Department of
Primary Industries and Regional Development

GOVERNMENT OF WESTERN AUSTRALIA

Frost
frequently asked questions

GRDC Partner Project

NATIONAL FROST INITIATIVE

List of questions

At what temperature does frost occur in a cereal crop?

1. **Cold damage** occurs when plants are exposed to temperature less than 10°C down to -2°C. If this occurs during pollen development (Z39 - 45) it can cause spikelet damage.

2. **Desiccation damage** occurs when ice forms on the outside of the leaves at temperatures from 0°C to -2°C. Moisture is drawn from the leaves leaving them dry and brittle, subsequently dying at the tips.

3. **Freezing damage** usually occurs at temperatures below -2°C when there is rapid ice nucleation and ice crystals form within the leaf. The ice crystals physically rupture cell walls and membranes within the cells causing physical damage. Damage can be seen once thawed as dark green water soaked areas, 10 days after a frost bleached heads might be evident.

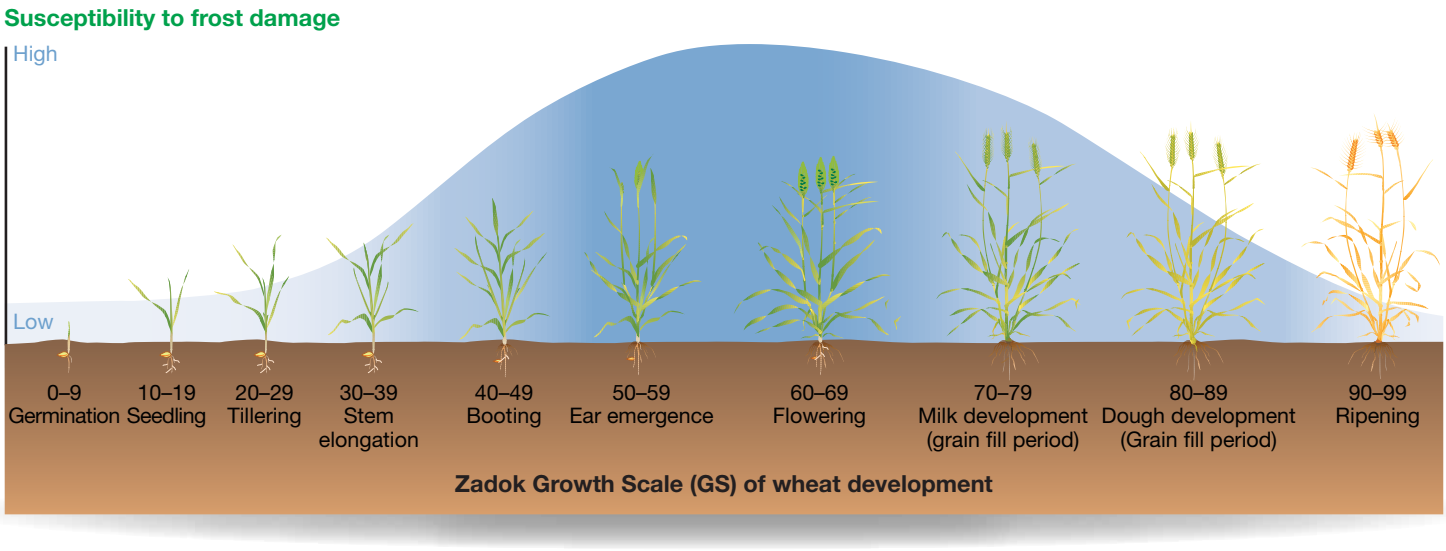
Why does rain make it worse?

A canopy that is wet from a light shower of rain is often more prone to frost damage. This is because rain contains ice nucleators such as bacteria or dust. These ice nucleators raise the freezing point of water (Christner *et al* 2008). As a result, a slightly wet canopy may get frosted at warmer temperatures compared to a dry canopy.

This might happen at home when you put a beer in the freezer and forget to take it out. Initially you might see that when you remove it, it isn't frozen but as soon as you open it, it freezes immediately as the super cooled liquid freezes. Super cooling is when a liquid, free from ice nucleators remains as liquid below its freezing point. Ice nucleators enter the bottle once opened, promoting rapid ice crystal formation. A similar reaction can happen within plant tissues out in the paddock, particularly with wet conditions.

When is the crop most susceptible?

Cereal crops are most susceptible to frost damage during and after flowering but are also susceptible at the early booting and grain filling stage.



Susceptibility of wheat to frost during the development cycle (©GRDC)

Pulses and canola are particularly susceptible during pod filling where affected pods have absent, mushy or shrivelled and distorted seeds.

What does frost damage look like?

The nature of frost damage depends upon the plant development stage at which the frost occurs.

Grain: Frosted grain at the milk stage is white eventually turning brown with a crimped appearance. It is usually spongy and when squeezed it doesn't release a milky dough substance. Frosted grain at the dough stage is shrivelled and creased along the long axis, like a pair of pliers has crimped the grain in the middle.

Flowering: Frosted anthers are white turning a dull brown colour, ovaries turn a dull brown and are spongy when squeezed. They begin to shrivel as no grain is developed. Also the head will be underdeveloped and/or have bleached florets.

Stem: Pale green to white ring on the peduncle (the stem below the head), which can lead to a crimped, cracked/ blistered appearance with a rough texture. The damaged area may turn white/brown and the head may bend over.


Healthy grain at dough stage


Frosted at the dough stage


Healthy at flowering stage


Frosted at flowering stage


Healthy wheat stem (left), frosted (right)

How do I check for frost damage?

When: Inspect crops when they are between ear-emergence and grain-fill, after the temperature drops below 2°C (screen temperature). Damage is usually most evident 7−10 days after a suspected frost event.

Where: Examine the crop in more susceptible lower parts of the landscape first and if the crop is damaged proceed to higher ground.

How: Walk through the crop and examine a whole plant every 10−20 paces.

If the head has not emerged from the boot, check that the head has not been damaged. You will need to carefully dissect the plant from the top down to find the head of the plant.

If the crop has flowered, open the florets to check if the grain is developing.

After a frost event, tag a few heads with tape and note the stage of grain fill. Return a week later to determine if grain development and grain filling is continuing.

To check for stem frost, remove the leaf sheath from around the stem from crown to peduncle to check for a pale to white ring.

Is stem frost damage as bad as flowering frost damage?

Stem damage may not be as bad as flowering frost damage, provided there are viable grains and mild weather conditions during grain filling. The stem structure is similar to a bunch of straws where water and nutrients travel to the head/grains. Not all straws may be affected, allowing water and nutrients to still reach the head/grains. Dye can be used as an indicator of how much damage has occurred. For example, place a stem sample in a jar with food colouring and water, then put it in the sun, the rate at which the dye travels up the stem will give you an indication of damage.

Normally it's the xylem (capillary tubes which transport water) that are the issue, (the phloem which transports the sugars can rebuild), if it is hot or water stressed, the heads can lose ability to maintain evaporative cooling because of restricted water flow and can over heat. This can result in white bleached heads after a hot day. Lodging of cereals can also be an issue if windy conditions occur during late grain filling stages.

Stem frost damage late in grain filling can be confused with root diseases such as, crown rot, rhizoctonia or septoria. To determine the cause of damage, remove the leaf sheath from around the stem from crown to peduncle to check for a pale to white ring.

Do all crops respond the same to frost?

All winter grain and oilseed crops are susceptible to frost. It is therefore important to consider less susceptible crop species for frost-prone paddocks. The order of susceptibility for cereals is (most to least); triticale, wheat, barley, cereal rye and oats. Wheat is more susceptible then barley at flowering, but it is not known if barley and wheat have different frost susceptibilities during grain fill. Field peas are the most frost-susceptible pulse crop followed by faba beans and lupins. Canola is susceptible to frost, however is least susceptible to damage from late flowering (90%) to the clear watery stage (about 60% moisture). Also due to its indeterminate nature canola has a good capacity to recover from frost, given a favourable finish. Canola is an expensive crop so careful consideration needs to be made for frost prone paddocks. Hay production requires biomass, a reproductive frost will not reduce yield and may in fact improve the quality of the product through the mobilisation of sugars. Pasture rotations are a lower risk enterprise and oats are less susceptible to frost during the reproductive stage than other cereals.

Why do crops with high yield potential get frosted more?

Position in the landscape influences temperature variations, frost damage and yield more than management practices. High production areas in a paddock are often lower in the landscape with the increased moisture promoting higher yields. Current frost research indicates that crops sown with high seeding rates, high nitrogen and higher yield potentials may be more susceptible to frost. It is thought that high inputs creates denser canopies which shades the soil, minimising soil heat retention and the ability of the soil heat bank to buffer the frosts. As a result these crops can experience an increase in severity and duration of the frost events compared to crops grown with more conservative approaches.

Do all wheat varieties respond the same under frost?

All wheat varieties are susceptible to frost however their risk profile during flowering can differ. The frost performance values provided on the National Variety Trial website (www.nvtonline.com.au) give an indication of a varieties risk to frost damage during flowering (refer to following question for more information). Variety choice and time of sowing is a major driver of variation in yield and is still the most reliable way of reducing yield losses from frost. To minimise the impact of frost, first select varieties adapted to your region and then match to the appropriate sowing time to ensure the optimum flowering period. Sowing the correct variety early can lengthen the growing season and deliver increased yields. However, when sowing early, it is critical to choose a variety that flowers during the optimum flowering window (refer to DPIRD's Flower Power www.agric.wa.gov.au/frost/flower-power).

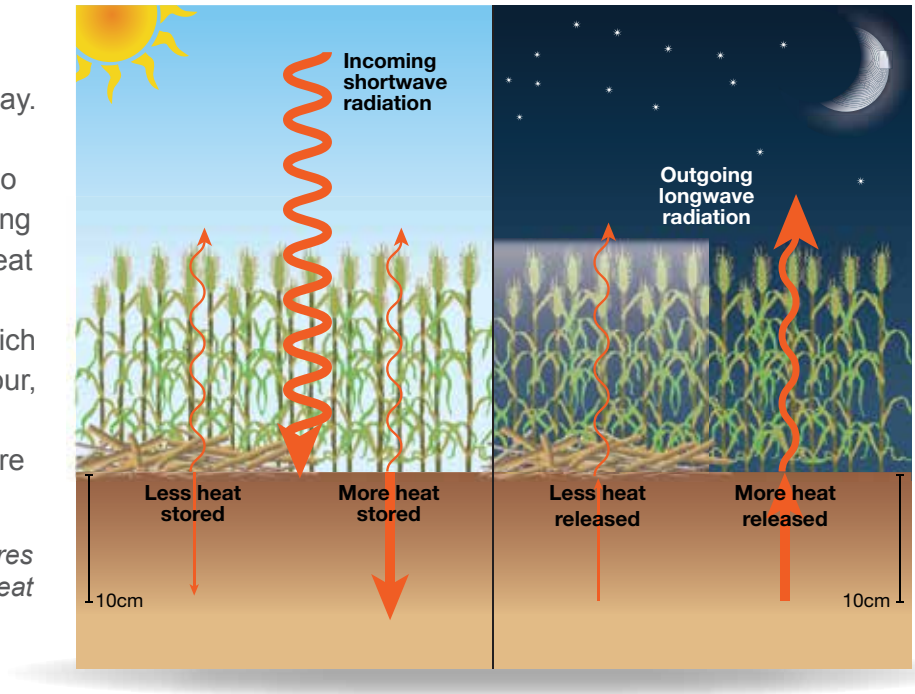
Consider using multiple varieties (with different flowering times) to target flowering throughout the optimal flowering period for your location to minimise the impact of frost. This can decrease the impact of sporadic frosts that occur within the optimal flowering window in some years.

How do you use the frost performance values on NVT?

All wheat and barley varieties are susceptible to frost. Consider using wheat and barley varieties that have a lower Frost Performance Values (FPV) to manage risk while maximising yield potential. The frost performance values provided on the National Variety Trial website (www.nvtonline.com.au) are an indication of a variety's risk to frost damage during flowering. Using these values, enables the direct comparison of the relative frost risk between multiple varieties. The lower the frost performance value, the lower the frost risk of that variety. A new variety should be managed based on similar variety's performance under frost. However, there is no economic benefit in selecting less susceptible varieties for the whole cropping program in the absence of frost.

What is the soil heat bank?

The soil heat bank refers to the amount of heat absorbed and retained by the soil during the day. This heat is then radiated back into the crop canopy overnight to warm flowering heads, minimising frost damage. The amount of heat stored depends on a number of factors such as row spacing which affects canopy closure, soil colour, stubble loads and soil moisture. A moist soil profile will store more heat than a dry soil.



Caption: The soil heat bank captures heat during the day and radiates heat into the canopy overnight to warm flowering heats and minimise frost damage. © GRDC

How does stubble loads affect frost severity?

Research has shown that by reducing stubble loads, there is a reduction in the severity and duration of frost events, resulting in less frost damage and better yields under frost conditions. No differences were observed between stubble height, orientation or composition. Data to date suggest it's mainly a load issue.

Stubble reduction can be achieved by various management strategies including; cutting low, windrow burning/chaff carting, stubble mulching, raking and burning, strategic blanket burning and summer grazing. In terms of minimising frost risk, a good rule of thumb is that stubble loads should match target grain yield. For example, in a low production environment, 2 t/ha grain yield potential equates to 4 t/ha stubble remaining after harvest. The stubble load needs to be halved prior to seeding, back to 2 t/ha to minimise frost risk. In a medium production environment, 3 t/ha grain potential equates to 6 t/ha stubble remaining after harvest. This can be reduced to 3 t/ha to manage frost risk. This calculation assumes a harvest index of 0.5. Research to date suggests it is mainly a stubble load issue, as no differences have been observed between stubble height, orientation or composition. Current research shows that without frost, a once off stubble reduction does not reduce yield. It may give a slight improvement in yield due to reduced disease and less nitrogen tie up, depending on site, season and variety choice. With multiple severe frost events, stubble reduction does not increase yield (Smith *et al* 2017).

Does sowing direction impact frost severity and duration?

This question relates to the soil heat bank. The theory that more sunlight reaches the soil surface in north-south sown paddocks compared to those sown east-west was tested. From our research, changing sowing direction from east-west to north south did not change the severity or duration of frost events. There was no advantage in yield or grain quality from either treatment. It is recommended that growers use current practice when sowing paddocks. East west sowing is currently used as an intergrated weed management tool.

What is the effect of nutrition, nitrogen, potassium and copper?

The relationship of crop nitrogen (N) status and frost severity and duration is complex. This is the focus of ongoing research. To date there is no strong evidence that N softens wheat to frost. The 2016 WA frost trials concluded that managing wheat varieties had a greater impact on frost risk than varying nitrogen and seed rates.

However, it is suspected that high N rates promotes increased synchronisation of canopy development, head emergence and flowering. If a greater proportion of the canopy is flowering all at the same time, this will potentially increase the frost risk, as the whole crop will be vulnerable at the same time.

Adequate potassium (K) fertiliser application is important for reducing the effects of crop stress on grain yield. K deficiency results in poor water use and uptake of other nutrients, making crops more susceptible to drought, waterlogging, frost and leaf diseases. Based on 21 K experiments since 2011, it has been shown that K fertiliser provides added protection for cereal crops against crop stress such as drought and frost, especially if on marginal light sands (low in K < 50ppm) (Bell *et al* (2017). Luxury levels have not been shown to reduce damage economically; however work is ongoing in this field.

If a crop is deficient in copper (Cu), correcting with a foliar spray at booting is economical without frost. The role Cu plays in reducing frost, is not fully understood. Luxury levels have not been shown to reduce damage. The symptoms of copper deficiency are similar to frost often leading to misdiagnosis as frost damage. Whole-top plant test provides a rough guide if paired good/poor samples are taken, but this should be confirmed with a youngest emerged blade (YEB) test. YEB levels below 1.5 mg/kg indicate Cu deficiency.

What is meant by synchronicity of the canopy? Why does this matter?

When a crop experiences different environmental conditions plant development will vary slightly. When a canopy synchronises, it means that plant development throughout the canopy is aligned, potentially as a result of limited environmental variation/canopy closure i.e. light, moisture and competition for nutrients. So, if a greater proportion of the canopy is flowering all at the same time, this will potentially increase the frost risk as the whole crop will be vulnerable at the same time.

Does soil amelioration reduce frost severity on light textured soils?

In WA, there has been a lot of anecdotal evidence on the affect of frost on ameliorated soil. Some growers reported reduced frost damage in paddocks that have been mouldboarded, spaded, delved or clayed. However, there are many confounding factors occurring as a result of the soil amelioration making it difficult to narrow down impacts to a reduction in frost damage alone.

Amelioration of water repellent sands may reduce frost damage by improving the capacity of the soil to absorb and then release heat. Increased heat absorption by the soil can occur as a result of improved wetting and changes to the colour of the soil surface. However, research is continuing to further understand the possible impacts of soil amelioration on frost severity and the impact of soil types and amelioration methods. Soil amelioration is unlikely to be an economically feasible practice for frost damage alone. Potential reductions in frost damage are an additional benefit in years when frost is an issue.

The decision to undertake soil amelioration should be made primarily in regard to weed control, soil water repellency, subsoil constraints and profitability.

Harvesting a frosted cereal crop?

Frosted crops are difficult to thresh due to higher residual sugars in the grain, lower grain volume and high screenings. Despite lower tonnages, daily harvest maintenance and regular machinery clean down is vital to minimise machinery fatigue and fire risk in these difficult harvesting conditions. Frosted crops generate more dust when harvested due to shattering grain and increased fungi populations on the crop, thus contributing to increased fire risk. If practical to do so, harvest frosted paddocks last.

Grain quality may also be compromised depending on the timing of the frost event. Frost affected grains usually have a lower hectolitre weight and higher screenings. Adjusting header settings and/or grading can be beneficial but check the feasibility first.

Frosted stubble can also rot off at ground level and be difficult to seed into. To minimise trash flow problems in subsequent seasons, frosted stubbles may have to be cut low.

WHAT MANAGEMENT OPTIONS DO I HAVE TO MINIMISE FROST DAMAGE?

1. IDENTIFY FROST PRONE PADDOCKS - with topographic, electromagnetic, yield maps and paddock history

2. CONSIDER ENTERPRISE IN A ZONE - cropping/sheep balance

3. REVIEW NUTRIENT MANAGEMENT - targeted nitrogen, potassium, copper inputs

4. MODIFY SOIL HEAT BANK - stubble levels, crop canopy

5. SELECT APPROPRIATE CROPS - oats, barley wheat, canola

6. MANIPULATE FLOWERING TIMES - stage sowing time, mix long and short season varieties

7. FINE TUNE CULTIVAR SELECTION - wheat, barley susceptibility during flowering

Refer to Frost Management Tips and Tactics

For Northern, Southern and Western regions for more detailed information: www.grdc.com.au/ManagingFrostRisk

Frost terminology

Word	Meaning
Tolerance	Used to describe a plant under stress when the extent of loss does not exceed the economic threshold level particularly during freezing and survival during the reproductive stage.
Susceptibility	The inability of a plant to restrict damage from frost.
Resistance	Resistance is an absolute term where the plant is completely unaffected by a frost event.
Sensitivity	The degree to which the plant responds to stress.
Avoidance/Escape	The plant has never been exposed to frost or freezing damage.

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