Photo: Ben Biddulph, DAFWA

# Sandy soils increase risk of frost damage

## Key facts

- Crops grown on sandy soils can be more prone to frost damage— white sands are more frost prone than darker-coloured sands.
- Sands are less able to store water near the surface, which is important for producing radiated heat, reducing frost risk.
- Stubble reflects light and has extremely low bulk density, resulting in lower temperatures and greater frost risk.
- Changes to colour, density and texture of sandy soils can reduce frost impacts. Clay delving or spreading, rolling and the use of dark soil amendments can reduce frost risk.

**Frost can damage crops and pastures** across south-eastern Australia. Pasture production losses due to frost are generally lower than those for crops, as most common pasture species are better able to recover from damage incurred during vegetative stages.

Cereal crops have a wide window of susceptibility to spring frost, which can damage stems, heads, spikelets or flower parts. Developing grain can also be affected by frost.

Crop losses cause significant economic impacts, as most of the cost of production has been spent by the time frost damage occurs.

*Severe frost damage on light-coloured, coarse-textured soils can severely limit crop yields and quality. Losses due to frost are more frequent when late-winter and spring conditions are dry.*

### Why sands are vulnerable

Sandy soils are particularly prone to frost because of their low bulk density, low water-holding capacity, reflective surfaces and relatively low nutritive status compared with other soil types.

Soil heats as it absorbs energy from the sun (solar energy), warming the air near the soil surface. The higher the soil water content, the more heat the soil absorbs, which increases the amount of warm air at the soil surface. At night the soil radiates (releases) heat at a faster rate than air, which means the temperature at the soil surface drops more quickly than the air above. Crop or other organic matter (OM) surfaces also radiate heat quickly and are colder than the air surrounding them. Water forms dew on these cooler surfaces and the dew freezes, resulting in a frost.

The total surface area of sand is low compared with finer-textured soils, which means less water is held on the surfaces of soil particles. With less water, these sandy soils have a lower capacity to release radiant heat, and are more prone to frost.

Water inside and between plant cells also freezes, causing cells to dehydrate, which can result in tissue death. The water between cells probably freezes near 0°C, but within cells there are solutes that act as antifreeze and there may be no freezing until lower temperatures are reached.

Plant tissue can recover after a frost event, but recovery depends on the severity of the frost event and how quickly the temperature increases following the event. Interestingly, warm weather following a frost makes it more difficult for a plant to recover.

## Managing frost risk

### Bulk density

Sandy soils naturally have a low bulk density, and sowing loosens the soil above the depth of the sowing implement, reducing the bulk density even more. A low-density sandy soil holds less water than a high-density soil because water evaporates and drains more readily. Rolling the soil after sowing will compact the surface layer, improving water retention, at or near the surface. This soil water absorbs more solar energy, which increases the potential to release some of this energy as heat to the atmosphere during the night.

### Soil texture

Fine-textured soils (e.g. clay) have a much larger surface area to volume ratio and the total pore space in a given volume of soil is much lower than coarse-textured soils, such as sands. This directly impacts the soil water-holding characteristics of a soil. The increase in soil surface area means there is more water at the surface and the reduced pore spaces means less water is lost to drainage and evaporation. The application of clay to sand acts to both increase the surface area and reduce pore space (see pages 11–12 for more information on amelioration with clay).

### Soil colour

Light-coloured soils reflect more solar radiation than dark-coloured soils. The principle is the same as wearing light-coloured clothing on a hot day compared with dark-coloured clothing. When light is reflected so is much of the energy it contains, resulting in reduced heating of the material itself.

Red or black sands absorb more solar energy than white sands. Part of the impact of claying to increase soil and re-radiated heat is due to the darker nature of the clay itself. It is not economical to change soil colour just to slightly change the temperature dynamics, but it can be a partial justification for spreading or delving clay.

### Soil nutrient status

Recent research offers little evidence of a direct correlation between nutrient status and frost damage. It had been thought that copper-deficient plants are more prone to frost damage, but this may just be that the symptoms are similar. Even if there is a correlation, recent GRDC research has indicated there is no response to copper (Cu) in plants with sufficient levels when exposed to frost.

There has been limited recent research indicating that low potassium (K) levels may lead to plants being more susceptible

*ABOVE: Variation in frost damage during grain filling four days after frost. Centre is a healthy grain. Photo Mick Faulkner, Agrilink Agricultural Consultants*

to frost. It appears these protection responses kick in somewhere between 50 and 100ppm soil potassium. Applying additional potassium to crops where soil potassium levels are already adequate, which is likely across much of South Australia's cropping regions, is unlikely to offer any additional frost protection, or to be cost effective. However, some sandy soils are low in potassium and an application of potassium may be warranted to reduce frost risk and improve grain yield. Always carry out a soil test before developing a fertiliser program.

High nitrogen (N) status is linked to greater frost damage and increased financial loss. There is evidence that nitrogen-rich crops are more frost prone than nitrogen-deficient crops. The interactions are complex and not completely understood.

### Cold air drainage and topography

Cold air is denser than warm air and, being heavier, it descends. Generally, cold air will pool at the base of a slope. As it moves, the air is still segregating and the coldest parts descend at each point, which may coincide with the top of a crop canopy or soil. It is not uncommon to have up to 5°C difference in temperature across a vertical column of just 1.2m.

When cold air drains, the pool of displacement may be intense at the base of a slope and not the lowest point in the paddock. It is not uncommon to observe frost damage emanating from the base of a slope and extending back up the slope, while lower parts of the paddock remain relatively unaffected.

*ABOVE: Frost damage can be found at the base of a slope, extending back up the slope, while lower parts of the paddock are relatively unaffected. Photo: Megan Hele*

Cold air above light-coloured sands can be much colder than the air lying above adjacent areas where soils are darker because the areas with lighter soils cannot store as much heat. This can occur even if light-coloured sands are upslope from the base or the lowest point.

At the same time cold air is descending, heat continues to be lost by radiation across the landscape, until the sun rises and starts to heat the atmosphere, plants and soil surfaces.

There are no frost mitigation strategies growers can employ to eliminate frost on a broadacre scale. Creating air mixing is only possible over small areas because the amount of air that can be moved by fans or heaters is limited and is not effective across the wider landscape. Some of the practices used by horticulturalists are simply not possible, practical or affordable on a large, farm scale.

## Changing soil characteristics

Trials carried out by SARDI in SA across a number of seasons found the amount and intensity of frost damage could be influenced by delving or spreading clay on sandy soils or by rolling after sowing. It must be stressed that these tactics only produced minor changes in temperature at vulnerable parts of a crop during spring frosts.

## Stubble management

Retaining stubble lowers the soil temperature and contributes to lower re-radiation of heat. Recent research carried out by DAFWA during 2015 suggests stubble loads greater than 1t/ha could increase the impact of frost in low-rainfall environments and greater than 3t/ha in medium-rainfall environments.

It has been suggested that in extremely high-yielding environments, where stubble loads exceed 5t/ha, the crop canopy has a greater influence on frost impact than stubble load.

Stubble that is fully incorporated has little effect on the impact of frost other than by reducing the overall bulk density of the soil. Rolling could be an advantage where stubble is incorporated.

Removing stubble is desirable for frost mitigation, but the impact on erosion risk, crop establishment and nutritional status may outweigh the advantages.

## Whole-farm risk management

Frost risk is best managed on a farm-by-farm basis and requires a whole-farm approach. Avoiding frost damage by having plants at less vulnerable stages of growth (e.g. by delaying sowing) is possible, but for winter cereals delaying sowing and maturity can lead to severe yield losses where there is a hot dry finish to the growing season. The optimum sowing time for a crop and variety is a balance between minimising the risks of both frost and heat and maximising plant available water and minimising drought stress.

Growing less-susceptible crops, such as oats and barley, can reduce losses from frost compared with wheat. Pulses generally perform poorly on sandy soils and are highly vulnerable to frost damage, but may be useful on small, targeted areas. Pasture growth can be slowed by frost but will recover if there is sufficient soil moisture in the profile.

## Best practice frost management tips

Frost management tips

- Cropping sandy soils entails a greater risk of frost damage and white sands are higher risk than darker sands. In some cases frost risk can be associated with topography and soil type.
- Knowing where frost occurs regularly across the farming landscape can allow growers to develop frost maps, which build a picture of potential risk. Maps can be based on previous experience, checking and recording when frost damage occurs and verifying yield maps.
- Monitoring temperature can indicate whether conditions have been met that could cause frost damage but does not guarantee frost damage has occurred.
- Delving or spreading clay has been shown to reduce frost damage on white sandy soils, but this approach needs to be considered as part of an overall soil amelioration program.
- Rolling sandy soils after sowing or after emergence can reduce frost damage by compacting the soil, increasing water retention.
- The combined risk of frost with areas of inherent poor crop performance, can make cropping on some sandy soils a poor return on investment and other land uses may be lower risk and more profitable.
- Applying nutrients (e.g. potassium) to reduce frost, unless a nutrient is deficient, is unlikely to provide a benefit.
- Incorporating stubble can reduce the impacts of frost compared with standing stubble, but may increase the risk of erosion, chemical damage and poor crop establishment.

*ABOVE: Standing stubble can increase the risk of frost, but the combined benefits of retaining standing stubble can outweigh these risks. Photo: GRDC*

## Further information

- Managing frost risk: a guide for southern Australian grains (SARDI and GRDC, 2007)
  https://grdc.com.au/uploads/documents/GRDC_FS_Frost.pdf
- Cereals — Frost Identification: The back pocket guide (GRDC, 2000)
  https://grdc.com.au/Resources/Bookshop/2012/01/Cereals-Frost-Identification-The-Back-Pocket-Guide-GRDC416
- Frost — Ground Cover Supplement (GRDC, 2014)
  https://grdc.com.au/Media-Centre/Ground-Cover-Supplements/GCS109
- Managing Frost Minimising Damage — GRDC Farmer Advice
  https://grdc.com.au/uploads/documents/frost.pdf