Focus on frost

By Dr Juan Juttner

With frost costing growers tens of millions of dollars annually across Australia’s cropping zones, it is not surprising that frost resistance is at the top of many grain growers’ research and development wish list.

While it is unlikely that total immunity to frost can be delivered in cereals, the GRDC is making a considerable investment to reduce the frost susceptibility of Australian wheat and barley crops through a combination of genetics and crop management research.

This *Ground Cover Supplement* details the scope of the GRDC frost investment across each of its cropping zones.

A major aim of the investment is to incorporate frost-resistance traits, sourced both internationally and from within the existing Australian cereal collection, into new varieties better adapted to frost-prone environments.

The genetic research component of the GRDC frost initiative is a significant undertaking and like all pre-breeding programs will take considerable time. If suitable traits are found the plan is to start to deliver these genes to Australian cereal breeding programs by 2026 (page 4).

The objective of the initiative is to deliver wheat frost resistance at least equivalent to that of the most frost tolerant Australian barley varieties.

In the shorter term, research is underway to evaluate management practices that can be used to either avoid or lessen the impact of frost.

A range of pre-crop and in-crop management practices are being investigated, the details of which can be found in this supplement.

Stubble management (page 18) is emerging as a promising pre-crop tool to lessen the impact of frost. Preliminary research indicates that high stubble loads exacerbate frost damage by restricting the amount of heat stored in the soil and radiated into the canopy at night.

In-crop frost management practices being examined include crop grazing (page 19) and the potential for spray-on products to be used to protect growing crops from imminent frost events (page 19).

The frost management research will use the field frost measurement knowledge and capacity developed under past and present GRDC-supported frost projects including the Australian National Frost Program.

The unpredictable and sudden nature of frosts makes planning for them extremely difficult. Effective frost management will require a range of tools that enable crops to avoid, tolerate or recover from frost events.

The GRDC frost initiative will run until 2019 and has been designed to tackle frost from several angles and deliver growers a combination of genetics and management solutions. The GRDC will continue to update growers on the progress of the research projects outlined in this supplement.

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New GRDC research will focus on reducing the frost susceptibility of Australian wheat and barley varieties and developing practices and tools to better manage the impact of frost on crop yields

By Janet Paterson

ThE GRDC WILL more than double its national investment into frost research from July 2014, with funding increased to $3 million per year until 2019.

The new investment, structured to address frost research priorities identified by the GRDC’s Regional Cropping Solutions Networks, will focus on finding genetic and management solutions to frost – an issue estimated to cost Australian growers hundreds of millions of dollars each year.

The GRDC’s senior manager for discovery, Dr Juan Juttner, says the sudden and unpredictable nature of frost results in growers playing Russian roulette each season as they balance the need to sow early to reach yield potential with the risk these crops will encounter a spring frost during flowering and early grain-fill.

“Frost risk tends to drive a conservative sowing strategy, resulting in lost yield potential in later-sown crops that do not encounter a spring frost,” Dr Juttner says.

Research has confirmed that in many areas the ‘frost window’ is ending later in the season, increasing the exposure of cropping systems to frost risk.

“This was particularly evident in the 2013 growing season, with Queensland, New South Wales and Victoria being hit by several severe frosts in mid-October – a period when frost risk is traditionally on the decline,” Dr Juttner says.

The new frost research will have three components: genetics, management and environment.

FROST GENES
Dr Juttner says the frost genetics work will involve a two-pronged approach. Plant breeding tools will be developed to shift Australian cereals towards the more resistant end of the frost spectrum and additional frost genetics will be sought internationally to develop more frost-tolerant varieties.

“A major focus of the genetics research will see cereal germplasm imported from all over the world and tested for its frost resistance under Australian conditions,” Dr Juttner says.

“The ultimate goal is to identify frost genes that can be incorporated into Australian wheat varieties to increase their frost resistance.”

FROST MANAGEMENT
The new frost investment will also investigate if there are preventive products, stubble and nutrition management practices or other measures that growers could implement to reduce the impact of frost.

“We will be examining the capacity of in-season and pre-season options to better manage frost impact, with a focus on stubble and grazing management as well as nutrition and plant growth regulators.”

Dr Juttner says there is evidence from Western Australian research that retaining stubble has an effect on frost severity, with preliminary research indicating that reducing stubble could increase the heat radiated from the ground overnight, keeping the crop warmer.

he says there is also interest in using growth regulators to delay flowering in the face of a frost risk.

A product that could be applied by boomspray and which remained effective for five to seven days would be widely taken up by Australian growers.

“But we are a long way off even knowing if such a product exists and, if so, whether it is cost-effective in a broadacre context,” Dr Juttner says.

ENVIRONMENTAL PREDICTION
The third component of the new frost investment will focus on predicting the impact of frost events on crop yields across Australia and mapping frost events at the farm scale to enable better risk management. New research will investigate the use of in-paddock temperature loggers so that soils can be mapped for temperature differences during frost events.

“Knowing the location and severity of frost events in the landscape enables growers to plan plantings and make post frost decisions accordingly.”

– DR JUAN JUTTNER

GRDC Research Codes ICY47, PFS36, ICY49
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Frost gene search turns international

New GRDC research will access international germplasm banks for frost genetics of use in Australian crop varieties

By Dr Juan Juttner

The COmm ON SAy ING in business that 'you can’t manage what you don’t measure' applies equally to the business of frost management in cropping systems. However, until recently, a consistent method had not been applied to the measurement of field frost damage in wheat and barley in different regions, making it difficult to compare frost results. Since 2008, the GRDC has focused frost research on the development of a nationally consistent and coordinated system for measuring field frost damage in wheat and barley. The development and implementation of a national system is currently the responsibility of the GRDC-funded Australian National Frost Program (ANFP), led by the University of Adelaide in collaboration with the Department of Agriculture and Food, Western Australia (DAFWA).

ANFP researchers have spent the past three years applying an identical method to measure frost tolerance in wheat and barley across Australia. The program has been a massive undertaking — spanning the three GRDC growing regions and requiring millions of individual measurements in synchronised field trials across Western Australia, South Australia and New South Wales.

Leader of the western region node of the ANFP, Dr Ben Biddulph says the similarity between ANFP field trial results to date and grower experiences with some varieties over many seasons of cultivation provides confidence to apply the method to the search for cereal germplasm with higher frost tolerance. “We can screen germplasm and breeding lines for frost tolerance in different regions and be confident that the results are accurate and comparable. We can also apply the method to the identification of A Selection of material from international germplasm banks.

B Importation and quarantine.

C Genotype material, select maximum diversity and phenotype for frost resistance equivalent or better than regional barley benchmarks.

D Material with increased frost tolerance rapidly introgressed into nested association mapping (NAM) populations based upon regionally adapted germplasm. Lines phenotyped and markers associated with resistance identified.

E Frost resistance of derived NAM lines validated in large-scale, replicated regional frost trials.

F Breeders access NAM lines and markers to develop varieties with increased frost resistance.
of enhanced germplasm with improved tolerance and to develop molecular markers for tolerance and deliver these to breeding companies to support the development of varieties with reduced frost susceptibility.”

**FROST ALERT**

Spring frosts have awoken Dr Biddulph before 4am more than 80 times in the past four years, as automatic weather station equipment installed at his western region ANFP node has triggered an alert to his mobile phone whenever canopy temperatures have fallen below 2°C.

The early morning alerts have allowed Dr Biddulph and his research team to tag flowering wheat and barley plants immediately after a frost event and then follow these plants through to assess the level of frost damage.

The tagging system was replicated across all Australian ANFP research sites.

“Following a frost event, we dissect wheat and barley heads within each plot to determine if the plants are at the flowering stage,” Dr Biddulph says. “If they are flowering we tag a minimum of 30 flowering heads within each plot and inspect these again at mid-grain-fill to quantify the number of sterile florets within each head.”

From this measure of sterile florets the relative frost tolerance of each breeding line and crop variety in the program is determined.

“One of the issues with past frost research was that measurements were taken at different stages of crop development, making it impossible to compare data from different regions and across different events with any degree of confidence,” Dr Biddulph says.

“Frost tolerance changes throughout the life of a crop, so measuring plants at the same stage of development is critical to achieving comparable results,” Dr Biddulph says.

The current system is accurate across different environments because the measurements and tolerance comparisons are performed at the same developmental stage, regardless of the variety or when it was sown.

**EVALUATION OF LINES NEARING COMMERCIAL RELEASE**

Since 2012, wheat and barley lines entered into the National Variety Trials program are also being evaluated by the ANFP to determine how floret fertility is affected by frost. The program will assess 30 varieties of wheat and 20 varieties of barley each season to generate information on the relative level of sterility of each line over several seasons and frost events and ultimately how these events impact on yield.
Gene mix and match to lift frost tolerance

New research aims to determine the best gene combinations to lift the frost tolerance of Australian wheat varieties

By Janet Paterson

Before flowering many winter wheats are tolerant of extremely low temperatures, down to minus 20°C in some cases, however, after head emergence wheat suffers severe damage at much milder temperatures (minus 4°C).

CSIRO scientist Dr Ben Trevaskis wants to identify gene combinations that enable wheat to maintain yield potential under frost – and he is prepared to search the entire Australian wheat genome to find them.

“The aim is to identify combinations of genes and traits that help wheat to either avoid or tolerate frost or recover lost yield potential following frost damage.”

Dr Trevaskis has a valuable genetic resource available to help achieve the task – a special wheat population that is virtually identical genetically except for flowering behaviour.

“As the wheat plants differ only in flowering time and length we can get a really clear handle on how flowering traits interact with environmental conditions – including frost,” Dr Trevaskis says.

Dr Trevaskis will grow the wheat plants in trials across the GRDC cropping regions and identify the flowering characteristics that help wheat to avoid or tolerate frost.

“We will also be looking for plants that are able to compensate for frost damage by producing larger or additional grain in response to losing florets and grain to frost.”

Flowering-trait genes showing promise under frost will be captured...
Frost genetics

New research will unravel the genetics behind frost avoidance, tolerance and compensation in wheat. Using two specialised wheat populations grown across each GRDC cropping region, the research will identify the flowering characteristics that help wheat to either avoid or tolerate frost. It will also identify wheat traits that help compensate for frost damage by producing larger or additional grain in response to losing florets and grain to frost. Results of the research will be delivered to plant breeding companies.

via molecular marker technology and fed back to breeding companies for incorporation into new wheat varieties.

“We will also feed the best 10 lines into the Australian National Frost Program for detailed testing using their frost damage measurement system.

“We want to identify the optimum flowering-time genes for frost avoidance across Australia’s agro-ecological zones and also those combinations of genes that enable wheat plants to tolerate or compensate for frost events, such as those associated with spike length, tiller number and plant height.”

FROST TOLERANCE

Dr Trevaskis says there is a treasure trove of mutations within cereal flowering-time genes that have faced natural selection over millions of years.

“There is strong evidence that the genes that control flowering in response to cold also influence frost tolerance, with frost tolerance declining as plants prepare to flower,” Dr Trevaskis says.

For example, wheat varieties bred for the cold areas of northern Europe and North America are extremely frost tolerant in winter, during vegetative growth, but lose this frost tolerance once they start to flower in spring.

“We want to find ways to maintain frost tolerance during flowering by examining how flowering behaviour interacts with the genetics of frost tolerance.”

Dr Trevaskis is also using the CSIRO four-way multiparent Advanced Generation Inter-Cross (mAGIC) wheat population to investigate whether combinations of traits can improve yield stability in frost-prone regions.

“The mAGIC population randomly shuffles all the traits from four elite Australian wheats into a population of test lines,” Dr Trevaskis says.

Dr Trevaskis will measure the yield stability of the mAGIC lines across different sowing times at frost-prone sites in New South Wales and Western Australia.

“The hope is to identify trait combinations such as spike length, flowering time and tiller number that provide greater yield stability following frost events in each of the regions.”

The mAGIC population enables genes underlying specific traits or trait combinations to be linked to molecular markers, which can then be used to accelerate the development of new wheat varieties.

Any lines that perform well under frost will be put through rigorous testing at a third site in Toowoomba, Queensland, by research collaborators Dr Troy Frederiks and co-workers at the Queensland Alliance for Agriculture and Food Innovation.

“This third test site is an important part of the project because different regions have different types of frost and we want to be sure that any potential genetic solution for frost during flowering holds up across multiple environments,” Dr Trevaskis says.

The Toowoomba trials will use a special artificial light method to coordinate the flowering of different wheat varieties in the field.

“By synchronising flowering we can determine whether differences in frost tolerance are due to intrinsic genetic differences or because the plants are avoiding frost through flowering time.

“We can also determine how the different wheat lines compensate for yield lost to frost at flowering through changes in grain size or tiller number.”

GRDC Research Code CSP00180
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Frost risk on the rise despite warmer climate

An increase in the number of frosts later in the season means more growers are reassessing sowing dates and varieties

IT IS A cruel paradox that although Australia’s climate is warming, the number of frost days and the length of the frost season have increased across much of the Australian grainbelt (Figure 1).

CSIRO analysis of climate data between 1960 and 2011 suggests the increasing frost incidence is due to the presence of more highs centred further south (37.5°S) and further west (125°E) and to the existence of more El Niño conditions during this period. CSIRO climate application scientist Dr Steven Crimp says the southern shifting highs bring air masses from further south than in the past. This air is very cold and leads to extensive frosts.

“We think this so-called ‘southward displacement’ is what is driving the changing frost patterns,” Dr Crimp says. Modelling work indicates that the increased incidence of frosts in August is likely to remain around current levels until the mid-2030s. “By gaining a better understanding of
A new two-year research project will quantify the severity, timing and frequency of frost events in different agro-economic zones across Australia. The University of Queensland’s Queensland Alliance for Agriculture and Food Innovation (QAAFI) project leader Dr Jack Christopher says the ultimate goal of the new project is to quantify the direct and indirect yield losses associated with frost across each of the GRDC growing regions to better inform research investment.

“Frost causes direct and indirect yield losses,” Dr Christopher explains. “We want to quantify these for each region to guide research investments chasing frost avoidance versus frost tolerance and resistance.”

Data collected from nearly 3000 weather stations across Australia will be used to analyse the frequency of frost events in each cropping region.

“We will also use the frost damage and climate data collected at research sites in past years to determine the minimum temperature required to produce frost damage in each of the major cropping regions,” Dr Christopher says.

The resulting crop damage thresholds will be used to quantify yield reductions due to direct frost damage and these, combined with indirect yield losses from late sowing, will be used to estimate the total economic impact of frost in each region.

By quantifying the economic impact of frost the potential impact of research into improved frost management and genetic frost resistance can be estimated.

“Using this information we can then estimate the likely economic return from a research investment achieving a 1°C, 2°C or 3°C improvement in genetic frost resistance.”

Along with an increased incidence of frosts between August and November there has also been a shift to frost occurring later in the year. “many people think the increase in frosts is due to dry conditions, but frost events over the past decade have included some very wet years,” Dr Crimp says. “Even though we are in a warming trend, we have this surprising change in frost risk. In the east, the window of frost occurrence has widened, so frosts are occurring earlier in the season and much later in the season. As we move to the west there is less occurrence of earlier frosts and it is more of a shift to frosts later into the season.”

The frost window has lengthened by three weeks in the Victorian grainbelt and by two weeks in the New South Wales grainbelt. Western Australia has, statistically, remained the same, while eastern South Australian sites are similar to Victoria, and sites in the west of SA are more like WA.

Northern Victoria seems to be the epicentre of the change in frost occurrence. Analysis of long-term temperature data for longerenong in the Victorian Wimmera indicates the incidence of moderate (2°C) and extreme (0°C) frosts during the wheat flowering window has increased in the past 15 years (Figure 2).

Dr Crimp and his team found the frost window over much of northern Victoria had lengthened considerably in the decade to 2011. “If you look at the risk of experiencing a 2°C minimum temperature event, the 10 per cent risk now occurs 46 days later than in any of the previous decades. The frost window over this past decade has been much wider than farmers have experienced before.”

**Figure 1** Regions of increasing August to November frosts.

**Figure 2** Historic number of frosts in flowering window 20 September to 30 October, Yitpi\(^2\), Longerenong, Victoria.

**GRDC Research Codes MCV00010, UQ00071**

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Identifying frost in wheat

In the event of severe frost, monitoring needs to occur for up to two weeks after the event to detect all the damage. Accurate assessment of frost damage can help with decisions about whether and when to cut for hay or leave for grain harvest. An inspection five to 10 days after the frost event will reveal whether grain development has been affected.

PHOTOS: DR BEN BIDDULPH

**FROST-DAMAGED HEADS**

Cold conditions and frost can damage florets during booting and render them sterile.

**EMERGING WHEAT HEAD**

A frost-damaged floret on an emerging head. Exposed florets cannot tolerate low temperatures and will usually be sterile.

**HEALTHY DEVELOPING GRAIN**

Peel open the floret and inspect the developing grain. Healthy developing grain is light to dark green, plump and exudes a white milky dough when squeezed. Frosted developing grain is white, turns brown and has a dimpled and crimped appearance.
If affected, the heads will feel soft and spongy when squeezed between thumb and forefinger. It is important to note that frosted paddocks can contain all of the symptoms detailed below because earlier cold damage may go undetected until a serious frost prompts a paddock inspection.
Grain growers in some frost-prone areas of Western Australia celebrated the 2013 season without a damaging cold snap. But long-term trends indicate frosts are becoming more frequent and growers in the region need to actively manage for potential frosts each season.

With SI x OF the past 10 years delivering frosts significant enough to wipe out a large proportion of Western Australian crops it is no surprise that most growers in the region rank frost management at the top of their research, development and extension wish list.

As president of the local Facey Group, Tincurrin, WA, grower Wade Hinkley keeps a close eye on research – especially frost research.

Wade says his ideal frost-prevention toolkit would include a practical strategy to help make ‘hay or harvest’ decisions for frosted paddocks, rather than relying on visual assessment to gauge if crops are still growing.

“We had a really bad frost in September 2012 and lost 50 per cent yield in some paddocks,” he says.

The extent of the frost justified the family decision to diversify into export hay several years ago as a means of frost-proofing his 4000-hectare mixed enterprise 250 kilometres south-east of Perth.

“We baled the worst of the frosted wheat, which tripled our returns compared to the areas we left to harvest.”

Although hay offers an alternative market and helps drought-proof their livestock the family also relies on a ‘prevention’ strategy based on variety selection and management.

They use the Department of Agriculture and Food, WA, online tool Flower Power calculator to identify varietal seeding dates to target optimal flowering. Grazing is sometimes used to manipulate flowering until after the frost period. Other frost-management strategies include:

- thermal imaging, which has identified a 3ºC to 4ºC difference in minimum temperatures between paddocks, guiding where frost-sensitive varieties are planted;
- planting frost-prone paddocks last to help avoid the high-risk frost period;
- using paddock records to monitor frost history; and
- planting according to frost-prone areas, such as concentrating pasture crops and hay varieties on sandy zones and around creeks.
FARMING FRUSTRATION

Peter Roberts identifies frost as his most frustrating farming challenge, but the WA grain grower says he is optimistic research is edging closer to delivering wheat varieties that are more resistant to these extreme cold snaps.

Rather than sow crops later and take a hit on yield potential, Peter today sows a range of crops and varieties with differing flowering times.

On low-lying parts of the farm he sows barley and oats. Where wheat is grown on frost-susceptible areas, the later-flowering variety Yitpi is preferred. He has tested Fang wheat in small plots, but found its growth period too long for his environment.

“As growers, we often sacrifice yield to mitigate the damage that frost could potentially do to our crops by sowing later and with less profitable cultivars, such as oats, on frost-prone sites,” he says.

Instead, Peter has sought to maximise yield from the same level of inputs by sowing early with effective weed control.

Rather than wait for the seasonal break, Peter adopts a sow-by-the-calendar approach, planting dry and using technologies that allow him to chase weeds. Two examples of available technology are Clearfield® wheat and barley and Roundup Ready® canola. In 2011, he bulked up new Intervix®-tolerant varieties of wheat and barley.

“The biggest driver of higher yields is time of sowing,” he says. “Crops have to be in the ground early.”

In an effort to improve farm profit in high-rainfall areas is integrating crop and livestock systems through grazing canola and grazing cereals, which has been validated through the GRDC’s investment in Grain & Graze 2.

“It can take guts to open the gate on a bulky canola or wheat crop,” he says. “But we can do this with our current best adapted varieties. All that’s needed is the opportunity to sow early, have good weed control and then graze them hard. This allows more crop to be grown other than by reducing stock numbers.

“Studies so far have shown there is very little decrease in yield, usually an increase in protein and the extra benefit of being able to push back the flowering window, which also helps in managing frost.”

GRDC Research Codes UWA00160, DAW00234, DAW00162

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‘HAY OR HARVEST’ TOOL

New ‘proof-of-concept’ research planned for 2014 will investigate the possibility of using remote sensing technology to detect frost damage in wheat and the likelihood of these damaged crops going on to yield sufficient grain.

If a tool, based on the potential method, could be developed it would help growers decide how much of a frosted crop to cut for hay or grain.

The goal is to combine biomass and yield estimates via satellite or aerial imagery with a measure of frost damage collected via grower records and yield mapping data. Using this information researchers will then attempt to calculate a frost-induced yield map.

Growers with yield mapping capabilities will be approached to identify at least five paddocks in which wheat has previously suffered frost damage.

A further five non-frosted paddocks close to the frost-prone paddocks will be selected as controls. The 10 paddocks will then be mapped using satellite imagery and yield maps. From these, the relative yield impact of frost-induced stress will be calculated.

Satellite images with 28 metre by 28 metre spatial resolution will be obtained for the time points immediately before and in the weeks following the defined frost events.

A range of analytical procedures will then be assessed for their capacity to predict the yield of frosted paddocks.
Late frosts cause southern concern

By Janet Paterson

IN THE PAST decade, frost days in southern Australia have occurred 20 to 46 days later than in the 1950s.

Grenfell, New South Wales, grower Rob Taylor says late frosts have caused extensive yield losses in 2009 and more recently in 2013.

SIGNIFICANT DAMAGE

Yield losses following the 2013 October frosts were significant and the worst that Rob has experienced – ranging from 50 to 95 per cent damage.

“All the crops were looking so promising during the winter and early spring, which encouraged us to apply extra nitrogen, which, in the end, cost us money.”

A shortened spring added to the frost damage because there was very little surface soil moisture to buffer the effects of the late frost. Crops with the highest yield potential were harvested for grain while the worst wheat paddocks were cut for hay.

“The canola crops were too far advanced to make decent quality hay, so we harvested them instead but their yields, oil and test weights were all very ordinary,” Rob says.

“Hyola 559 was the worst performing variety and a complete write-off.”

FROST RISK

“Frost has always threatened crop production in our region and it seems late frosts are becoming more frequent,” Rob says.

The three 2013 frosts hit the Taylors’ property within the week commencing 15 October, with canopy temperature dropping as low as minus 5°C on each occasion.

“The crops were well past the flowering stage with most between half to full grain formation, and three frosts at such low temperatures really smashed further development, causing stem flow to stop and the grain to simply wither up.”

Grain crops are particularly sensitive to frost at grain fill, with anything from a 40 to 80 per cent yield loss possible. Most of the Taylors’ farm is situated on valley floors, resulting in a relatively flat to slightly undulating topography and an elevation ranging from 350 to 365 metres.

“Because we don’t have any hills, the colder air associated with frosts definitely seems to drain toward the lower paddocks and we manage our cropping program accordingly to minimise potential frost damage.”

MANAGING FROST

The Taylors use a wide spread of planting times, crop type and varietal maturity to avoid crops flowering in the greatest period of frost risk.

“But late frosts are the difficult ones to manage as they occur well past the flowering stage and can damage crops of all maturity regardless of the sowing date.”

Sowing extremely late is not a viable option for frost avoidance, as the yield loss incurred every year would not counter the
Late frosts are becoming more prevalent on Rob Taylor’s property in Grenfell, NSW. GRDC-funded research hosted by the Taylors is evaluating how physical traits such as spikelet length and awn type interact with frost events across a range of sowing times.

Photo: Rob Taylor

damage from the occasional late frost.

“We tend to zone our farm, with the lowest country usually planted to grazing cereals, which seem to be much more frost tolerant,” Rob says.

The Taylors are mixed farmers. Sixty per cent of the farm is winter-cropped with cereals, canola and pulses and the remainder grazed with lucerne-based perennial pastures.

“Thankfully the grazing enterprise is immune to the impacts of frost, which certainly helps in a year like 2013 and reinforces the value of mixed farming and spreading the risk.”

having a commercial hay enterprise in their farming mix means the Taylors have hay-making equipment on hand to use when wheat crops hit by frost need to be cut for hay.

Data-logging temperature sensors in the crop canopy are increasingly being used to monitor frost on the Taylors’ farm.

“They are relatively inexpensive and certainly help us to make timely decisions about cutting crops for hay before quality declines,” Rob says.

ON-FARM FROST RESEARCH

The Taylors hosted a large GRDC-funded frost trial on their farm in 2013 to evaluate a range of genetic material for yield stability under frost.

“The trial is examining whether traits such as spikelet length and awn type can help wheat avoid frost impact.”

Results so far suggest some traits might enable wheat to compensate for frost damage, with the awnless types seeming to perform better following frost.

“The very early-sown varieties seem to handle the late frost the best, with one particular European variety with a waxy cuticle performing quite well across all the sowing windows.”

FROST WISH LIST

Not surprisingly, high on Rob’s frost research wish list is the development of varieties with genuine frost tolerance across a range of sowing dates.

“We hear a lot of negative publicity about genetically modified crops but if frost resistance genetics could be plugged into our best-performing cultivars it would be a fabulous outcome,” Rob says.

Rob would also like to see more research into the physical traits that enable grains such as oats and barley to be more frost tolerant than wheat.

“Spikelet length and the distance between the flag leaf and head are worthy of further work, particularly with the incidence of late frosts becoming more common.

“There is also some evidence of frost damage being worse in retained stubble which needs closer investigation.”

GRDC Research Code CSP00180

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Frost curbs early sowing in north

Northern region growers often miss sowing opportunities in April and May to avoid the high risk of flowering cereals encountering frosts in July and August

By Janet Paterson

PARADOXICALLY, CROPS GROWN in warmer climates, such as Australia’s northern cropping region, are at greater risk of frost injury because they develop faster, increasing the risk of heading and grain fill coinciding with frost.

The University of Queensland’s Queensland Alliance for Agriculture and Food Innovation frost researcher Dr Jack Christopher says while July and August are theoretically the optimum flowering months for northern region crops they are also the region’s highest frost-risk months.

“Long-term climate data shows there are typically multiple severe frosts in July and August so growers need to delay crop sowing to ensure they flower after this high-risk period,” Dr Christopher says. (See Figure 1.)

However, delaying flowering costs growers considerable yield potential and, even under best management, crop losses due to frost are estimated to average about 10 per cent in the northern region.

“Frosts across southern Queensland and northern New South Wales in late August 2013 caused significant damage, particularly on the Western Downs,” Dr Christopher says.

FROST-TOLERANT CEREALS

Development of wheat and barley varieties with higher frost resistance is therefore a high priority for the northern region.

“If we had access to varieties with higher frost resistance we could sow earlier and reap more of the region’s yield potential,” Dr Christopher says.

Yield potential of northern cereals drops rapidly after the optimum flowering date in July–August, by one to two per cent per day. But until more-resistant varieties are available frost avoidance is the only option available to growers to manage frost risk.

Dr Christopher says variety guides and decision-support tools can help growers...
match the best time for planting varieties to optimise yields with an acceptable frost risk. “There is little useful difference in frost resistance between current cultivars, so choosing the variety with the optimum flowering date for a particular sowing opportunity is much more important,” Dr Christopher says. 

he recommends that northern growers:
- use several cultivars and planting dates to spread the frost risk;
- determine the correct sowing window for the district for each cultivar;
- consider early sown cultivars with a longer growing season when favourable seasonal conditions are expected; and

**WEATHER TRENDS**

Severe frosts are common on northern grower Brian Gibson’s cropping property in Dulacca, Queensland. “We can lose half our yields to frost and grain quality can drop from Prime Hard to Feed overnight,” Brian says.

Over the past decade, Brian has observed a trend towards warmer weather from May to June, which induces wheat to head sooner, exposing it to frost risk in August. “Thermometers at head height monitor minimum temperatures, giving us a good indication of where the frost line is. We plant above this line on the elevated country, which is usually 2°C to 3°C warmer than lower areas, and select slower varieties with a longer coleoptile length if we have to moisture-seek, as these will flower after the frost risk has passed.”
STUBBLE LIFTS FROST SEVERITY

Tactical management of stubble loads in high-frost-risk areas could help mitigate the impact of frost on crop yields

By Janet Paterson

RESULTS FROM FROST trials in the Western Australian wheatbelt in 2012 and 2013 indicate that high stubble loads can increase the severity and duration of frost events.

New GRDC-funded research planned for 2014 will continue to investigate the relationship between stubble load and frost impact on crop yield.

Project leader Dr Ben Biddulph says stubble appears to insulate the soil surface, which lowers the amount of heat absorbed into the soil compared with paddocks without stubble.

“We also think less heat is radiated from the soil in stubble paddocks at night, which lowers the canopy temperature and leads to greater frost severity, duration and damage.”

In a 2012 trial at Wickepin, WA, with the Facey Group, yields of mace wheat were 0.7 tonnes per hectare higher in burnt stubble high in the landscape (where there was moderate frost risk) and 0.3t/ha higher in burnt stubble lower in the landscape where the frost risk is higher (Table 1).

“Wheat in the stubble sections appeared to have a higher frost-induced sterility than wheat on burnt stubble but we need to do more work to fully understand the relationship between stubble load, frost and yield loss,” Dr Biddulph says.

Similar trials at Nyabing, WA, with the Nyabing Farm Improvement Group in 2013 showed significantly higher frost-induced sterility and almost non-existent yields on plots with high stubble loads (more than 3.5t/ha) following a severe frost on 10 October.

“Wheat in the high stubble plots had almost 85 per cent sterility, while plants beyond the stubble had 20 to 30 per cent sterility, indicating that the high stubble load increased the frost damage,” Dr Biddulph says.

Temperature data showed substantially colder temperatures in plots with high stubble.

A yield map of the research trial exposed large ‘edge effects’ of stubble on yield, independent of elevation.

However, in the absence of frost, plots with low stubble loads had less biomass and lower yield potential than higher-stubble plots.

Stubble load: Impact of stubble load on frost severity and duration.

Stubble architecture: Impact of standing versus horizontal stubble on frost severity and duration. Previous research indicates that standing stubble with small amounts of horizontal residue results in higher minimum soil temperatures (by about 0.8°C to 1°C) than low-cut stubble with more horizontal residue.

Stubble and crop row orientation: Sowing in an east-to-west direction results in more soil shading, but the effects on soil temperature and frost are largely unknown. This trial will determine whether sowing and stubble direction can be used to manipulate frost incidence and severity.

Stubble composition and colour: Soil colour is thought to have a significant effect on frost severity, with lighter-coloured soils generally more prone to frost events. This trial will examine whether stubble colour and composition also affects frost severity.

Crop architecture: This trial will compare ‘skip row’ seeding with conventional seeding to determine if wider rows enable more heat to be stored and released from the soil (less frost) and if they improve cold air drainage out of the canopy after a frost event.

TABLE 1 Yield and yield component data for Nyabing. Where frost induced sterility (FIS), harvest index (HI) 100 grain weight (100GW) and screenings <2mm were measured. Values are the predicted means, n=3, estimated using linear mixed models.

<table>
<thead>
<tr>
<th>Position</th>
<th>Stubble</th>
<th>Low landscape</th>
<th>High landscape</th>
<th>LSD0.05</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Additional</td>
<td>Standing</td>
<td>Removed</td>
</tr>
<tr>
<td>Stubble biomass in August</td>
<td>3.5</td>
<td>2.6</td>
<td>0.5</td>
<td>2.6</td>
</tr>
<tr>
<td>Average minimum canopy temperature during September-October frosts</td>
<td>−2.4</td>
<td>−2.0</td>
<td>−1.8</td>
<td>−1.1</td>
</tr>
<tr>
<td>Hours below zero</td>
<td>45</td>
<td>33</td>
<td>32</td>
<td>22</td>
</tr>
<tr>
<td>Yield (t/ha)</td>
<td>0.6</td>
<td>1.0</td>
<td>1.8</td>
<td>1.9**</td>
</tr>
<tr>
<td>FIS (%)</td>
<td>87</td>
<td>33</td>
<td>35</td>
<td>20</td>
</tr>
<tr>
<td>Screenings (%) &lt;2mm</td>
<td>56</td>
<td>9</td>
<td>9</td>
<td>13</td>
</tr>
</tbody>
</table>

*Additional stubble plot was unreplicated and was only located low in the landscape.
**Yield estimated from small plot trial harvester cuts with two replicates per plot.

PLANNED STUBBLE–FROST RESEARCH

A series of large-scale trials in 2014 will further investigate the impact of stubble on frost severity and duration. Precision agriculture equipment will be used to sow and harvest the trials to develop detailed yield maps of the trial sites. Following frost events, treatments at flowering stage will be tagged and monitored during grain fill for frost-induced sterility. Trials will cover the following topics.

GRDC Research Codes DAW00234, SDI00019

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CROP GRAZING COULD REDUCE FROST RISK

Crop grazing is the only in-crop agronomic practice currently available to influence flowering time.

Photography: GRDC

The use of crop grazing as an in-crop frost management tool will be explored further in new GRDC-funded research planned for 2014-15.

Trial work in 2012 by the GRDC Regional Cropping Solutions Network (Albany) indicated simulated grazing could delay flowering time in wheat and that this might be a way of avoiding frost damage once a crop is in the ground.

The delay in flowering time was equivalent to half the time grazed, with a two-week ‘grazing’ period delaying maturity by one week.

In 2014-15 the grazing research will be replicated in frost and frost-free sites in Western Australia so that the economics of grazing value for frost avoidance versus yield loss from grazing can be determined.

Frost damage will be measured using the frost damage measurement system of the Australian National Frost Program.

If found to have a positive impact on mitigating frost, the grazing research will be replicated across all GRDC cropping regions in low, medium and high-frost-prone areas.

PLANT GROWTH REGULATORS

A proof-of-concept research trial planned for 2014-15 will examine the potential of several promising chemical compounds to protect flowering wheat from spring frost damage.

Wheat plants will be grown in pots outdoors at a density of about 150 plants per square metre and watered and fertilised as required.

Groups of plants will be exposed to frost conditions (in a frost chamber) at either one of four stages of development: flag leaf, post-heading, flowering and grain filling. At least three days before frost exposure plants will be treated with each chemical candidate.

Frost events of the duration of one, two or four hours will be applied at temperatures of minus 6°C, minus 4°C, minus 2°C or 0°C in a freezing chamber.

Frost exposure will occur at between 4am and 6am to best simulate conditions occurring in a real field situation. Following frost exposure plants will be returned outdoors. Visual assessments of treated plants will occur in the following weeks until seed maturation.

At complete seed maturation total aboveground plant biomass, biomass of reproductive organs and total seed output will be measured from individual plants exposed to frost events.

If found to have a positive impact on mitigating frost, the grazing research will be replicated across all GRDC cropping regions in low, medium and high-frost-prone areas.

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