GRDC's National Frost Initiative – Update February 2017

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Keywords

- Frost: incidence, genetics, management, forecasting.

Take home messages

- Occurrence and severity of frost is very variable, spatially and temporally - but the frost 'window' is widening and the number of frosts is increasing; frost in 2016 was very challenging for growers across Southern Australia
- Average loss from frost is conservatively estimated as $400M p.a.; GRDC's National Frost Initiative co-ordinates a $4M p.a. program of genetic, environmental and management approaches to deliver solutions for the grains industry
- The GRDC Frost Initiative Ranking of susceptibility of cereal varieties to frost has been updated for 2016 and is available on the NVT website.

Background to the GRDC National Frost Initiative

In 2014, GRDC formally established the *National Frost Initiative*. This runs initially for five years, with a GRDC investment of around $4.0M p.a. Frost R&D is a high priority research area for GRDC with projects in the Northern, Southern and Western cropping regions of Australia.

The focus of the Initiative is on cereals and particularly wheat, as this is the dominant winter crop in all regions, and thus underpins the sustainability of farm enterprises and farming systems. Future phases of investment in frost research will consider investment in oilseeds and pulses which are essential components of cropping systems.

Table 1: GRDC projects in the National Frost Initiative as at 1 January 2017.

Leader/ organisation	Title	Finish date
GENETICS		
Tim March (University of Adelaide; UA00162)	Screening of frost tolerance in cereals	June 2019
Rudy Dolferus (CSIRO; CSP00202)	Identification of wheat frost tolerance loci using genetic, biochemical and molecular approaches	June 2021
Ben Trevaskis (CSIRO; CSP00180)	Maintaining yield stability of wheat under spring frosts	Jan 2017
MANAGEMENT		
Ben Biddulph (DAFWA)	Advancing profitable farming systems – frost risk management	June 2019
Ben Biddulph /Brenton Leske (DAFWA; DAW00234)	Determining yield under frost - one degree at a time	June 2019
Richard Bell (Murdoch U: UMU00045)	Farming systems to improve crop tolerance to frost: Crop nutrient management	Dec 2016
ENVIRONMENT		
James Risbey (CSIRO; CMA00002)	Assessing forecast and management options for mitigating extreme temperature (frost and heat) impacts on grains	Dec 2017
Steve Crimp (CSIRO: CSP00198)	Spatial temperature measurement and mapping tools to assist growers, advisors and extension specialists manage frost risk at a farm scale	June 2019

The **Outcome** of the Initiative is for "*Australian cereal producers manipulating their farming system to minimise the impact of frost on crop yield and maximise seasonal profit*". Through the formation of the Initiative, GRDC thus invests in genetics, agronomy and management research on aspects of managing frost. Coupled with forecasting and decision support projects the initiative will deliver information and tools which are relevant tactically (i.e. within and between seasons) and strategically (i.e. systems and genetic improvement); current projects are listed in Table 1.

Achievements of the Initiative in 2016
2016 was regarded as an unusually severe year for frost across Australia. However, this must be considered against analysis to compare "frost season" length between 1960 to 1984 and 1985 to 2014; this shows that on average, there has been a 26 day extension of the "frost season" across the whole southern portion of Australia in 1985 to 2014 compared with the 1960 to 1990 long term mean (Figure 1). Recent cropping seasons (including 2016) suggest that frost will continue to be a serious problem for the grains industry in future years.

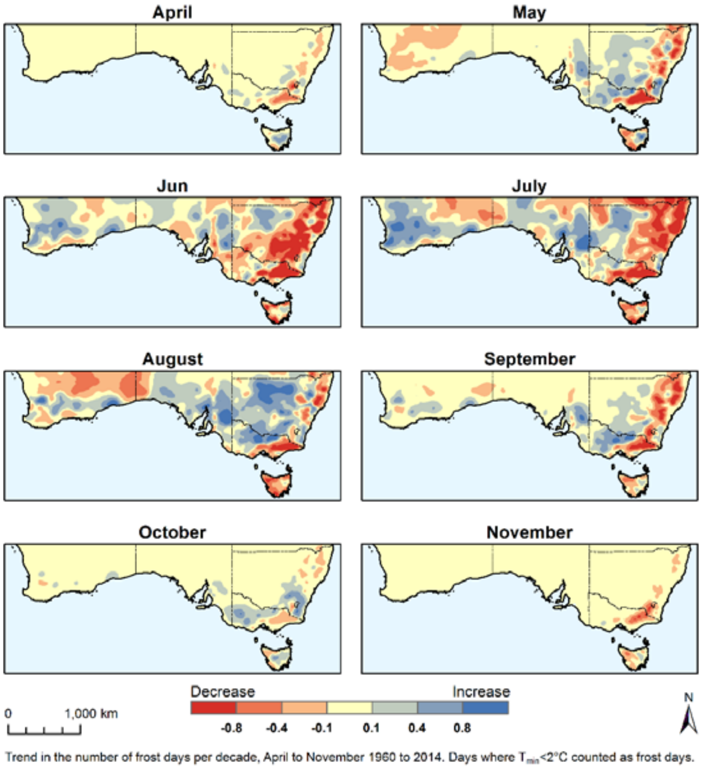

Figure 1. Broad scale changes in frost risk across southern Australia (Source: Peter Hayman, SARDI)

Genetics:
The Genetics Program has two main aims:

1. *Introduce and evaluate new germplasm*
   Current Australian cereal varieties have a relatively narrow genetic base, but a large number of landraces and varieties are available in international collections; some of these are likely to offer the potential for less susceptibility to frost, particularly at reproductive stages of growth. Material from international collections is now being imported, quarantined and multiplied, and screening of this material for susceptibility to frost in the field using standard phenotyping and genotyping methods started in 2016. Material offering superior performance to frost to current varieties and cross-breds will be made available to cereal breeding programs in Australia.

   CSIRO projects have identified improved performance of some varieties and germplasm exposed to frost in field and growth chamber studies; but does this reflect the existence and triggering of genuine frost tolerance genes? In some cases improved tolerance may be related to 'avoidance' of frost by changes in phenology and heading. Frost chamber studies are looking at a range of physiological characters in contrasting varieties, which is expected to help identify genetic markers of value to develop new, potentially tolerant varieties.

2. *Rank the frost tolerance/susceptibility of new germplasm, and current and near-release lines of wheat and barley:*
   The Frost Initiative has developed reliable phenotyping methods to identify the impact of frost on crop performance, and thus to rank the performance of new germplasm and varieties in genetic and management

trials in western, southern and northern regions. The criterion for ranking varieties is currently 'Frost Induced Sterility' (FIS), which describes the impact of frost events on floret sterility in each season at sites in all GRDC regions. The first compilation of this ranking information was released on the NVT web site in 2016 (www.nvtonline.com.au/frost); in 2017 the on-line data, and the appearance and explanatory information for the site has been improved. This ranking data comes from NFI field sites; however, high-throughput testing of susceptibility to frost in growth chambers will accelerate progress in mapping genes that influence potential frost tolerance.

Information will be continually reviewed as new varieties are released and new germplasm is developed, and a clearer understanding of the relationship between frost induced sterility (FIS) and grain yield is gained. Material with lower susceptibility to damage by frost will allow growers to:

a. sow earlier to maximise yield potential without increasing potential damage if exposed to a frost;
b. sow at current times but experience a reduction in the level of damage resulting from frost events; and
c. sow cereals in regions where the incidence and severity of current frost events precludes the economical cultivation of wheat in favour of perceived more frost tolerant crops (oats and barley).

Management:

The best genetics will be of little value if varieties are grown in frost-prone parts of the landscape, and/or use agronomic systems and inputs which may increase susceptibility to damage by frost. The *Management program* evaluates the effectiveness of agronomic and management options to reduce the impact of frost – there is much anecdotal information but little reliable field research to test management options and provide advice and tools to industry.

Research investigates pre-sowing, and in-crop management options. Pre-sowing decisions are based on landscape and knowledge of the incidence of frost, variety selection and options to blend varieties, and select appropriate agronomic/management inputs. Crop management choices include fertiliser timing and amount, row spacing and orientation, seed rate and density, products and growth regulators, grazing management, delving/claying etc. The interactions between these are complex (Figure 2), and the first research project (DAW00241 – to June 2016) identified the management factors that have a measureable influence on the impact of frost on cereals. These factors (particularly stubble management; canopy management – including timing and amount of nitrogen, and interaction with seed rate; some work on PGR's in high rainfall areas; and the value of different cereal crop types – barley, oats for grain/hay to minimise the impact of frost) are now being researched in more detail in a new project which started in July 2016. Analysis to determine the economic benefit of crop management options will also be completed to provide growers with the best information to balance cost of inputs against potential loss in yield.

Sites are chosen in collaboration with grower groups across western, southern and northern regions; trials are managed as 'extensive' (i.e. gathering information on farm to build a record of response to selected treatments) or 'intensive' (i.e. usually run with a grower group and/or research partner to gain a better understanding of mechanisms driving crop response to frost). All sites are instrumented with data loggers to record temperature at head height, and all use the standardised phenotyping methods developed in the genetics program (above) to assess the impact of frost on floret sterility and yield.

Environment program:

Climate research (via BoM, CSIRO and other providers) has quantified the severity, timing and frequency of frost events in different agro-ecological zones across Australia (e.g. - see Figure 1). However, this is of limited value within a particular season even at catchment scale, and of increasingly lesser value at farm, paddock and within paddock scales where management decisions in relation to frost are made. To manage frost risk growers need good on-farm records of minimum temperature, an understanding of temperature variation across paddocks, reliable predictions of when a crop will flower for a given sowing time, and an understanding of the potential damage caused by different temperatures. The environment program will explore tools and technologies to generate accurate, user-friendly, spatial temperature information at a resolution consistent with the scales of farm and crop management.

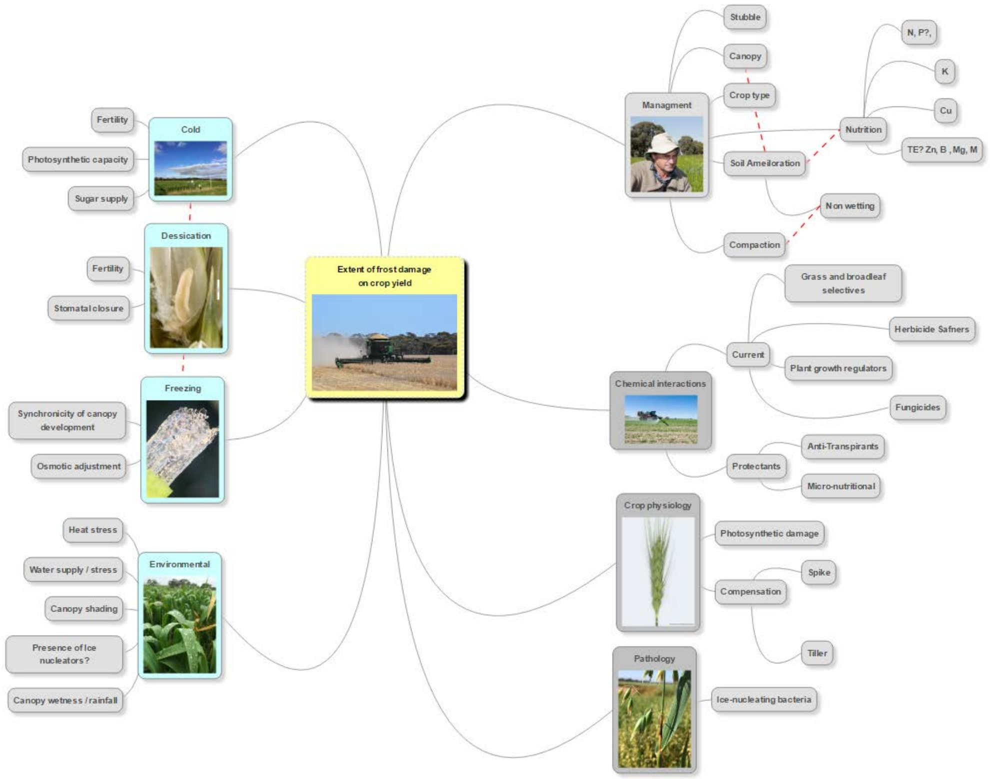

Figure 2: Management and environmental factors that influence frost damage on cereal crop yield (Source: Ben Biddulph, DAFWA)

CSIRO project CMA00002 (Assessing forecast and management options for mitigating extreme temperature (frost and heat) impacts on grains) aims to:

- Understand the synoptic patterns that cause frost in a region. This will help understand occurrence of individual frost events and clusters of events. Making sense of the climate drivers of damaging frosts will help assess if there is a basis for future prediction at a seasonal time scale. Analysing models of weather and climate and linking these to crop models are difficult tasks and progress is challenging, but is a valuable part to turn uncertainty about frost into viable risk assessment.

Project CSP00198 (Spatial temperature measurement and mapping tools to assist management of frost risk at farm scale) has three interrelated components: these are temperature mapping, rapid frost damage assessment, and temperature-damage models.

Work on these components is now underway. Ground (hand held, proximal), airborne (drone) and satellite sensors are being used to monitor the spectral and thermal response of crops affected by frost. Two years of funding will answer the following questions:

- most promising sensor/assessment method (thermal/spectral)
- most promising approach (ground/air) and economics
- when will these approaches work and how can they be used - time of day and day(s) after a frost event
- where and how to deploy (and move) temperature sensors

To effectively use genetic and agronomic solutions to manage frost, growers must be able to a) plan farming systems that minimise the risk of frost damage to crops (e.g. crop selection, time of sowing, agronomic inputs), and b) make rapid post frost-event decisions regarding the management of affected crops (e.g. cut for hay). A healthy respect for frost is rational, but growers must balance the rewards of earlier flowering against the risk of frost; being overly conservative on frost risk, by delaying sowing, can lead to increased risk of heat and water stress.

Conclusions

GRDC have established a National Frost Initiative, with GRDC funding of $4.0M p.a. to 2019. This Initiative includes tactical and strategic investments that will generate information and tools to help growers make decisions to minimise the impact of frost on cereal crops. Frost is conservatively estimated to cost the cereal industries $400M p.a. across Australia.

Genetic research imports and screens new genetic material to identify lines with potentially better tolerance to frost in Australia; the work also ranks current varieties for their tolerance to frost, and will deliver genetic tools to breeding companies to incorporate in new varieties in the future.

Management research explores agronomic and management factors that can be manipulated to lower the susceptibility of crops to damage by frost, and provide information and tools to industry;

Environmental research is evaluating synoptic patterns which describe the occurrence and risk of frost, considering the form and value of forecasting tools to raise awareness of likely frost events, and exploring effective ways to determine temperature on-farm and allow pre-season and post frost event planning to minimise losses and maximise returns.

Useful resources and references

1. *GRDC National Frost Initiative GCTV Frost Playlist on YouTube: www.grdc.com.au/GRDC-Video-NationalFrostInitiativePlaylist*
2. *Varietal susceptibility to frost - rankings (www.nvtonline.com.au/frost)*
3. *Tips and Tactics – Managing Frost risk (www.grdc.com.au/Resources/Factsheets/2016/02)*
4. *Understanding frost risk in a variable and changing climate (GRDC Grain Research Update Southern Region, June 2013, Issue 24)*
5. *Cereals – frost Identification: The Back Pocket Guide, GRDC: http://grdc.com.au/Resources/Publications/2011/03/Cereals-Frost-identification-The-Back-Pocket-Guide*
6. *Managing Frost Risk – a Guide for Southern Australian Grains (Melissa Rebbeck and Garren Knell, June 2007)*

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