



Department of
**Primary Industries and
Regional Development**



Frost Identification Guide

for Canola and Pulses



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Images

Rohan Brill, Gordon Cumming, Justin Kudnig, Mick Faulkner, Sarah Ellis, Pulse Australia, Ben White, Wade Longmuir, Kelly Angel and Kate Finger.

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3 Baron Hay Court, South Perth WA 6151

Tel: +61 (0)8 9368 3333

Email: ben.biddulph@dpird.wa.gov.au

Web: www.dpird.wa.gov.au

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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 canola and pulse crops between bud formation and pod-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 pod development and seed-fill 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



Symptoms may not be obvious for 5–7 days after the frost.



Check flowers for wilting, discolouration and/or failure to set pods.

Check pods for blistering, distorted shape and/or discolouration.

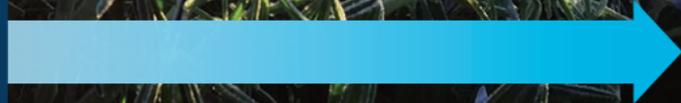
Check stems for splitting, discolouration and/or bending.



Open developing pods. Check for mushy, shrivelled or abnormal seed.



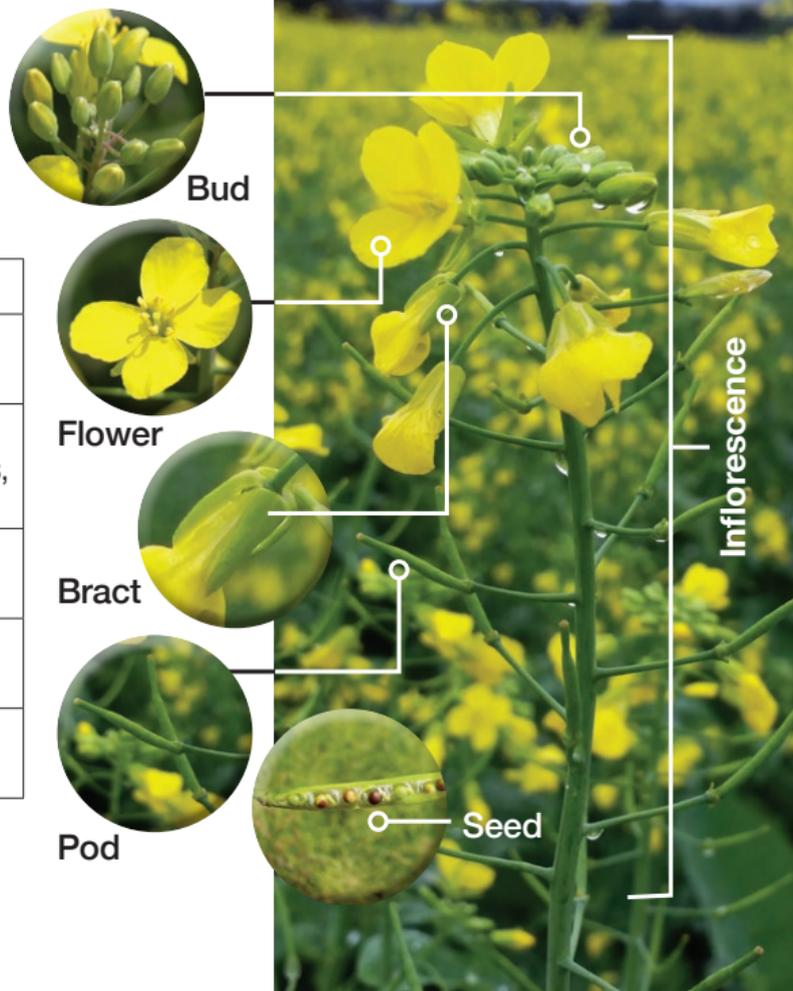
A magnifying glass and sharp knife can be useful when inspecting pods and seeds.



Glossary of terms used in this guide

Bud	Unopened flower
Flower	Open reproductive organ of a plant
Inflorescence	The complete flower head of a plant including buds, flowers, pods, bracts and stalks
Bract	A modified leaf associated with a flower
Pod	Fruit or seed case of a legume or canola plant
Seed	Reproductive unit of a plant containing an embryo

Figure 1. Reproductive structure of a canola plant



Canola and pulse frost susceptibility

Factors affecting frost damage

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

Period of risk and plant susceptibility

In canola and pulses, budding, flowering and pod-fill occur on the one plant at the same time and as a result, buds, flowers, pods, seed and stems can all be affected by the one frost event. Canola and pulses are most susceptible to frost damage around early flowering to late pod-growth and early seed-fill (Fig. 2).

Frost during these reproductive stages results in flower abortion, poor pod-set and pod-fill which, in turn, leads to a reduction in yield and quality (Maqbool et al. 2009).

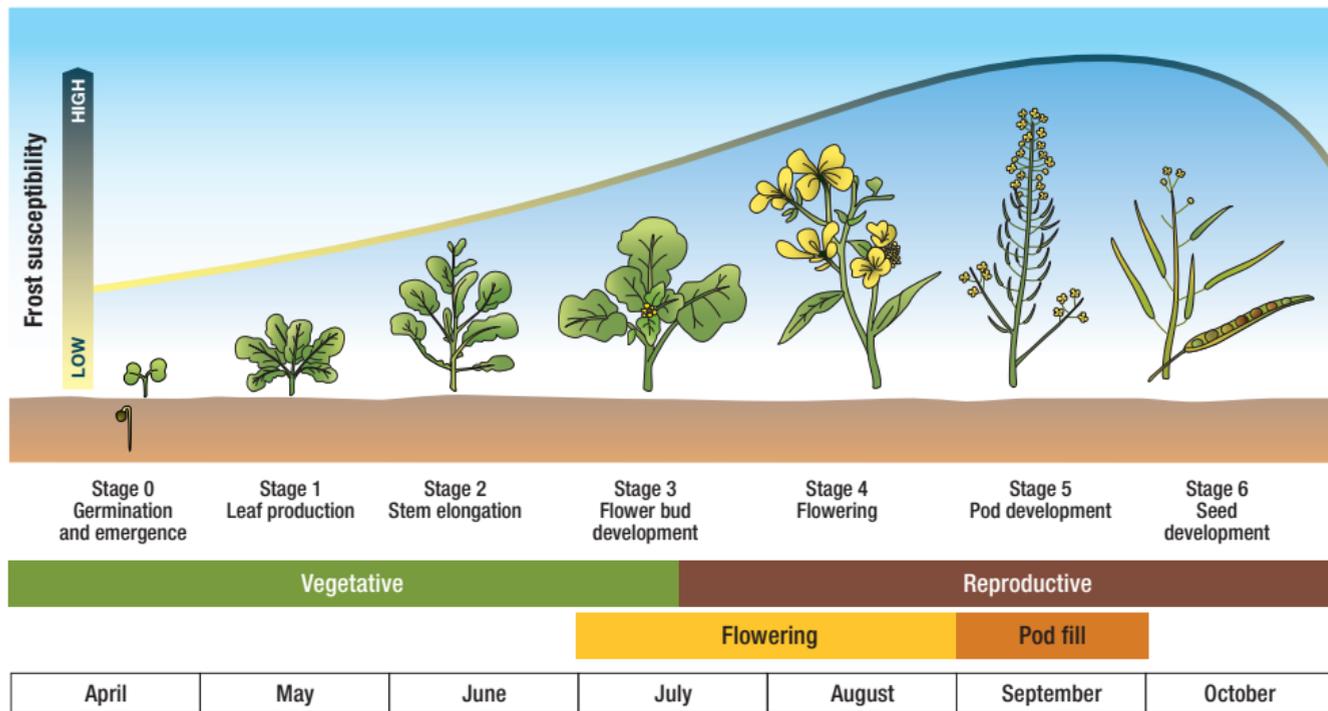


Figure 2. Susceptibility of canola and pulses to frost during each stage of development.

What else could it be?



The symptoms of frost damage are similar to many other constraints often leading to misdiagnosis. For example hail damage, particularly from small hail stones, can be misdiagnosed as frost damage because it often results in the typical 'blistering' frost symptom.

Frost damage can also make crops more susceptible to disease and insect attack, which complicates diagnosis.

For images and further information about other possible causes of frost-like symptoms please see the **DPIRD MyCrop** page or download the app from the DPIRD website.

 www.agric.wa.gov.au/mycrop



Canola



Symptoms

Canola is most susceptible to frost damage from flowering to the clear, watery stage of pod-fill. Plants frequently recover from frost during early flowering by producing more flowers. The most economically damaging frosts on canola are late, severe events that kill developing seeds when flowering has finished and there is no opportunity to produce more pods.

Leaf, stem and flower symptoms

- Canola can be affected by frost at the seedling stage, resulting in scarring, yellowing and whitening of leaves or death of seedling (at cotyledon stage) (Fig. 3A).
- Frosted plants lose flowers, abort young pods and wilt (Fig. 3B).
- If flowers are open they can be aborted due to frost damage while buds and young pods remain unaffected (Fig. 3C).
- Canola is indeterminate so it can continue to develop more flowers and set pods if there is sufficient time and soil moisture remaining in the season (Fig. 3D).

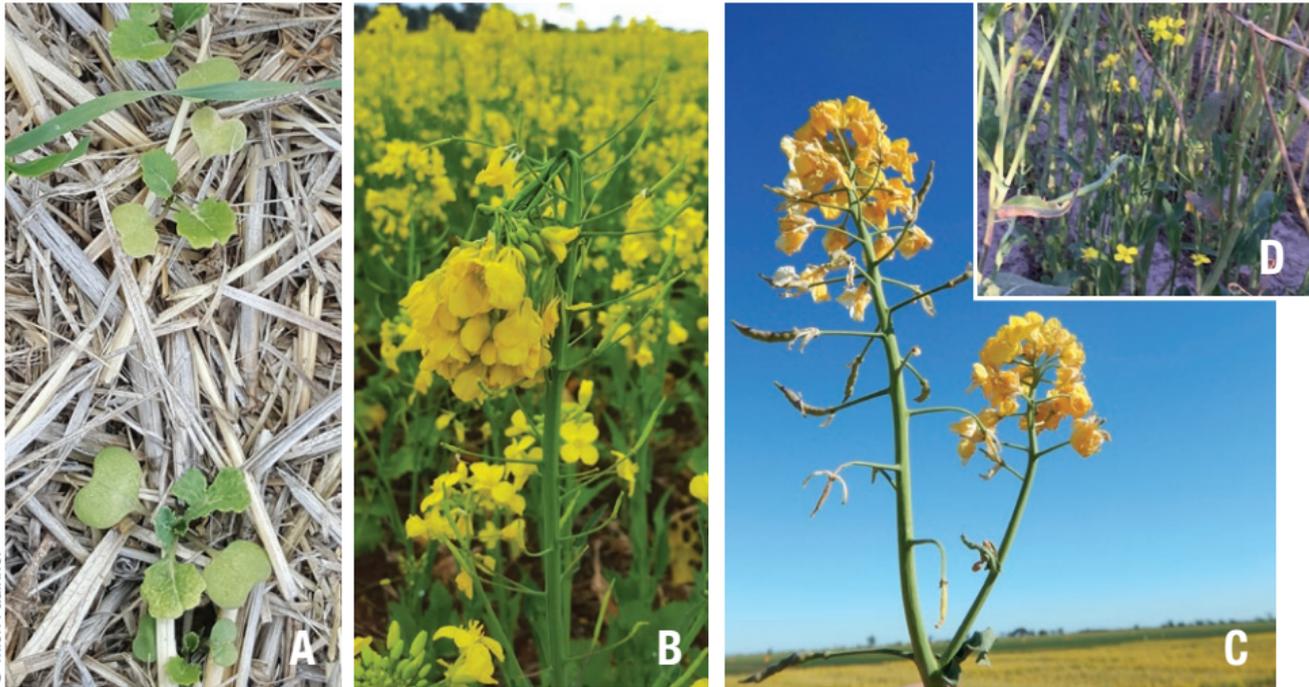


Figure 3. A) Canola seedlings affected by frost. B) Frost-affected canola can wilt. C) Canola crop showing various stages of pod loss and flower abortion. D) Given favourable conditions, canola can re-branch.

Pod set symptoms

- Frost at pod set results in abortion and death of developing seed. Pods must be opened to assess damage.
- The frosted pod surface can turn yellow/green (Fig. 4A and B) and/or develop a pale blistered surface.
- These pods eventually fall off and cause gaps in pod set and twisting of the inflorescence (Fig. 4C).



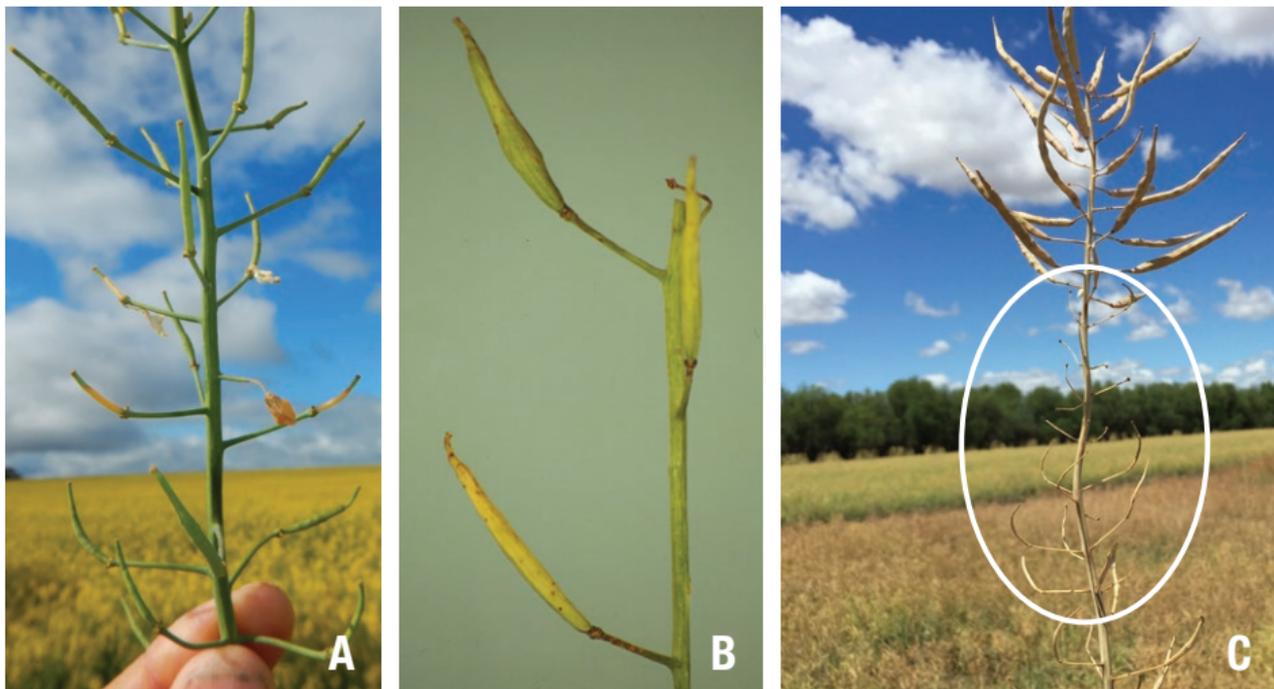


Figure 4. A) Frosted canola plant showing flower and pod loss. B) Yellow/green discoloration of frosted canola pods. C) Pod gaps and twisted inflorescence evident at maturity.

Pod fill and seed symptoms

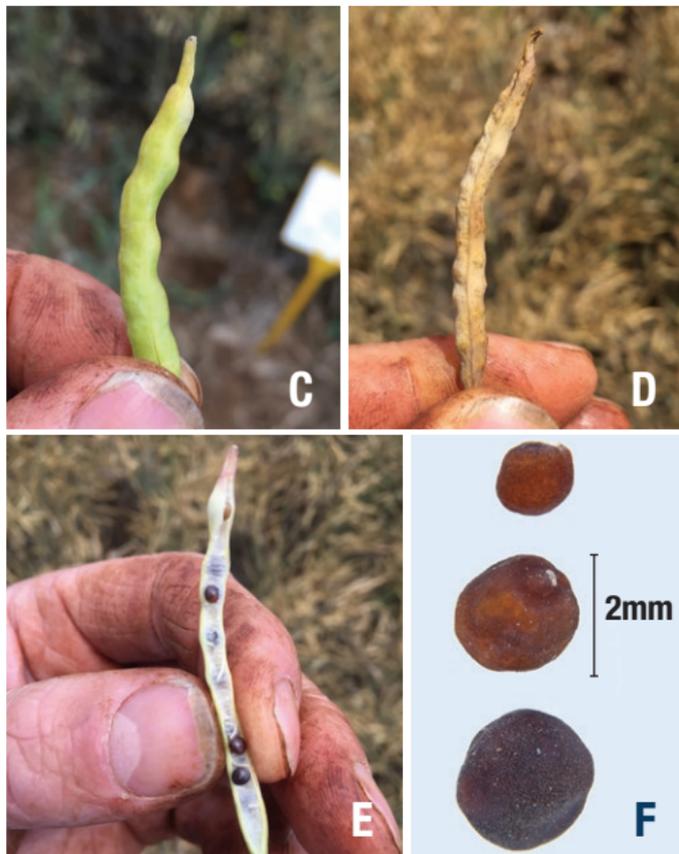
- Severe frosts can damage developing seed (Fig. 5A), which turn into a mushy green-brown mass (Fig. 5B) that dries to a small black or brown speck (Fig. 5B).
- Partial seed death leads to unevenly-filled watery-ripe pods (Fig. 5B).

Figure 5. A) Healthy and frost-affected seeds within the same pod. Note the yellow discolouration of frosted seeds. B) Aborted, frosted canola seeds show up as small brown or black specks.



- Frost-affected pods can become blistered and lumpy (Fig. 5C and D).
- Frost events that occur when the canopy has just finished flowering and pod-fill is just starting can cause significant yield loss and cause seed to shrivel (Fig. 5E and F). Seed may also retain green colour (image not shown).

Figure 5. C) Blistered, lumpy pod containing frost-affected seeds. D) Lumpy, mature, frost-affected pod. E) Pod-fill can be compromised by frost. F) Frost-affected seeds are small and shrivelled (middle and top) compared to healthy seed (bottom).



Recovery

Will the plant recover or compensate?

Time of flowering affects frost susceptibility and the ability of the plant to compensate following frost.

- Canola is indeterminate and flowers for a 30–40 day period, so compensatory growth during early flowering can occur given sufficient time and conditions. However, a series of consecutive frosts can delay pod set, leading to poor seed-fill.
- Frost will have the highest commercial impact if it occurs at the end of flowering when 10–20 per cent of the canopy is still flowering and the majority of the crop is at early, watery seed-fill. At this developmental stage and time of the season, canola generally is unable to re-flower and compensate for any frost-induced yield losses.

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What else could it be?

- **Heat stress and spring drought**

Similarities: Flower and pod abortion.

Differences: Contrasting weather conditions.

- **Chemical desiccation**

Similarities: Small and crimped seeds.

Differences: Timing of events/spray records.

- **Group A herbicides**

Similarities: Flower petal retention and unopened flowers.

Differences: Timing of events/management.



- **Aphids**

Similarities: Pods stunted and yellowing.

Differences: Flower petals retained, presence of aphids on other parts of the plant.

- **Sclerotinia**

Similarities: Branch death.

Differences: Stem and leaf lesions, fluffy white fungal growth and sclerotes on the stem. Breaking open the bleached stem may reveal black sclerotes inside.

 www.agric.wa.gov.au/mycrop



Lupins



Symptoms

Lupins are less susceptible to frost during the early vegetative growth stage but become more vulnerable when growing rapidly from flowering to early pod-fill. Laterals that develop after the frost event will continue to flower and set seed after the main stem has been frosted if there is sufficient time and soil moisture.

Leaf, stem and flower symptoms

- Upper foliage wilts, shrivels and senescences. Frozen upper stems become discoloured (turning dark green directly after thawing) and their associated foliage shrivels and dies (Fig. 6A).



Figure 6. A) Frost-affected plants have a wilted appearance, particularly the upper foliage.

- Often the damaged tissue will take on a brown colour due to infection from opportunistic pathogens (Fig. 6B). Stems may have surface splits that can turn brown with a mushy interior.
- Frosted lupin flowers fail to fertilise (6C) but symptoms of pod abortion take a few days to appear (Fig. 6D).

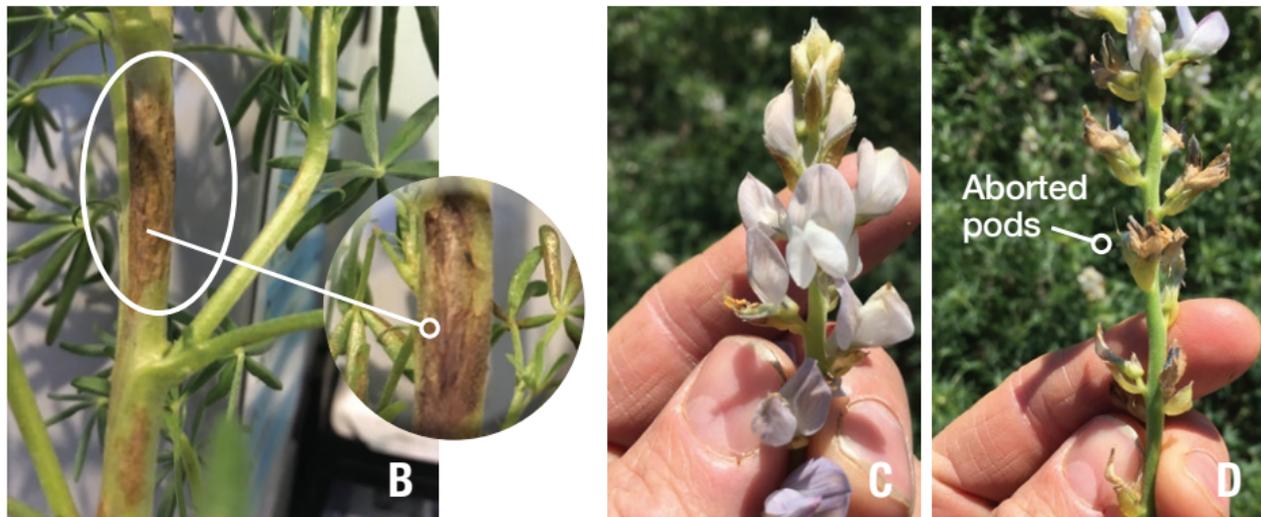


Figure 6. B) The surface of frosted stems can split and turn brown. C) Frosted flowers before symptoms appear. D) Frost-affected flowers with aborted pods a few days after a frost event.



Pod-set symptoms

- Frost will cause early-developing pods to abort (Fig. 7A and B).



Figure 7. A and B) Frost can cause flowers and early-developing pods on the main stem to abort.

- Abscission/natural pruning of the inflorescence may occur following a frost event (Fig. 7C and D).

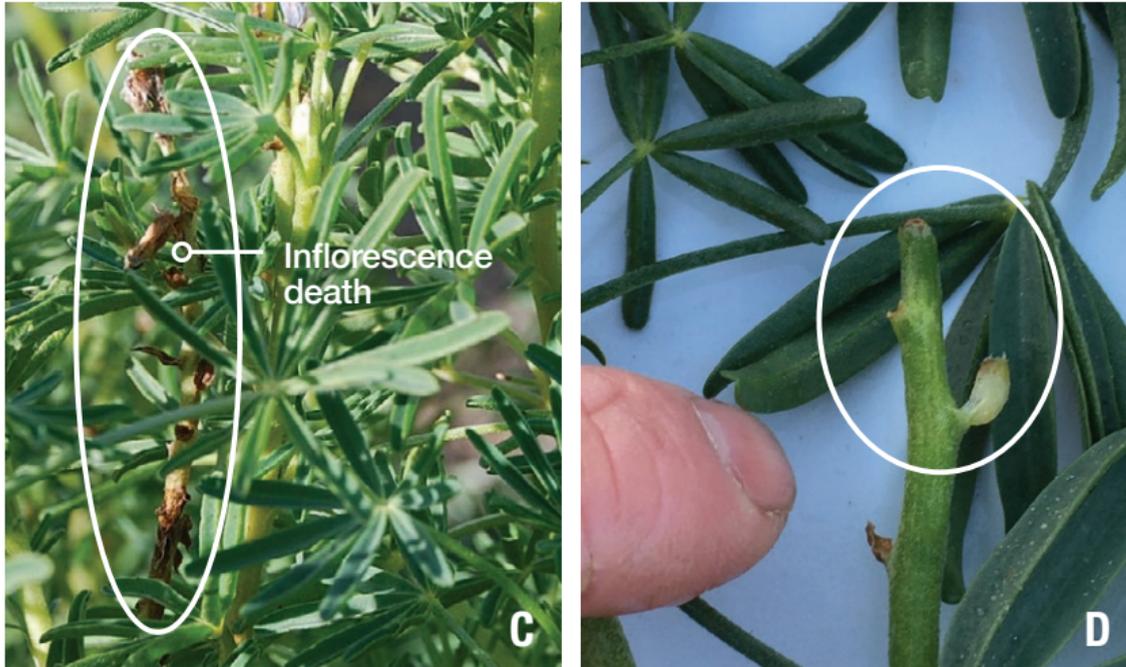


Figure 7. C) Inflorescence death followed by D) abscission.

Pod-fill and seed symptoms

- It is often difficult to detect frost damage when examining unopened pods. However under severe frosts, pods will develop pale spots and/or blisters on their surface (Fig. 8B and C), which can subsequently develop brown, mushy lesions due to infection from opportunistic pathogens.

Figure 8. A) Healthy pods
B) Severely-frosted pods develop a pale, scorched appearance.



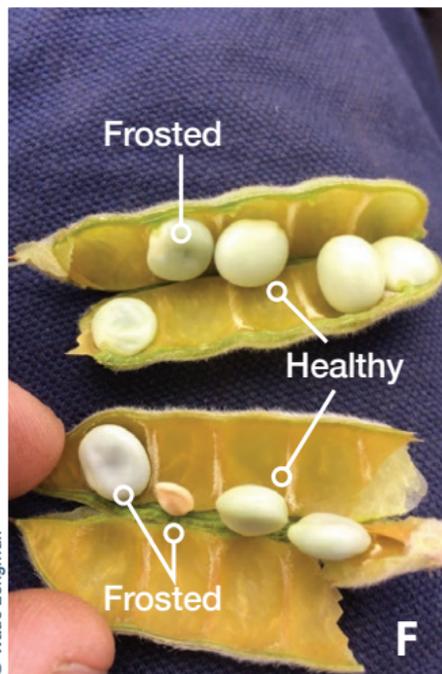
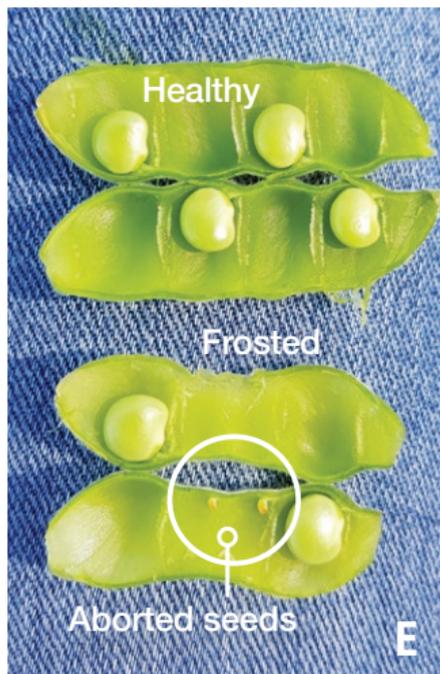
- Often the damaged tissue (stem and pods) will take on a brown colour due to infection from opportunistic pathogens (Fig. 8C).



Figure 8. C) Brown, mushy diseased lesions develop on frost-affected pods.

- Developing seed may abort (Fig. 8E).
- Some seeds remain unaffected in the pod (Fig. 8F).

Figure 8. E) Healthy seeds (top) frosted (bottom). Arrows indicate aborted seeds. F) Some seeds remain unaffected in the pod. Note the shrivelled or dimpled appearance of frosted seeds.



Recovery

Will the plant recover or compensate?

- Lupins can recover from frost if the event occurs during early flowering but only if there is sufficient soil moisture and time left in the season.
- Most commercial-scale damage occurs once flowering has stopped and the crop is at early pod-fill.

Main image: © Pulse Australia



What else could it be?

- **Anthracnose in narrow-leaved lupins**

Similarities: Similar shepherd's crook symptoms on stems.

Differences: Brown lesions and pink spores in the bend of the crook.

- **Group I herbicide damage**

Similarities: Bent and twisted plants.

Differences: Plants pale and slowly die without marked leaf necrosis.

- **Bean yellow mosaic virus – non-necrotic**

Similarities: Bent necrotic upper stems.

Differences: Plants die back from growing point. Usually occurs in patches or on edge of paddock.

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Field Peas



Symptoms

During the reproductive stage, field peas are very susceptible to frost due to their exposed flowers and thin-walled pods (Fig. 9A). Frost damage can be compounded by bacterial blight infection. Managing inoculum loads and frost risk can reduce frost damage and disease.

Stem and flower symptoms

- The upper foliage of frosted plants will become wilted and often shrivel and abort (Fig. 9B).
- The frozen upper stems turn dark green directly after thawing, and associated foliage shrivels and abort.
- Often the damaged stem will take on a brown colour due to infection by opportunistic pathogens, such as bacterial blight.
- Stems can have surface splits that turn brown with a mushy interior.
- Flowers wilt, turn brown and fall off (Fig. 9C).

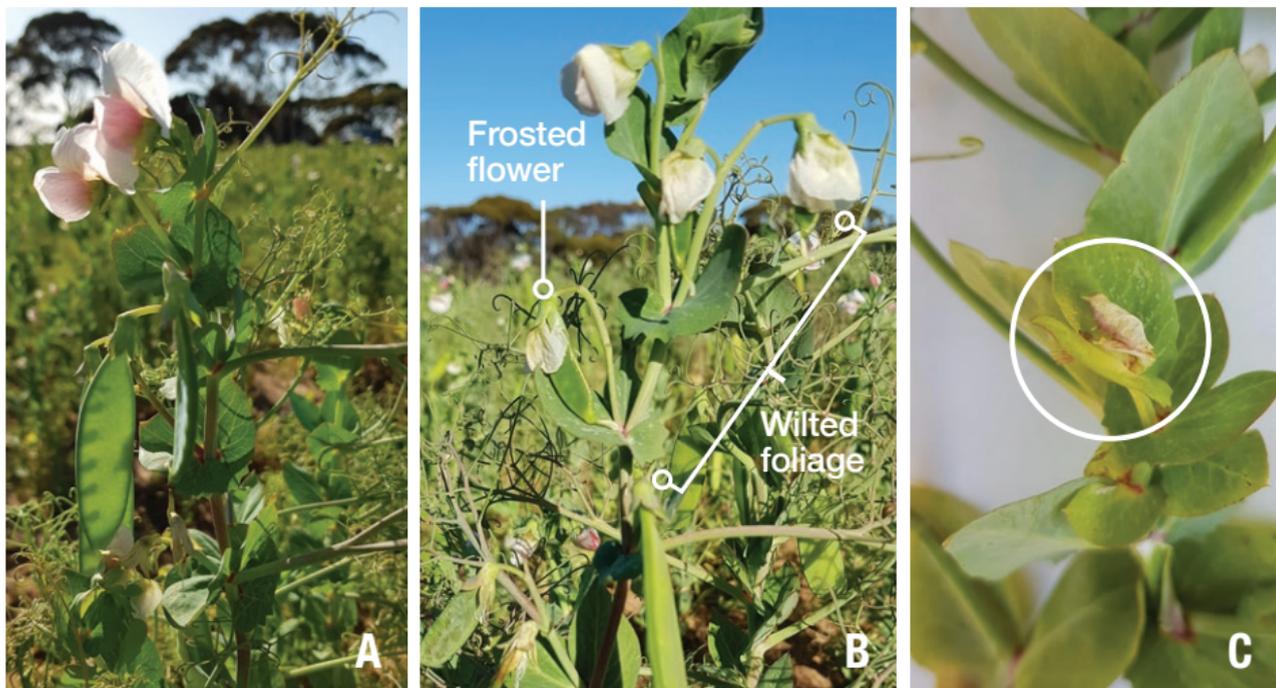


Figure 9. A) Healthy field pea. B) Frosted field pea, note the wilted upper leaves and flowers. C) Frosted flower.

Pod set symptoms

- Frosted pods develop pale spots or blisters on their surface and become shrivelled (Fig. 10A and B).



Figure 10. A) Frosted pods develop pale surface spots or blisters.

B) Distorted, shrivelled frost-affected pods.

- Often the damaged pods will take on a brown colour and a mushy texture due to infection from opportunistic pathogens (Fig. 10C).
- Young, developing pods abort and fall off (Fig. 10D).

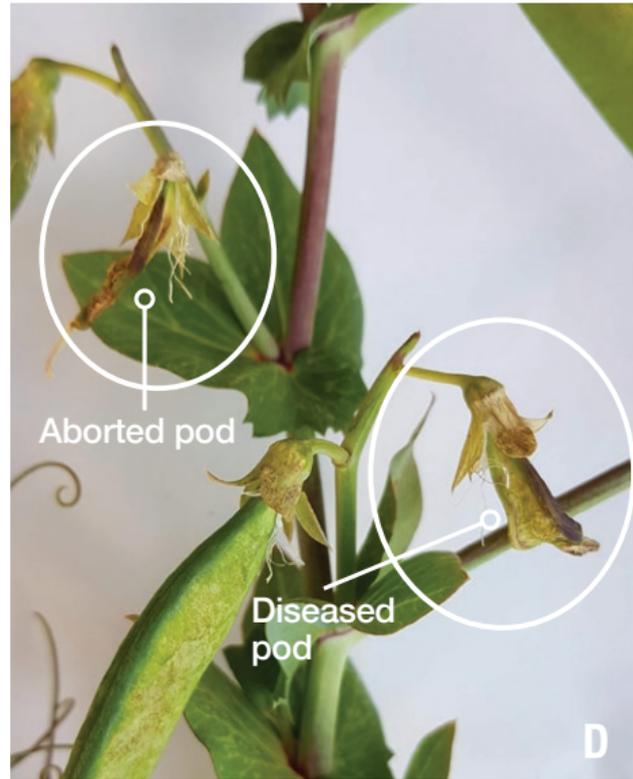


Figure 10. C) Distorted, blistered pods with brown lesions. D) Aborted and diseased pods.

Pod-fill and seed symptoms

- Frost during pod-fill will result in pods developing surface spots and blisters (Fig. 11A).

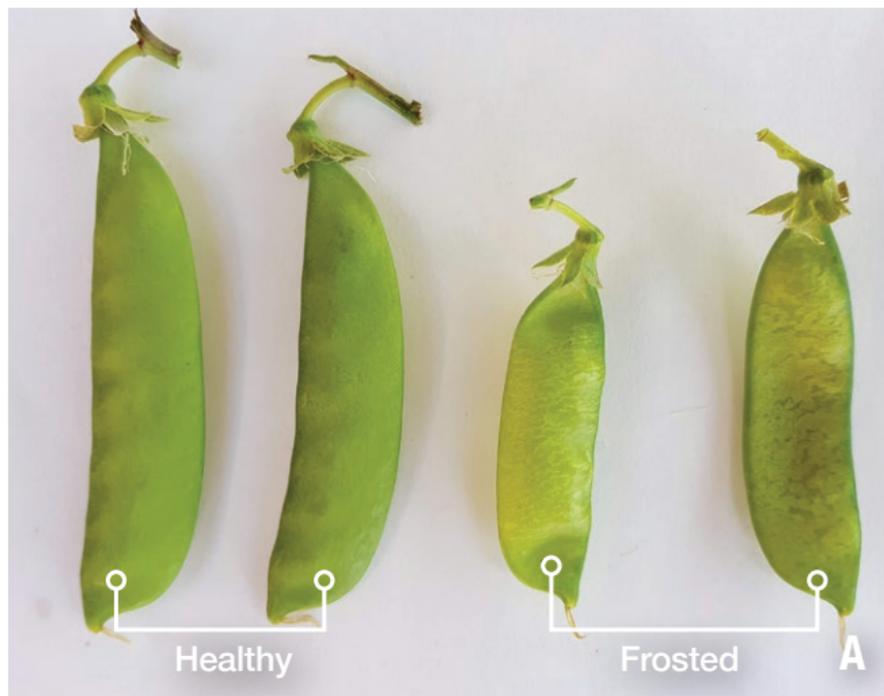


Figure 11. A) Healthy field peas (left) compared to frost-affected pods (right).



- Developing seeds turn brown/black and are aborted (Fig. 11B).
- Seeds are mushy and dark green immediately after a frost. They will turn yellow and then brown over time (Fig. 11C).
- Not all seeds in a pod are affected, sometimes only one seed will be damaged.



Figure 11. B) Healthy field pea pod and seeds (left) and frost-affected pod and seeds (right), note the shrivelled pods and brown-coloured seeds. C) Healthy (left) compared to frosted (right) field peas.

Recovery

Will the plant recover or compensate?

Time of flowering affects frost susceptibility and the ability of plants to compensate for damage after a frost event. In addition, managing bacterial blight in field peas can help reduce yield loss and economic impact (Bray, 2010).

- Field peas can recover if the frost occurs during early flowering but only if there is sufficient time left in the season and soil moisture available for continued pod-set.
- Most commercial-scale frost damage occurs either once flowering has finished or if the crop is infected with bacterial blight.



Main image: © Pulse Australia



What else could it be?

- **Heat stress and spring drought**

Similarities: Flower and pod abortion.

Differences: Contrasting weather conditions.

- **Bacterial blight**

The symptoms of bacterial blight and frost are different, however, plants damaged by frosts are more susceptible to infection.

Paddock symptoms (hot spots or position in the landscape) and weather conditions will help to determine cause and effect.

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Chickpeas



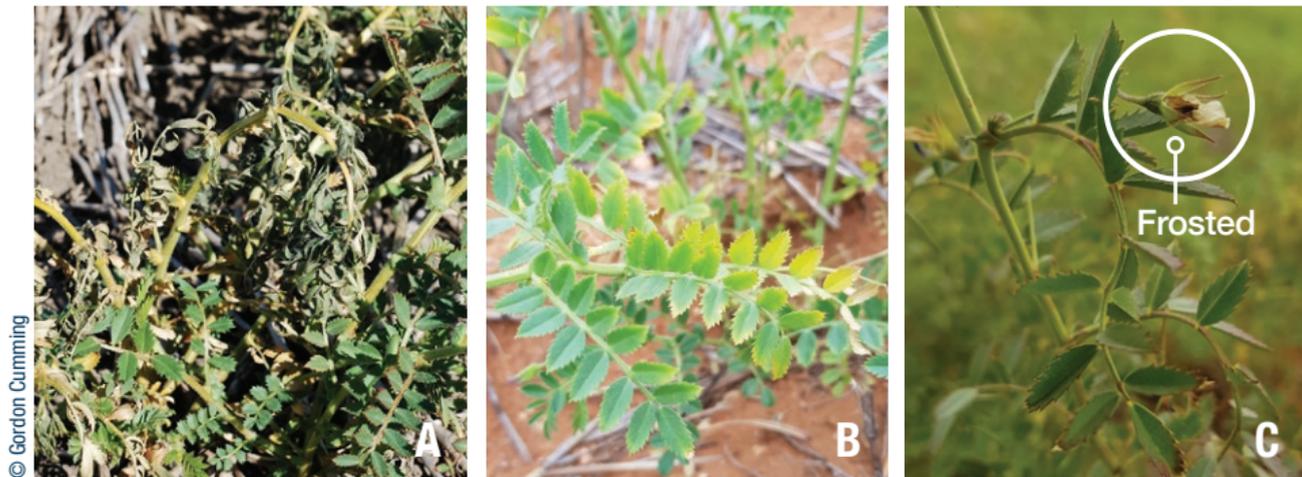
Symptoms

Chickpeas typically flower later than other pulses and because of this can often avoid frosts. However, their exposed flowers make them vulnerable to chilling and frost events during flowering. Chickpeas are particularly vulnerable to frost during 1) pollen development in the flower buds (resulting in infertile pollen when flowers open) and 2) early-pod development. Frosts normally affect the earliest-formed pods situated low on the primary and secondary branches.

Leaf, stem and flower symptoms

- Most current chickpea varieties will abort flowers and semi-filled pods when average daily temperature drops below 15°C. Chilling-induced abortion occurs below this temperature because the pollen becomes sterile and reproductive structures do not develop. Flowers can develop below 15°C but they will contain infertile pollen and will not set seed (Chickpeas Northern Region – GrowNotes™).
- Severe frost injury results in an irregular scorching and yellowing on leaf margins, which leads to leaf drop (Fig. 12A and B).

- Growing points are sometimes distorted (bent) during early vegetative and flowering stages (Fig. 12A).
- Severely frosted leaves can show signs of wilting and desiccation (Fig. 12A).
- Less severe frosts cause yellowing of leaves (Fig. 12B).
- Frosted flowers will abort, after first appearing scorched and wilted (Fig. 12C).



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Figure 12. A) Wilted, distorted stems and scorched, frosted leaves. B) Less severe frosts cause yellowing of leaves. C) Shrivelled, frosted flower.

Pod-set symptoms

- Frost can cause abortion of immature seed within the pod, but the pod can continue to develop to full size (Fig. 13A).
- Frost causes pods to blister/bleach and then abort (Fig. 13B).
- The frosted pods can lose their green colour and senesce.
- Pods usually abort low on the stem however, the plant can set pods later in the season if conditions are favourable (Fig. 13A).

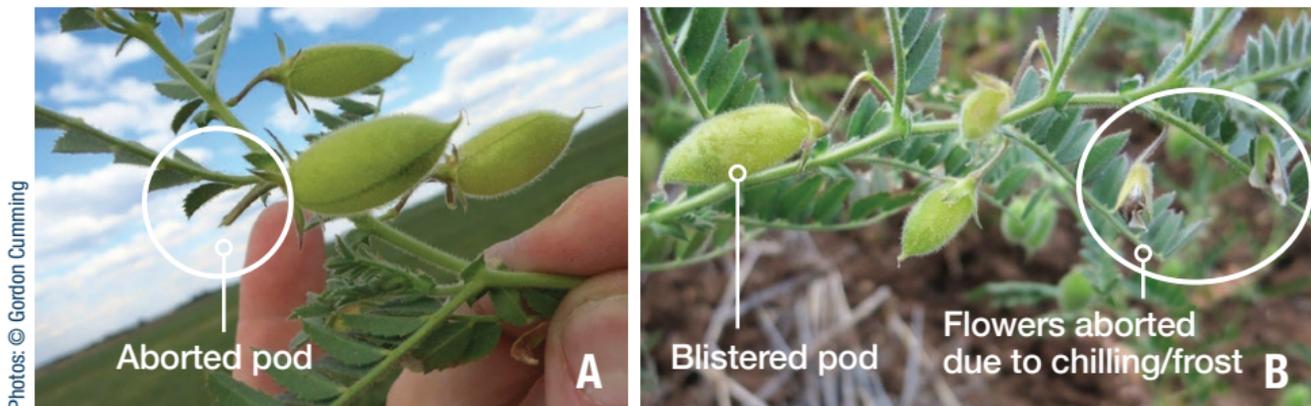


Figure 13. A) Immature seed can die within the pod, however, the pod can continue to develop to full size. B) Blistered pod and flowers damaged by chilling/frost.

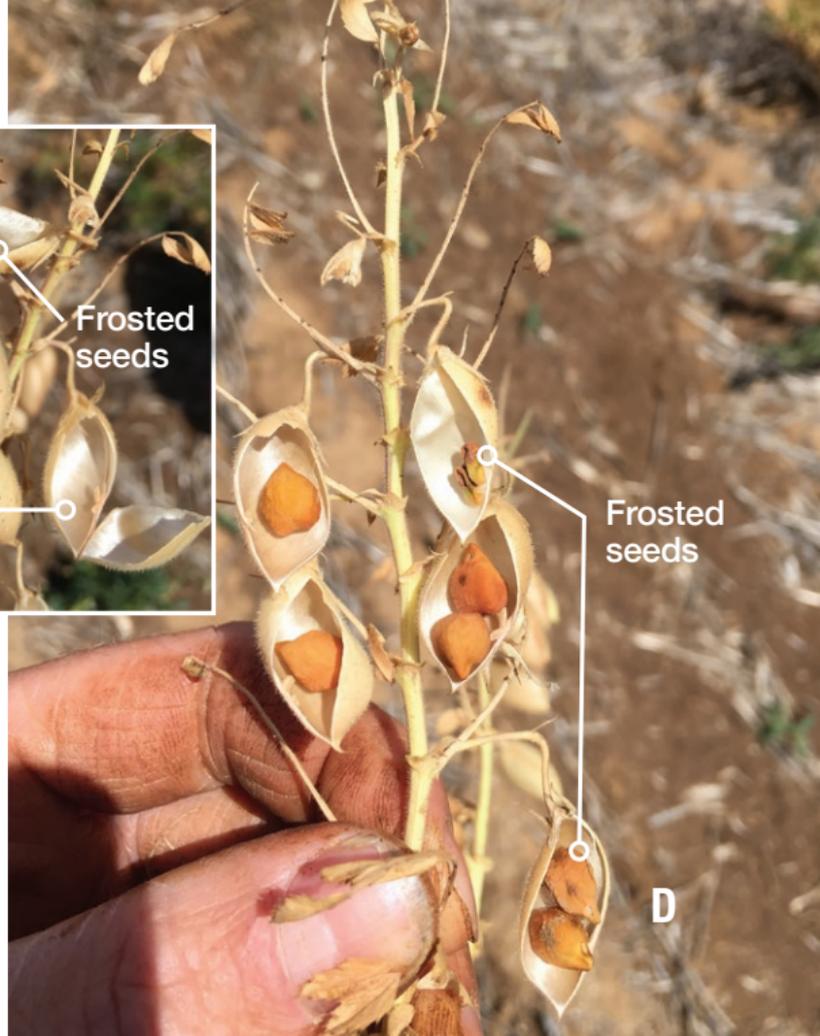
Pod-fill and seed symptoms

- Frosted seeds turn brown in the pod within about a week after a frost event (Fig. 14A).
- If frost occurs during late-maturity, seeds are generally less susceptible to damage with the seed-coat just becoming mottled and bleached, later darkening in colour (Fig. 14B and D).
- Frost can compromise seed quality and market end-use (Fig. 14C and D).

Figure 14. A) Blistered pod with frosted seed. B) Frost damage at late-maturity causes mottled seed.



Figure 14. C) At maturity frosted seed can appear discoloured with a crimped appearance and darkened seed coat. D) Frosted seeds.



Recovery

Will the plant recover or compensate?

Time of flowering affects frost susceptibility and the ability of plants to compensate following frost events.

- Chickpeas often lose early flowers due to low temperatures ($< 15^{\circ}\text{C}$) but will continue to flower and set pods well into spring if there is adequate soil moisture.
- Most commercial damage due to frost occurs once the plants have stopped flowering as the compensation ability is hindered. However, pods with well-developed seeds are generally less susceptible and may only suffer from discolouration.



Inset: © Pulse Australia



What else could it be?

- **Heat stress and spring drought**

Similarities: Flower and pod abortion.

Differences: Contrasting weather conditions.

- **Ascochyta blight**

Similarities: Premature haying-off of leaves; leaf and pod lesions.

Differences: Ascochyta blight lesions are round with an oval shape and brown centres and darker margin.

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Faba Beans



Symptoms

Faba beans are the least sensitive of the pulses to frost but still can be damaged. Thick pods help to protect seed from frost damage during seed-fill, unless the frost is severe. They are most sensitive during flowering and early pod-set and generally are unable to compensate for frost damage after flowering has finished.

Leaf, stem and flower symptoms

- In the vegetative phase, frosted leaves become scorched and withered and develop black leaf margins.
- Stems can be weakened by frost and typically show an 'S' bend symptom (Fig. 15A).
- Stem growth can continue as long as the frost event has not been too severe. However, often the point of distortion can become infected by opportunistic pathogens (Fig. 15B).

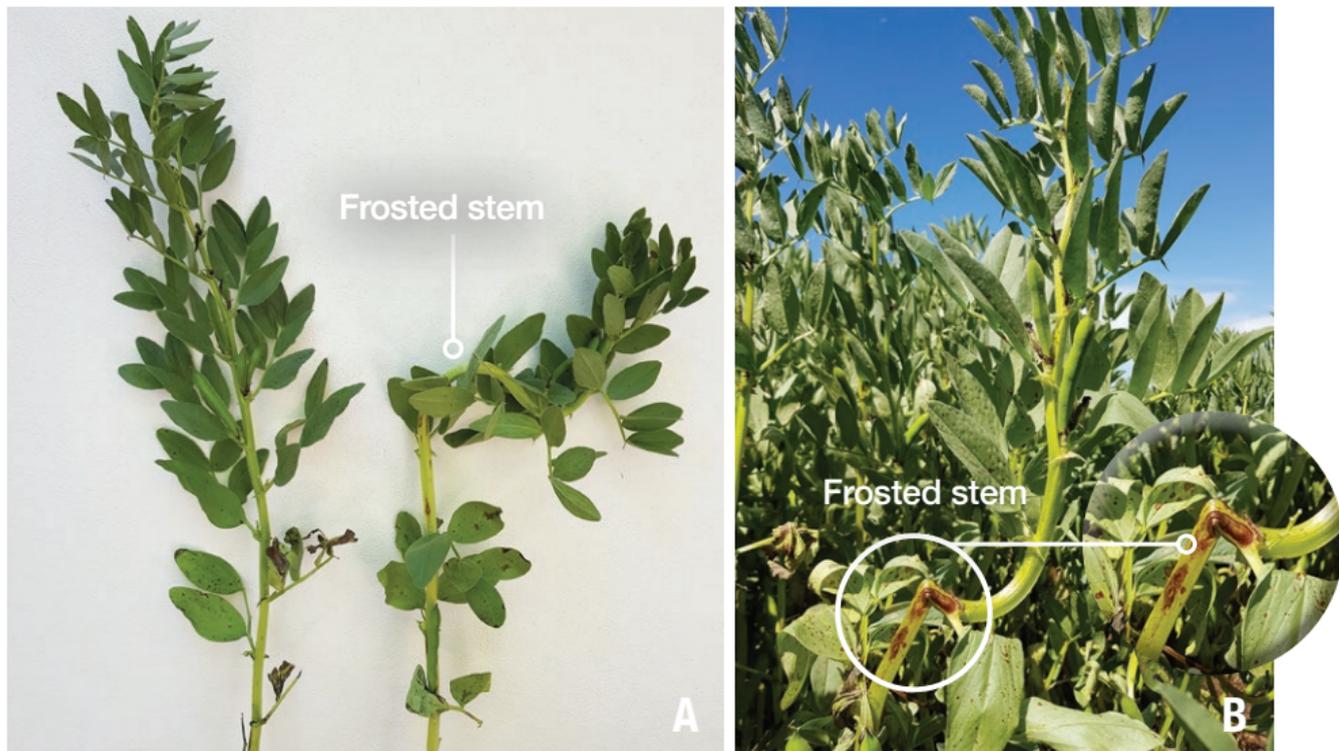
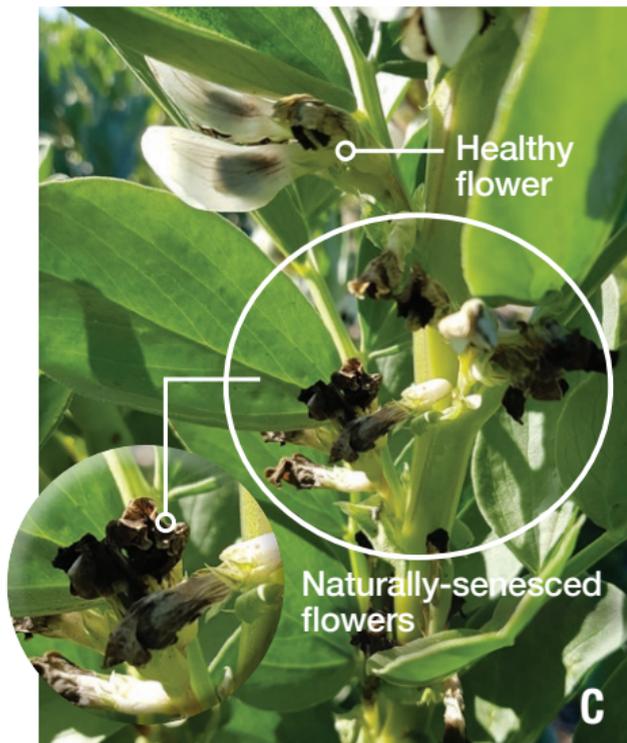


Figure 15. A) Stems can be distorted after a frost event, healthy (left) frosted (right).
B) The points of distortion can lead to infection by opportunistic pathogens.



- After flowering faba bean petals naturally shrivel and turn dark brown (Fig. 15C). Even without frost, about 85 per cent of flowers produced do not set pods, making frost diagnosis difficult (Fig. 15D).



Figure 15. C) Healthy petals can have a burnt appearance and shrivel after flowering. D) Even without frost, about 85 per cent of flowers produced senesce naturally, turn black and fail to set pods.

Pod-set symptoms

- The developing pod can abort completely due to frost damage (Fig. 16A)

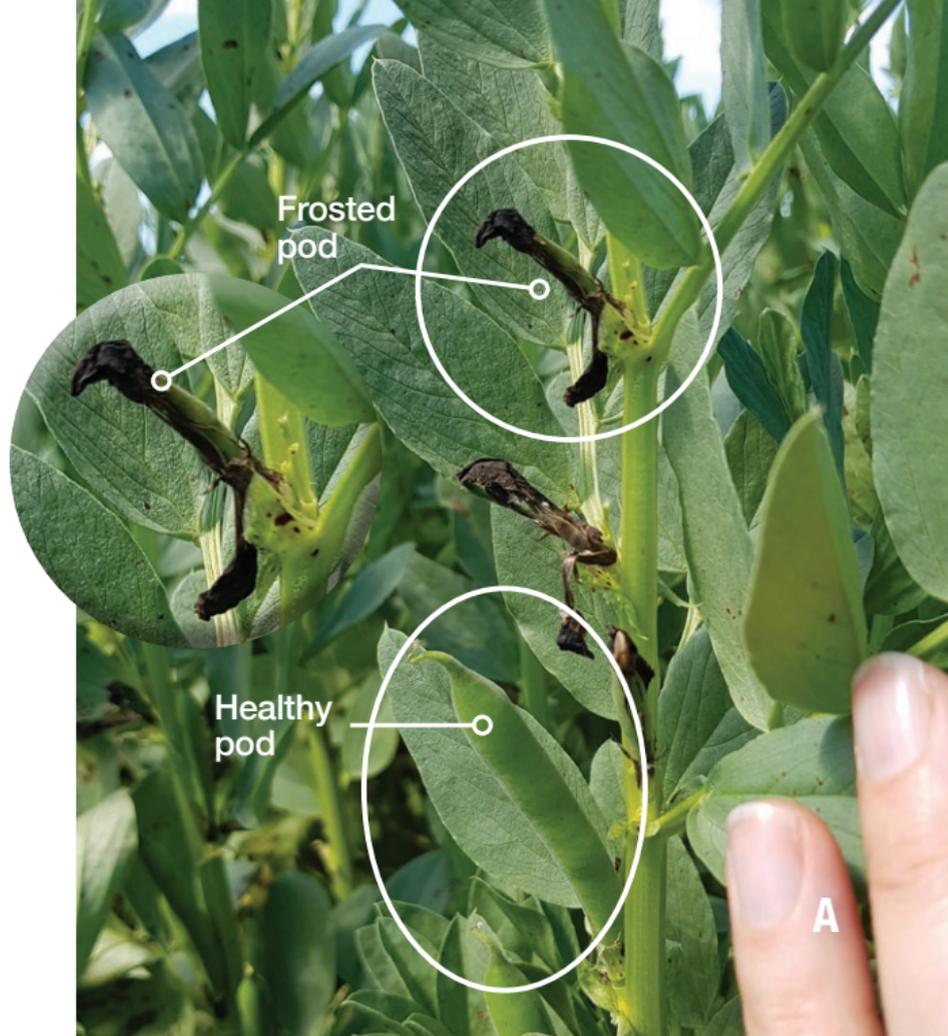
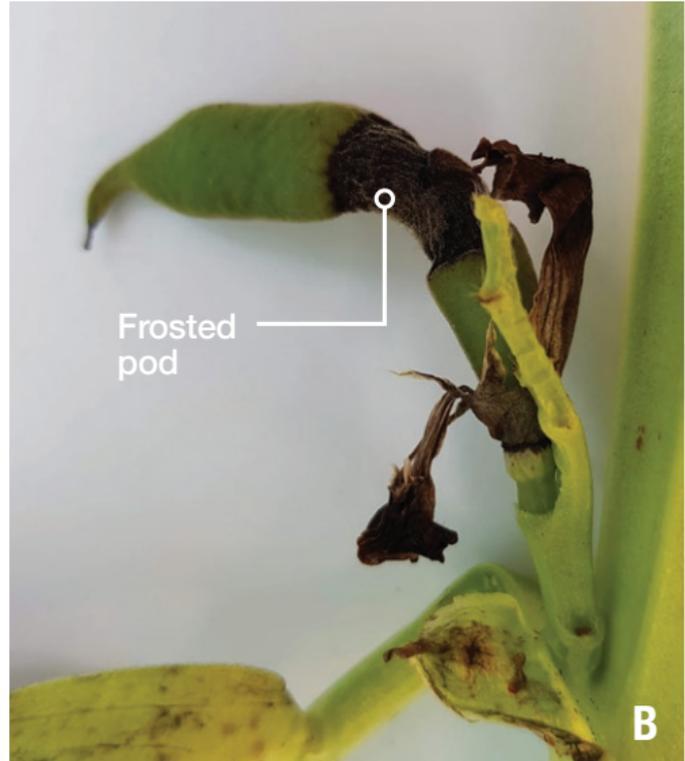


Figure 16. A) Healthy and frosted pods on the same stalk.

- Frosted, developing pods can appear burnt and shrivelled or abort (Fig. 16B).
- Faba beans can recover from frost if the events occur during early flowering but only if there is sufficient soil moisture and time left in the season.

Figure 16. B) Aborted flower stalk and severely frosted pod. Note the burnt symptoms.



Pod-fill and seed symptoms

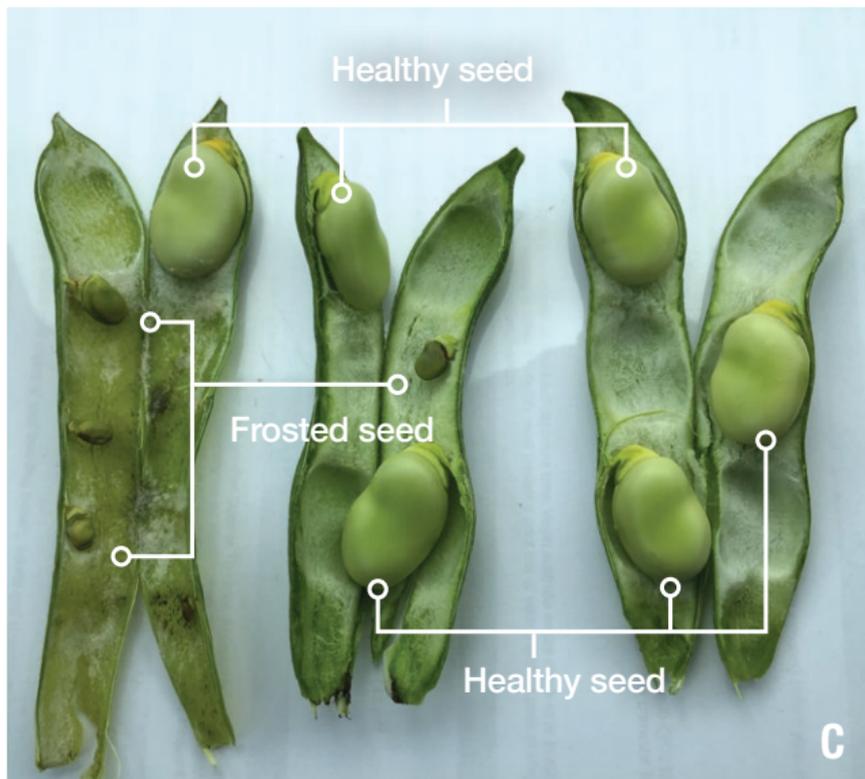
- It is important to dissect pods to confirm frost diagnosis as external damage is often limited. Frost-affected pods will feel spongy (Fig. 17A).
- Frost-affected seeds become shrivelled or abort (Fig. 17B).

Figure 17. A) Under severe frosts, developing pods become shrivelled (bottom). Under moderate frosts, pods can become spongy and irregularly-shaped (top). B) Not all seeds are affected within the pod.



- Not all seeds will be frost-affected, with some remaining healthy while others might abort or shrivel (Fig. 17C).

Figure 17. C) Frosted developing seeds are shrivelled or absent (note smaller, darker seeds). Healthy seed is highlighted for comparison.



Recovery

Will the plant recover or compensate?

Time of flowering will affect frost susceptibility and the ability of plants to compensate for frost damage.

- Faba beans can recover if the frost occurs during early flowering but only if there is sufficient soil moisture and time left in the season.
- Most commercial-scale damage occurs after flowering has finished and the crop is at early pod-fill.
- Frost can cause seed to become stained, affecting quality and marketability (Hawthorne 2007).

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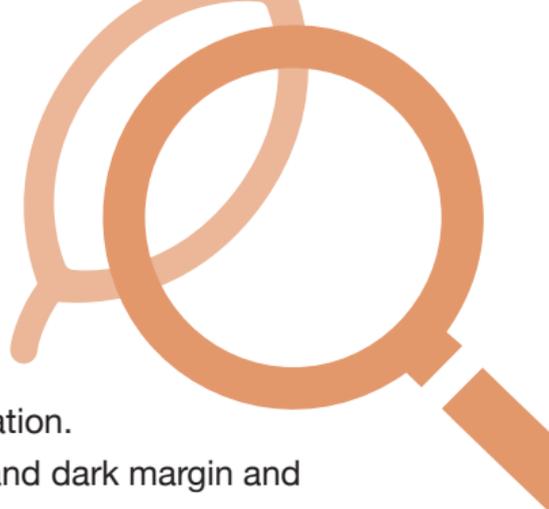
What else could it be?

- **Ascochyta leaf and pod spot**

Similarities: Dark lesions on pods, seed discolouration.

Differences: Lesions are sunken with pale centre and dark margin and can be covered with fruiting bodies.

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Lentils



Symptoms

Lentils are most susceptible during pod-fill (but are still susceptible during flowering).

Leaf, stem and flower symptoms

- During the vegetative stage damaged leaves have a bleached and wilted appearance (Fig. 18A).

Figure 18. A) Frost-affected lentil leaves; note the bleached and wilted appearance.



- Affected leaves wilt, senesce and drop from the plant (Fig. 18B).
- Frost-affected flowers abort (Fig. 18C).
- Flowers wilt and turn brown (Fig. 18D).

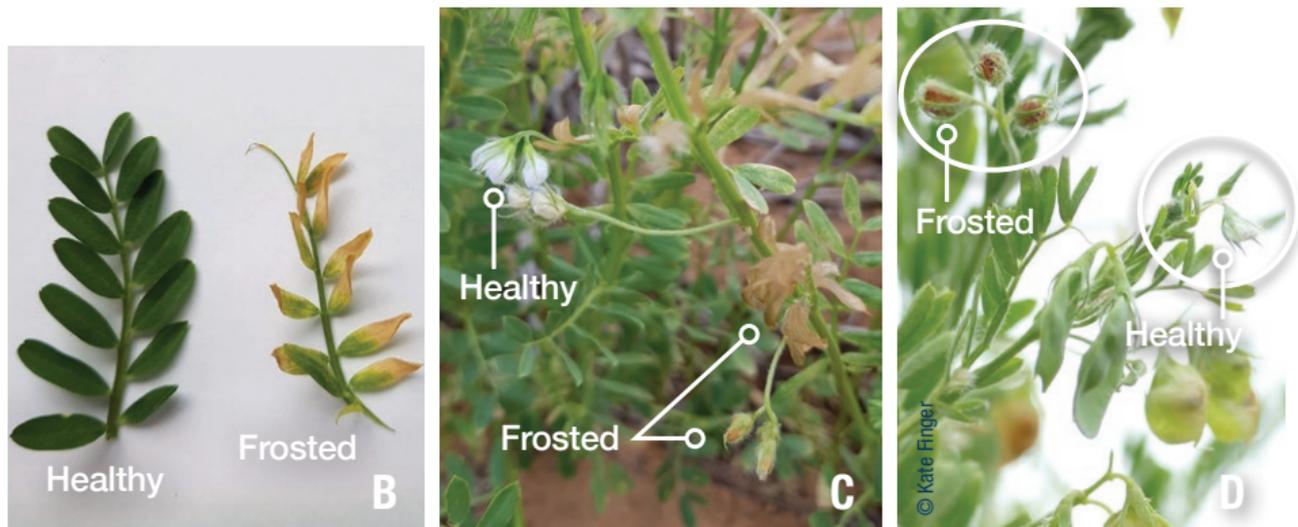
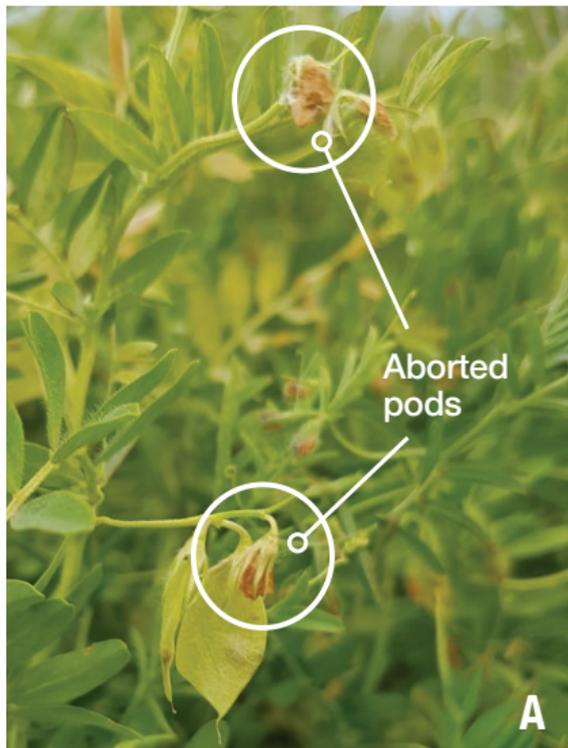


Figure 18. B) Frosted leaves will wilt and senesce. C) Frosted flowers are aborted. D) The indeterminate nature of lentils means the plant can continue to flower if conditions allow.



Pod-set symptoms

- Frosts can cause whole pods to abort (Fig. 19A), or disrupt seed-set (Fig. 19B).
- Pods turn a light-green colour before senescing.



Figure 19. A) Whole pods can be aborted due to frost (arrows show aborted pod). B) Seed development is disrupted and frost-affected pods turn a light-green colour then senesce.

Pod-fill and seed symptoms

- During pod-fill, frost can damage the seed coat and the kernel. Frosted seeds are generally finely wrinkled, blistered and may closely adhere to the kernel and show discolouration.
- While frosted pods can develop, their seeds often abort (Fig. 20A).
- Frosted immature seed is small, shrivelled and discoloured (Fig. 20B).
- Frosted well-developed seed will retain good size but be discoloured (Lentils the Ute Guide 2008).

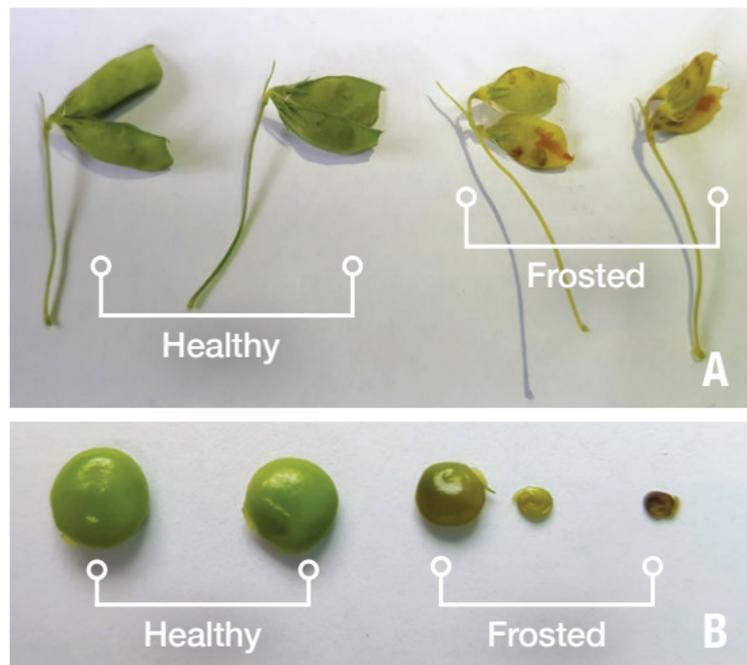
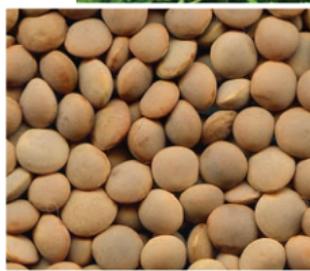


Figure 20. A) Healthy (left) through to frost-affected pods (right). B) Healthy (left) through to frost-affected seeds (right) dissected from pods shown in Fig. 20A. Note the shrivelled and brown/black appearance in frosted seeds.

Recovery

Will the plant recover or compensate?

- Lentils can recover if the frost occurs during flowering but only if there is sufficient time left in the season and soil moisture available for continued pod-set.
- Most commercial-scale damage occurs after flowering during pod-fill.
- Frosted seed can be classified as wrinkled, discoloured or shrivelled and down-graded from human consumption (Pulse Australia).



Inset: © Pulse Australia



What else could it be?

- **Herbicide damage**

Similarities: Bleached spots on leaves.

Differences: Management timing and leaf symptoms are not restricted to margins.

- **Ascochyta blight**

Similarities: Dark lesions on pods, seed discolouration, leaf drop.

Differences: Lesions can be covered by numerous fruiting bodies.

 www.agric.wa.gov.au/mycrop





Reporting frost damage

and Further information



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.



Available on the
App Store



GET IT ON
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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 cereals: <https://www.agric.wa.gov.au/frost/frost-identification-guide-cereals>
- 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
- Pulse Australia: <http://www.pulseaus.com.au>

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