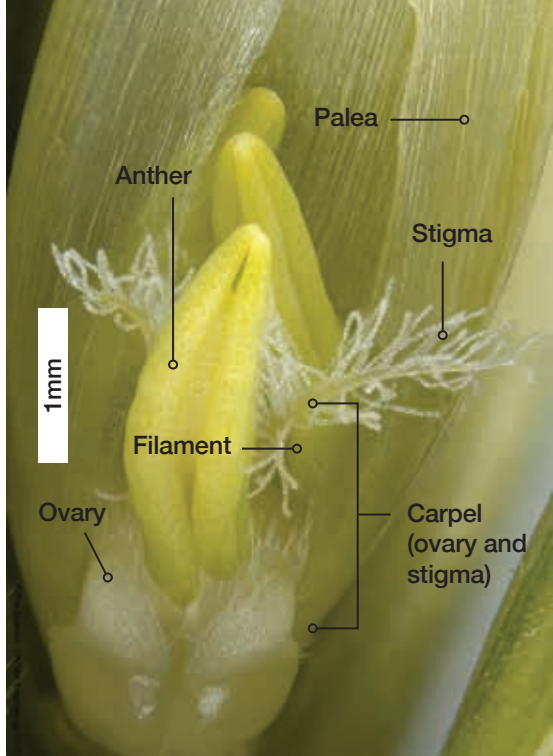


Figure 3. Structure of a wheat head.

Structure of a dissected healthy wheat floret

Figure 4. The inside of a wheat floret, (lemma and glume removed), showing palea, stigmas, anther, ovary and carpel.



Frost damage at stem elongation (Z30–36)

Frost damage during stem elongation manifests as flattened, bleached or discoloured stem internodes, which have a rough texture (Fig. 6C and D) and damaged developing heads (Fig. 5 and, 8A–C). Stem frost is generally more common in southern Australia due to the more extreme frosts experienced in this region.

Severe frost can cause damage to the leaves, developing head or the internodes of the stem (Fig. 6A–D). This damage can result in death of the primary tiller causing re-tillering (Fig. 7A and B). Stem-frosted plants are more prone to lodging.



Figure 5. Field level showing obvious signs of frost damage.

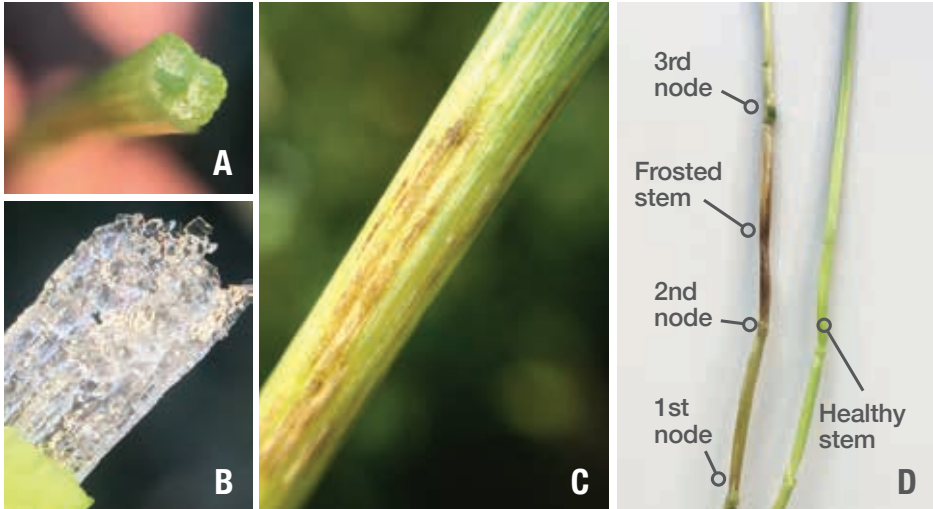


Figure 6. A and B) Ice formation within the stem following a frost event. C) Rough texture and discolouration of a frost-affected stem; D) Brown discolouring between 1st and 3rd nodes (left) compared to healthy stem (right).

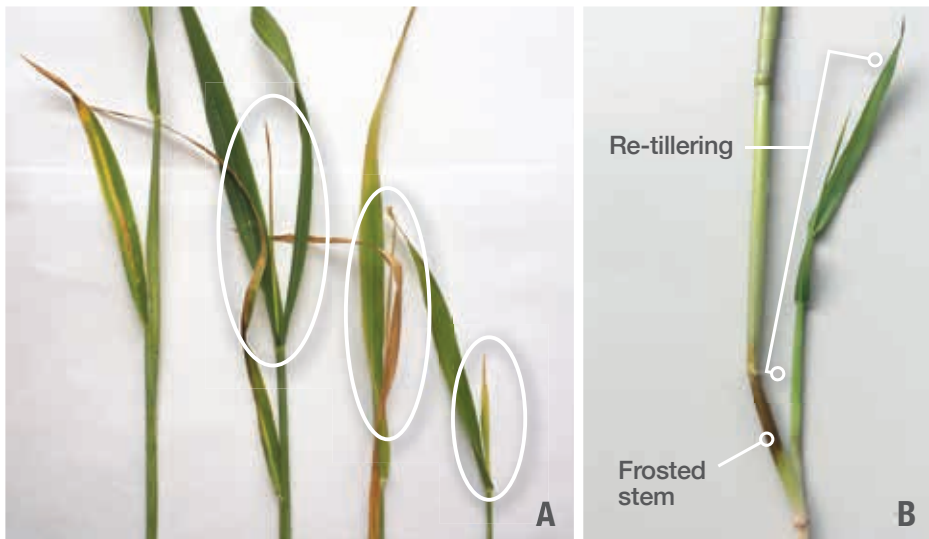


Figure 7. A) Frost-induced senescence of most recently emerged leaves; B) Re-tillering after primary tiller has been frost damaged.



Figure 8. A) Healthy head development stages; B and C) Frost damage for a range of head development stages, two weeks after a frost event (Inset: morning after a frost event).

Frost damage at flag leaf to booting (Z37–49)

Similar to frost damage at stem elongation, a frost event at flag leaf emergence to booting can result in head loss and stem damage. Frost can damage the sensitive tissue of the head leading to complete or partial pollen abortion. As a result, subsequent florets appear either under-developed or bleached (Fig. 9A–D).

Figure 9. A) Dissected wheat heads: healthy developing head (left) vs frosted developing head (right) – note bleached and under-developed florets.

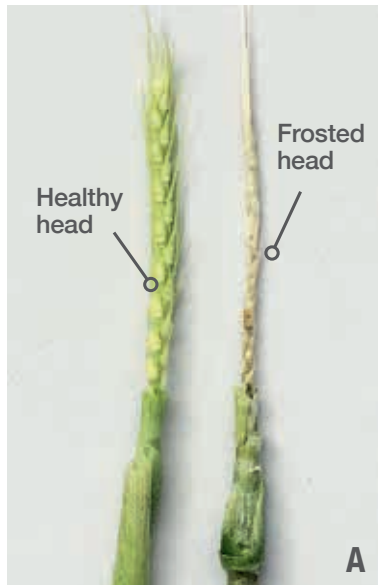




Figure 9. B–D) Visible symptoms of frost damage after head emergence. Note distorted heads and missing/bleached florets.

Frost damage at head emergence (Z51–60)

Frost damage during head emergence can result in peduncle stem frost damage (Fig. 10A) and, depending on severity, whole head damage (Fig. 10B–E). Such damage is normally associated with severe frost, or when rain falls just before a frost.

Figure 10. A) Frost damage of the peduncle showing pale green rings with leaf sheath removed.



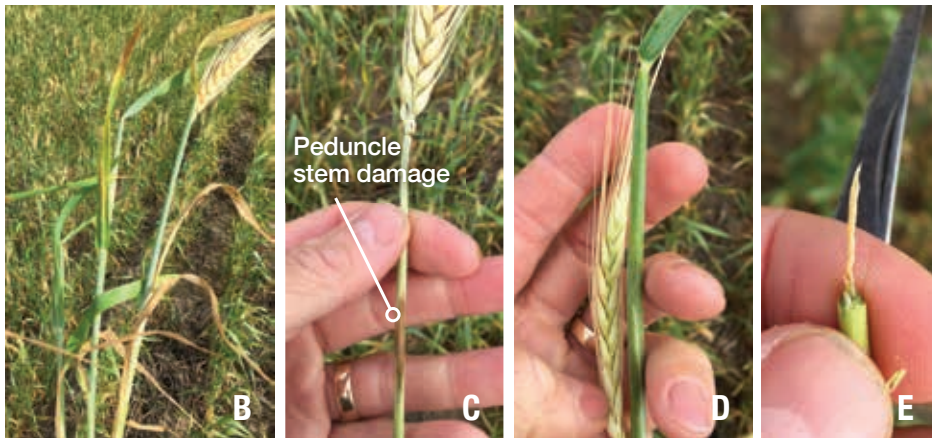


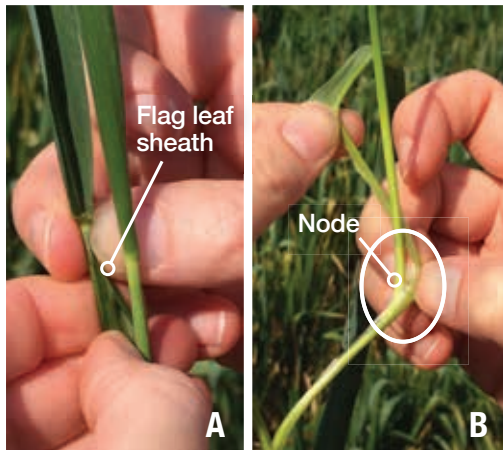
Figure 10. B–E) Frost damage symptoms in wheat heads at a range of developmental stages in the same crop.

How to identify pre-flowering frost damage (Z30–60)

To check for early head and stem damage:

- Peel the flag leaf away from the stem down to the node (Fig. 11A and B).
- Carefully roll the leaves away from the stem until two nodes appear (Fig. 11C).
- Using a finger nail or scalpel, slice open the sheath within to expose the head (Fig. 11D and E).

Figure 11. A and B) Peel the flag leaf away from the stem to reveal the nodes.



- If the head is a pale green, it is healthy. If it is dark green/water-soaked or white, it has been frosted (refer Fig. 8). Keep inspecting the stem further down for discolouration, rough texture or splitting (refer Fig. 6).

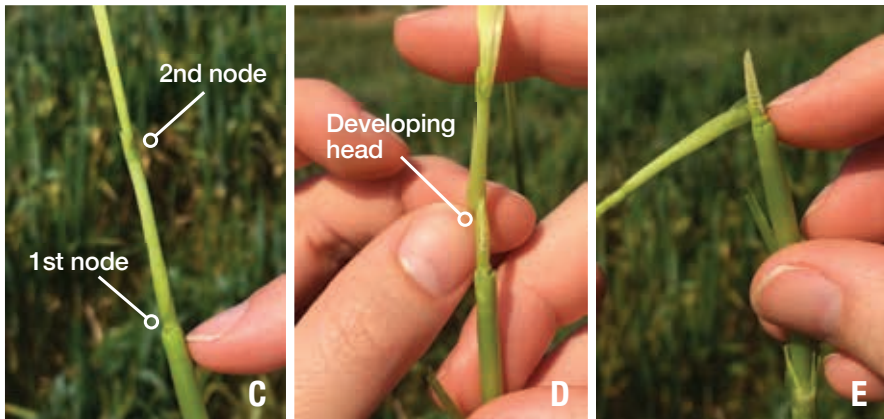


Figure 11. C–E) Dissection and removal of leaves to expose the healthy developing head inside.

Frost damage during flowering (Z65)

Flowering starts in the centre of the wheat head and then extends to the top and bottom of the head (Fig. 12A). A frost event during flowering can affect both pollen and ovaries, which then causes sterility (Fig. 12B and C).

Figure 12. A) Healthy flowering wheat head.



A

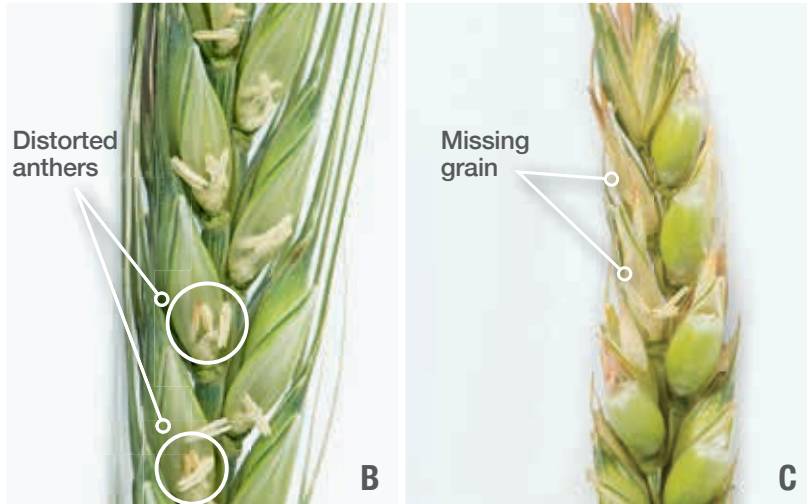


Figure 12. B) Frosted flowering wheat head – note distorted, banana-shaped anthers; C) Missing grain caused by frost damage.

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. 13A). Frost-affected anthers are white and distorted (banana shaped) and become dull brown in colour and fail to emerge from the florets (Fig. 13B).

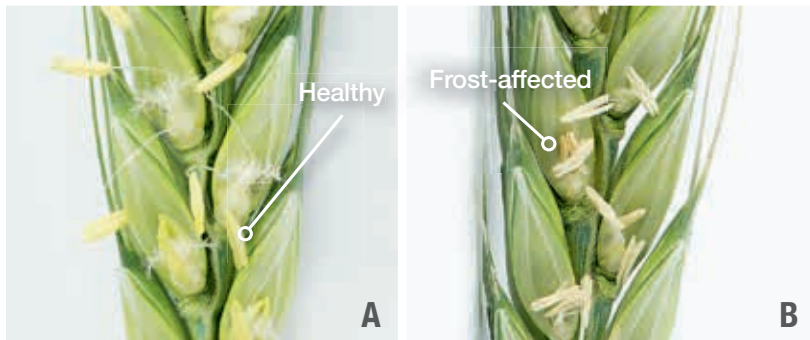


Figure 13. A) Healthy anthers during flowering; B) Frost-affected anthers.

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 turns green as the grain develops (Fig. 14A). A frost-affected stigma takes on a shrunken, distorted appearance while a frost-affected ovary turns dull brown and becomes shrivelled as no grain develops (Fig. 14B and C).

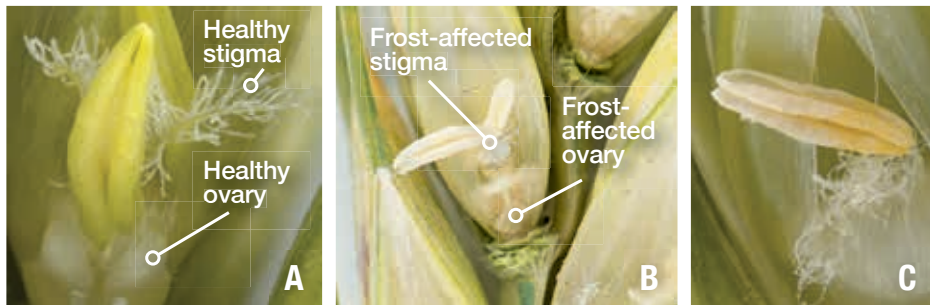


Figure 14. A) Healthy stigma and ovaries; B and C) Frost-affected stigma and ovaries

How to identify flowering frost damage

To check for floret sterility, the floret must be opened. To do this, peel back the lemma, exposing the reproductive structures and/or developing grain (Fig. 15).

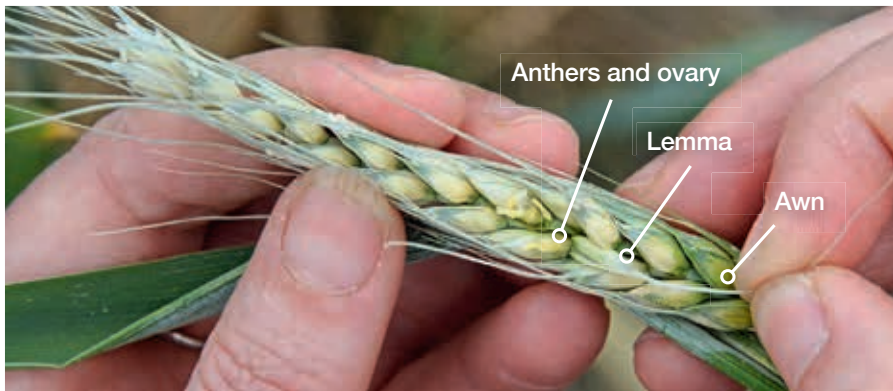


Figure 15. To check for floret sterility, peel back the lemma to open the florets and reveal the anthers and ovary.

Frost damage during kernel and milk development (Z70.2–79)

Developing grain can also be affected by frost. Healthy grain is white and hairy, gradually turning dark-green and plump (Fig. 16A and B). When squeezed, the grain exudes a clear liquid and yellow embryo (Z70.5-71, Fig. 16B inset) or white milk/dough (Z73, Fig. 16C inset).

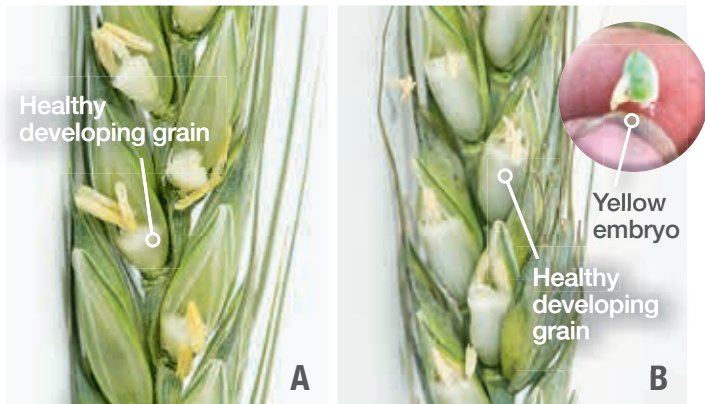
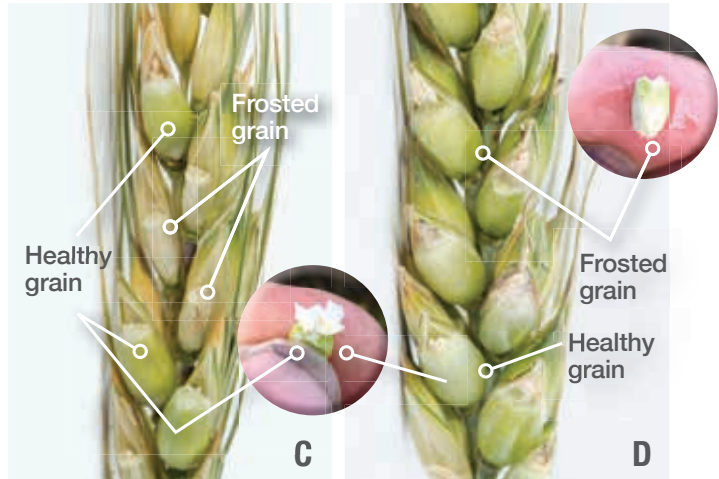


Figure 16. A) Healthy developing grain at Z70.5; B) Healthy developing grain at Z71. Inset showing healthy yellow embryo when squeezed.

Frosted grain initially appears as white and shrunken and later turns brown, crimped and dimpled. When squeezed, grain frosted at Z73 does not exude white milk/dough (Fig 16C inset) but rather a clear or straw-coloured liquid (Fig 16D inset). Depending on the severity and timing of the frost, there will be some healthy and unhealthy grains on the same head (Fig. 16C and D).

Figure 16. C) Healthy and frosted grain on the same head during grain fill at Z73; D) Dimpled appearance of frost-damaged grain at Z73. Inset showing clear liquid when squeezed.



Frost damage during dough development (Z81–89)

During dough development healthy grain becomes more solid and can be soft, firm or crumbly when squeezed. Grain at this stage is a light-green colour, turning yellow-brown with time (Fig. 17A and C). By contrast, frosted grain (Fig. 17B and D) appears yellow and shrunken with a dimpled, crimped appearance.

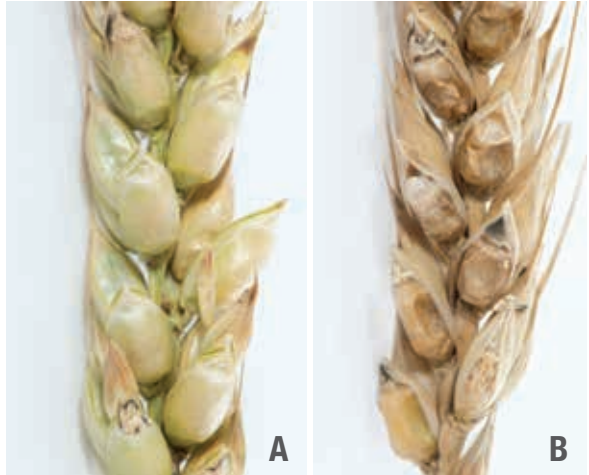


Figure 17. A) Healthy grain at Z81; B) Frosted grain at Z81.

Wheat heads can contain some healthy and some frosted grain, depending on the severity and timing of the frost (Fig. 17C and D).

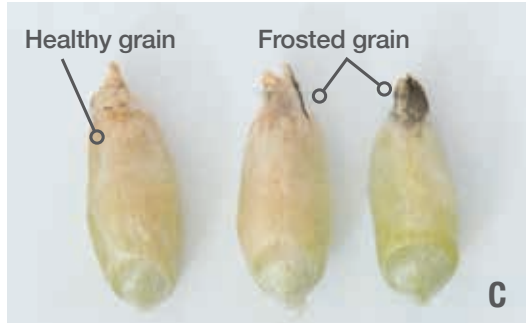


Figure 17. C) Healthy mature grain (left) and frost-affected grain (right); D) Frosted grain at Z81 (note the dimpled appearance).

Frost damage observed at harvest (Z91–93)

Frost-affected grain fails to fill and will appear small, discoloured and shrivelled at harvest (Fig. 18B and C) when compared with healthy grain (Fig. 18A).



Figure 18. A) Healthy grain at maturity; (B) Grain frosted at Z70.5–71; (C) Grain frosted at Z81–83



D

Figure 18. D) Healthy wheat (left) and frost-affected wheat (right) at maturity.

Barley



How to diagnose frost damage in barley

Flowering in spring barley generally occurs while the head is within or just emerging from the boot, which usually offers protection against frost (Fig. 19A). As a result, most frost damage in barley usually occurs after flowering, during early kernel and grain development (Z70-89) (Fig. 20). (Refer back to Fig. 4, page 17).

Some barley varieties, such as *RGT Planet*, are open-flowering and flower after head emergence (Fig. 19B). Flowering is often misdiagnosed as frost damage in these open-flowering varieties as the flowering florets look very like frosted closed-flowering varieties, when in fact they are just flowering (Fig. 20C and D).



Figure 19. A) At flowering, healthy closed-flowering barley varieties, such as *La Trobe*, flower within the boot; B) Healthy open-flowering barley varieties, such as *RGT Planet*, flower after head emergence – note transparent florets on healthy flowering *RGT Planet* florets.



A



B



Figure 20. A) Healthy closed-flowering *La Trobe* barley head at early grain fill; B) Partially frosted *La Trobe* barley head C) Healthy open-flowering *RGT Planet* barley head; D) Partially frosted *RGT Planet* head.

Frost damage during stem elongation (Z30-59)

Stem elongation and peduncle frost damage in barley is not as common as in wheat but when it does occur it has similar symptoms.

Frost at stem elongation can damage the developing heads and result in shrivelled, deformed and pale heads (Fig. 21).

Figure 21. Impact of frost damage at late stem-elongation on head development in barley. Note pale, stunted heads and empty florets.



Frost damage during flowering (Z60-69)

As barley varieties can be open or closed flowering, and flower either in the boot or after head emergence (e.g. *RGT Planet*) it is important to check flowering barley again a week after suspected frost damage is identified to determine if grain is filling (Fig. 22A–E).

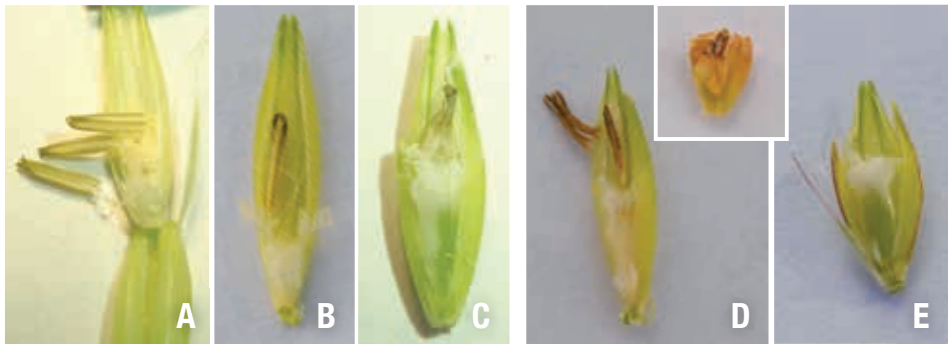


Figure 22. Healthy barley florets at flowering (A) and early grain development Z70.2 (B) to Z70.8 (C). Frosted at flowering (D and inset), and early grain development Z70.8 (D). Note shrivelled, damaged ovary (D and inset), and developing grain (D–E).

Frost damage during grain fill (Z70-89)

As grain develops, frosted, unfertilised florets remain empty and pale (Fig. 24A and C).

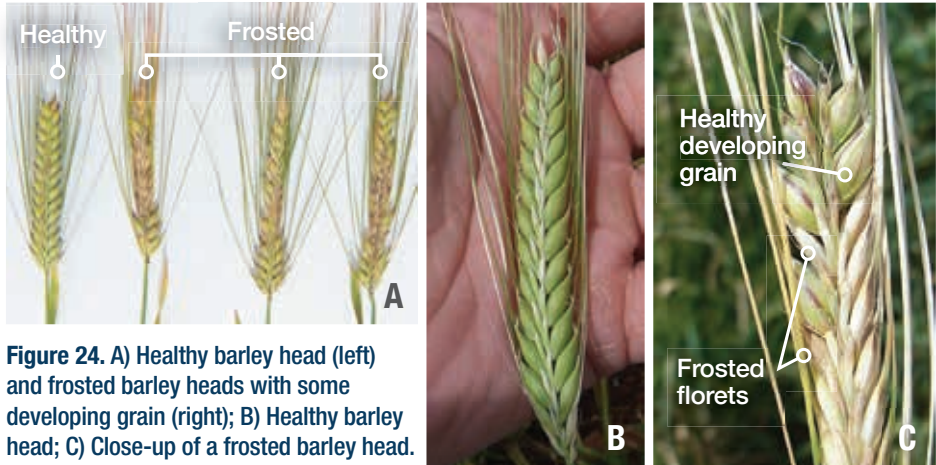


Figure 24. A) Healthy barley head (left) and frosted barley heads with some developing grain (right); B) Healthy barley head; C) Close-up of a frosted barley head.

Frost damage observed at harvest (Z70-89)

At harvest, barley frosted at flowering and early grain development will show up as missing grains on affected heads (Fig. 25A) while frosted grain can take on a discoloured appearance due to infection from opportunistic pathogens (Fig. 25C).



Figure 25. A) Matured barley head with missing grain; B) Healthy barley grain; C) Discoloured barley grain due to frost damage during reproductive stages.

Oats



How to diagnose frost damage in oats

At flowering, oats are not as frost susceptible as wheat and barley; however, oats are more sensitive during stem elongation particularly if the crop is also infected with bacterial blight. Frost damage can still occur from the time of panicle (head) emergence right through to harvest (Fig. 27).

Figure 27. Frost-affected oat crop showing bleached, frost-affected panicles.



Structure of a healthy oat panicle

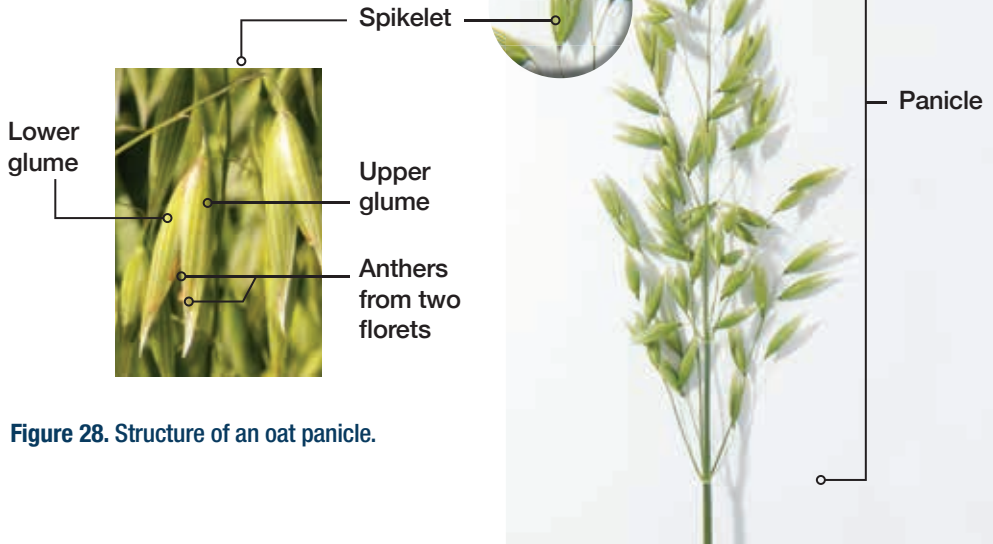


Figure 28. Structure of an oat panicle.

Frost damage during pre-flowering and flowering (Z45-65)

Healthy flowering oat panicles and spikelets are dark green with bright yellow anthers (Fig. 31A and D). Frosted oat panicles appear stunted, light green/yellow in colour with empty, shrivelled, white spikelets. Sterile oat florets can be seen once the panicle has emerged (Fig. 31B–E).

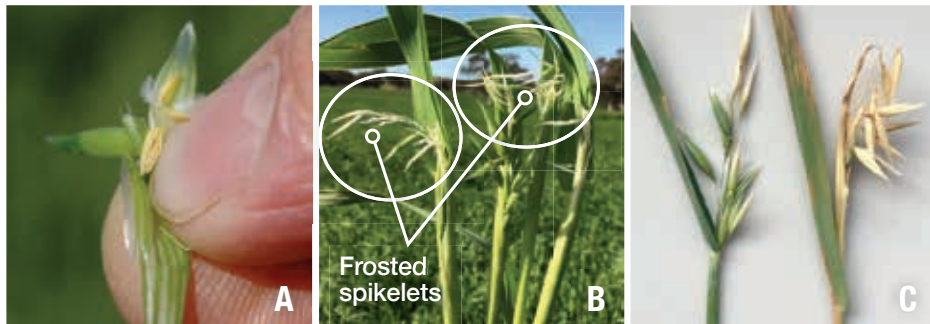


Figure 31. A) Healthy flowering oat floret; B) Frosted oat spikelets within panicles at heading (note stunted, thin, white appearance); C) Examples of frost-affected oat panicles.

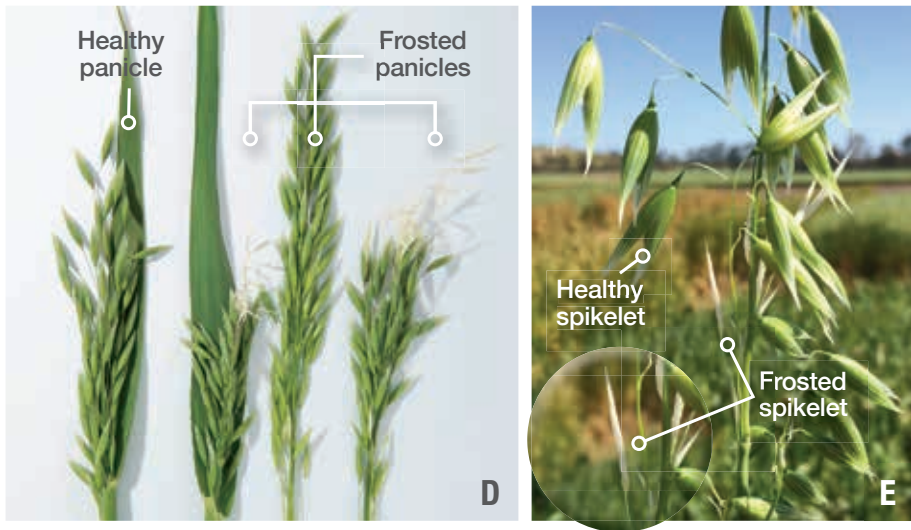


Figure 31. D) Healthy oat panicle (left) with a range of frost-affected oat panicles (right); E) Frosted and healthy spikelets within a panicle at early grain fill.

Stem frost damage

Stem frost in oats is not as common as in wheat. When it does occur it has a similar appearance and usually results in damaged panicles as well. (Fig. 29A–C).

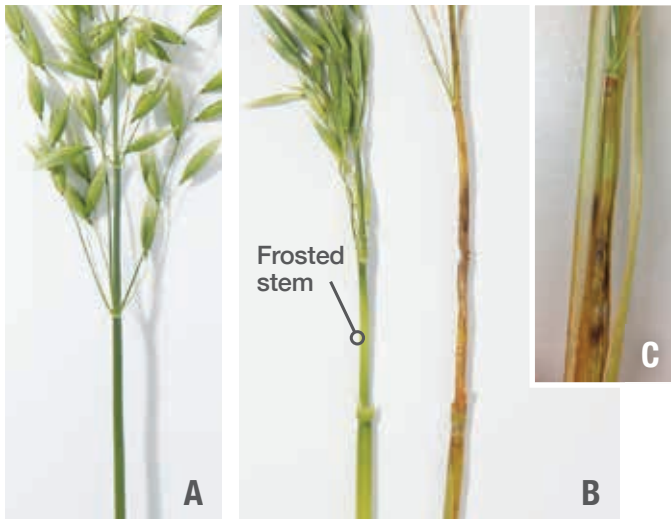


Figure 29. A) Unfrosted, healthy oat stem and panicle; B) Stem frost immediately after a frost event (left) and two weeks later (right) when stem death is visible; C) Close-up of stem-frost damage.

Stem-frost damage can lead to lodging, making grain harvest difficult (Fig. 30A–C).

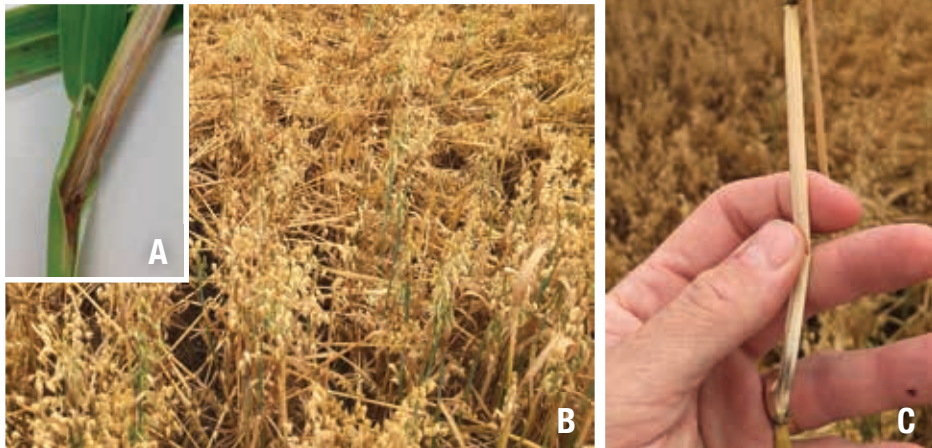


Figure 30. A) Frosted oat stem starting to lodge; B) Frosted oat crop lodging at harvest; C) Close up of a lodged, frosted oat stem at harvest.

Frost damage observed at harvest

Frosted oat grain appears discoloured and shrivelled, which results in either light or missing grain at harvest (Fig. 32B).



Figure 32. A) Healthy oat grain; B) Discoloured, shrivelled oat grain due to frost damage.

What else could it be?

Reporting frost
and Further information



What else could it be?

The symptoms of frost damage are similar to many other constraints often leading to misdiagnosis.

The following pages list the most common points of misdiagnosis in cereals. For images and further information visit **MyCrop** or download the app to your mobile device from the DPIRD website.

 www.agric.wa.gov.au/mycrop



Abiotic factors

- **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 four days rather than 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 temperatures and strong winds.

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.

Reporting frost damage

MyPestGuide™ Reporter App

- Download the **MyPestGuide Reporter** app to your mobile device.
- Turn on '*Location Services*' on your mobile device.
- Click on the plus sign (+) in the top right hand corner, turn on location to show latitude and longitude.
- Press camera icon to either attach a photo or take a photo of frost symptoms.
- Send report to **MyPestGuide**.
- Populate the '*Where*' and '*I found*' fields.
- Press '*Continue*'.
- Enter your email and phone details.
- Press '*Send*'.
- Your report will be sent to DPIRD and you will receive response.



Further information

- DPIRD 'Frost frequently asked questions' brochure: <https://www.agric.wa.gov.au/frost/science-frost-and-frequently-asked-questions>
- Frost ID guide for canola and pulses: <https://www.agric.wa.gov.au/frost/frost-identification-guide-canola-and-pulses>
- DPIRD weather stations: <https://www.agric.wa.gov.au/weather-stations-and-radar>
- DPIRD Extreme Weather Events Tool: <https://agric.wa.gov.au/n/5766>
- DPIRD MyCrop application: <https://www.agric.wa.gov.au/mycrop>
- Search 'Frost' on the DPIRD website: www.agric.wa.gov.au
- GRDC Frost management tip and tactics: www.grdc.com.au/ManagingFrostRisk



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