NORTHERN
SEPTEMBER 2018

GRDC™ GROWNOTES™

GRDC™ GRAINS RESEARCH & DEVELOPMENT CORPORATION

BARLEY

SECTION 14

ENVIRONMENTAL ISSUES

FROST ISSUES FOR BARLEY | SOIL MOISTURE ISSUES FOR BARLEY

SECTION 14

Environmental issues

More information

GRDC Back Pocket Guide: Cereals: Frost Identification at https://www.grdc.com.au/~/media/922066B41721409E9EFC6014A333769B.pdf

GRDC Farmer Advice: Managing Frost Minimising Damage at http://www.grdc.com.au/uploads/documents/frost.pdf.

http://www.grdc.com.au/Research-and-Development/GRDC-Update-Papers/2015/03/Whats-going-on-with-frost

14.1 Frost issues for barley

In the northern grains region, production losses due to direct frost damage in wheat and barley are estimated at AU$100 million/year. Direct losses are kept at this level only by delaying flowering every year, resulting in additional production losses well in excess of those due to direct frost damage. [1]

In 2014 the GRDC set up the National Frost Initiative (NFI) which to run over five years tackling frost from several angles using a combination of genetic and management solutions with tools and information to better predict frost events.[2]

Frost damage reduces crop yield and grain quality. Early identification of symptoms allows timely crop salvage decisions to be made.

Barley and oat crops can tolerate lower temperatures than wheat. This is due to the structure of plant parts and the way that the plant develops. In barley, flowering occurs close to the boot, offering protection to anthers against frost. The sterility of florets leads to absence of grains, and stem frost is rare.

Inspect cereal crops between ear emergence and late grain-filling if night air temperature (recorded 1.2 m above-ground) falls below 2°C and there is a frost. Check low-lying, light-coloured soil types and known frost-prone areas first, then check other areas.

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

To identify frost damage, open the florets and peel back leaves on plants to clearly see the plant parts that are affected. A magnifying glass and fine tweezers or a needle can be useful. [3]

For information on sowing times for managing frost risk, see *Section 3: Planting*.

14.1.1 Frost resistance in cereals after head-emergence

Spring radiant frost damage to cereals post head-emergence causes significant crop losses in Australia and internationally. The problem arises in areas where the heat and drought of summer restrict the cropping season to winter and spring. Typically, during the growing season, daytime temperatures are ideal for growth but night-time temperatures can fall to potentially damaging levels. Wheat can be affected when the canopy air temperature reaches -3.5°C (D Woodruff unpublished data), with damage increasing as the temperature falls further (Woodruff *et al.* 1997). Barley is generally considered more resistant than wheat, whereas triticale appears less tolerant.

To lower the risk of frost damage, winter cereals are planted ‘late’, so heading and grain development occur when warmer temperatures prevail. Unfortunately, this delay

1 Farmer Advice, Managing Frost Minimising Damage, GRDC. http://www.grdc.com.au/uploads/documents/frost.pdf

2 http://www.grdc.com.au/Research-and-Development/GRDC-Update-Papers/2015/03/Whats-going-on-with-frost#sthash.Y1ltvO2f.dpuf

3 C White (2000), Back Pocket Guide: Cereals: Frost Identification, GRDC June 2000. https://www.grdc.com.au/Resources/Bookshop/2012/01/Cereals-Frost-Identification-The-Back-Pocket-Guide-GRDC416

increases the likelihood of drought and high temperatures during grain-fill, dramatically reducing yield potential. Yield declines of as much as 16% for each week that flowering is delayed past the optimum time have been reported (McDonald *et al.* 1983; Woodruff and Tonks 1983). In the long term, optimum flowering time and maximised yields are achieved , when a compromise between the effects of frost and drought is reached (Woodruff and Tonks 1983).

On nights when still, cold air, clear skies, and low humidity combine, temperatures drop rapidly, resulting in radiant frost. Freezing of crops is a physical process moderated by factors such as plant development stage (Single 1964) and temperature. The crop temperatures experienced and recorded can vary widely due to differences in topography (Kelleher *et al.* 2001), micro-environment (Marcellos and Single 1975) and recording method (Hayman et al. 2007). To assist with early assessment of frost damage, accurate maximum–minimum field thermometers measuring temperatures at crop head height are useful. Minimum air temperatures measured at head height can be several degrees colder than temperatures measured in the Stevenson screen, as reported by the Bureau of Meteorology. For best results, a minimum of two or three field thermometers are required to give representative temperatures through a crop. In undulating country, more thermometers should be used to record temperatures at various heights in the landscape (Woodruff *et al.* 1997).

More information

GRDC Update: Frost resistance in cereals after head emergence at http://www.grdc.com.au/Research-and-Development/GRDC-Update-Papers/2011/04/Frost-resistance-in-cereals-after-heademergence

14.1.2 The effect of frost damage on different growth stages—better field identification of frost damage

Young crops

Major economic damage prior to stem elongation is uncommon (Single 1987; Woodruff *et al.* 1997). Young crops will usually regrow from damage, particularly if good follow-up rain is received (Afanasiev 1966). Rarely, very severe frosts (lower than -7°C canopy air temperature) may result in damage to the developing crown of the plant (Woodruff *et al.* 1997).

Advanced crops—not showing ears or awns

In addition to leaf and stem damage, booting crops can experience damage to developing ears. This damage usually shows as bleached sections with incomplete ear structures.

Figure 1: Frost damage prior to head-emergence.

Advanced crops—ears or awns visible

During and after ear emergence, the plant becomes much more susceptible to frost injury. In wheat, the breaking of the boot is critical for heads to become fully susceptible to frost (Livingston and Swinbank 1950; Single 1964; Afanasev 1966; Paulsen and Heyne 1983). Frost damage after head-emergence often results in severe stem and head damage, and frequently occurs at milder temperatures (crop air temperatures ~-4°C). Damage is most easily identified in the 30 mm of stem above the top node. Damaged stem tissue develops a water-soaked dark green colour before shrivelling, drying out and bleaching. If this happens, connection between the head and the rest of the plant is severed, and the head dies (Afanasiev 1966) (Figure 2).

Figure 2: Stem frosting (Woodruff et al. 1997).

Figure 3: The effect on developing grains of a severe –5.5°C frost 2 weeks after flowering.

Frosting of developing grain, after flowering, is difficult to assess. Damaged grain may continue to swell and to all outward appearances seem relatively normal. However, these damaged grains eventually dry back to shrivelled (potentially) harvestable grains, which may cause downgrading (Figure 3). To assess this damage, 7–14 days after a frost look for discoloured, shrunken, water-soaked or hollow grains that, when squeezed, exude a straw-coloured transparent, rather than milky, opaque liquid.

14.1.3 Field screening—varietal differences

Elite varieties with improved frost resistance would have a major impact on cropping in the northern grains region by reducing yield losses to frosts, and/or by allowing earlier flowering and higher yield potential. The aim of this research is to identify useful sources of post head-emergence frost resistance in winter cereals. Winter cereals are being screened using two strategies:

1. Small-scale, nationally coordinated frost trials
2. Screening diverse winter cereals for potential sources of improved post head-emergence frost resistance

Small-scale, nationally coordinated frost trials

Trials by Department of *Employment, Economic Development and Innovation* Queensland (DEEDI) provide a focus on screening methods and aim to:

- provide a framework to allow results to be compared between regions
- compare a small number of promising barley lines to wheat and barley controls
- use standardised meteorological stations at each site to characterise frost events

Results:

- Ten lines, very closely matched in flowering date, are tested at each site each year.
- There is little evidence that any of the lines consistently outperforms controls.

Screening diverse winter cereals for improved frost resistance

In addition to small-scale national trials, diverse wheat and barley types are being screened. Testing in the field is labour-intensive and expensive, but the reliability of screening in artificial freezing chambers is yet to be demonstrated. A field screening method has been refined and developed over four decades of frost research. Using this method, diverse wheat and barley lines are being assessed, with the aim of identifying new sources of resistance.

Screening results

- Screening methodologies are the key to maximising research effort—a rigorous screening method that minimises frost escapes and false positives is required.
- Method allows lines with different flowering habit (phenology) to be compared following a single frost event. This enables diverse sources for resistance to be screened.
- To date, no tested line significantly outperformed controls.

As no lines with useful levels of resistance have so far been identified, additional genotypes are being evaluated.

14.1.4 The need for a better understanding—how and when plants freeze

Given that identifying winter cereals with improved frost resistance has proven difficult, a more fundamental approach may be needed to better understand frost and frost damage.

Frost-sensitive plants, although not damaged by cold temperatures alone, show freezing damage when ice formation occurs in the tissues. These plants can supercool (without ice formation) below 0°C and avoid damage. As this supercooled water in plants freezes, a small amount of heat is released. This heat can be detected using infrared imaging and used to observe ice formation (Ceccardi *et al.* 1995; Wisniewski *et al.* 1997; Fuller and Wisniewski 1998). Research has shown that infrared thermal imaging can be used to observe freezing in wheat under field conditions (Figure 4). It is hoped that with a better understanding of how and when plants freeze, better strategies or varieties to minimise frost damage can be identified.

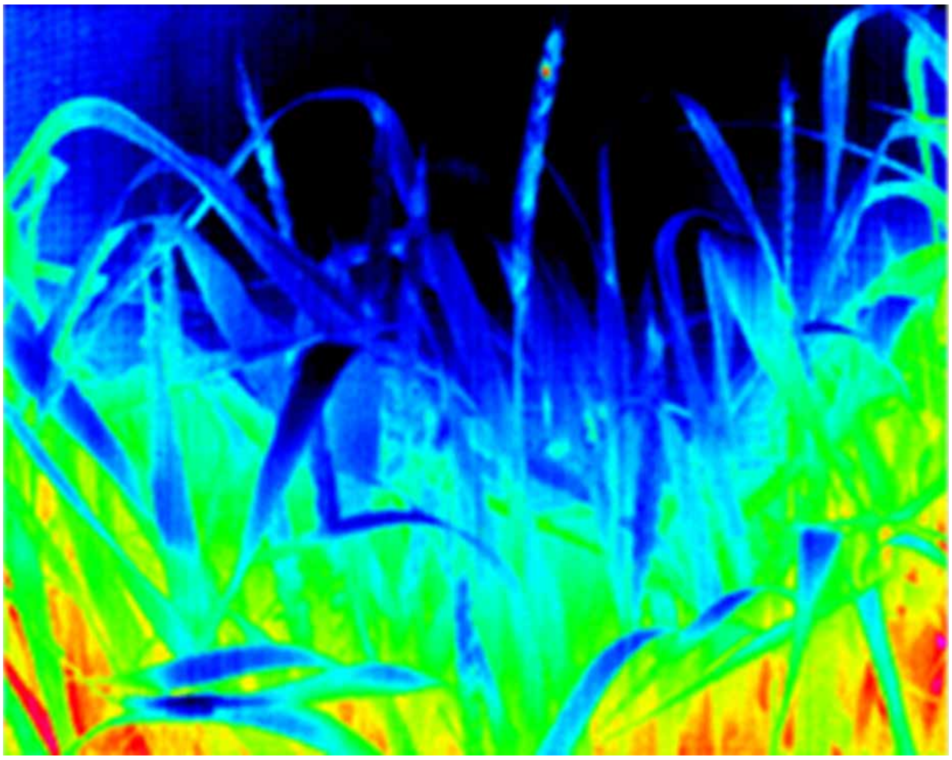

Figure 4: Artificially coloured infrared image (coldest dark blue, through blue, green, yellow, and red for the warmest), 16 July 2010, showing an individual wheat floret freezing. The freezing floret is coloured red and indicated with an arrow.

Figure 5: Infrared camera observing wheat row as shown in Figure 4.

Sowing dates

The GRDC-supported Barley Agronomy and Variety Specific Agronomy Projects are conducting sowing time trials for wheat and barley at Trangie and Condobolin. Up to 40 varieties, including all recent releases and advanced lines, have been sown at three or four sowing dates, and measurements taken include flowering time, biomass, tiller number, yield and grain quality.

Based on these 4 years of trials, it is recommended to sow barley from early to mid-May. Within this range, sowing date decisions need to be based on specific variety choice. Hindmarsh⦶ has yielded best from early May sowing dates, even when flowering occurs in late August. Commander⦶ has performed just as well from a mid-May sowing date as an early May sowing date, not necessarily because of reduced frost exposure from the later sowing, but more that the later sowing of Commander⦶ has a reduced lodging risk and reduced vegetative growth.

Agronomic management recommendations for Hindmarsh⦶ and Commander⦶ are also quite different. Hindmarsh⦶ responds favourably to high plant populations (100–150 plants/m^2) and early nitrogen applications, whereas the target plant population of Commander⦶ should be moderate (~80 plants/m^2). Early nitrogen application to Commander⦶ may lead to increased lodging.

The relatively lower grain protein of Commander⦶ may be an advantage where nitrogen levels are high; however, with declining soil nitrogen levels in northern NSW, Commander⦶ may be less likely to achieve the required 9% threshold for malting grades. This highlights the importance of soil testing at least a few paddocks each year to make sound nitrogen decisions.

While not compared experimentally, this barley time-of-sowing trial was adjacent to the 2012 wheat time of sowing trial. The average yield of the barley trial was 4.2 t/ha, compared with 3.2 t/ha in the wheat trial. Again, this highlights the risk-management benefits of barley, i.e. its ability to maintain relatively high yield in a tight finish. [4]

In agronomy trials conducted in 2014 as part of the Southern Barley Agronomy Project, with sites from Gerogery in the south, to Lockhart, Matong, Condobolin and Parkes in

[4] R Brill, Sowing time response of 15 barley varieties—Trangie 2012, NSW DPI Coonamble. http://www.dpi.nsw.gov.au/__data/assets/pdf_file/0004/468328/Northern-grains-region-trial-results-autumn-2013.pdf

A 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18

the north, and National Variety Trials (NVT) across the region, barley performed relatively well in the frosty winter and dry spring of that year.

Early sowing of fast developing barley varieties reduced yield as a result of frost; however this effect was much less pronounced compared with wheat.

There were differences in the performance of barley varieties across the southern region. Hindmarsh and La Trobe are most suited to low-medium rainfall zones with a sowing time of early to mid-May. Compass has performed consistently well across all rainfall zones and is only slightly slower to flower than Hindmarsh, so sowing date should be similar. Fathom also performed consistently well but is a feed only variety. Longer season varieties such as GrangeR and Oxford performed well in the higher yielding environments but were generally significantly lower yielding than faster varieties in drier environments.

These trials showed the benefits to grain yield of targeting populations of 150 plants/m^2 across all rainfall zones. [5]

14.2 Soil moisture issues for barley

Availability of soil moisture has major interactions with the rate of transpiration and therefore photosynthetic production.

14.2.1 Moisture stress

Moisture stress slows photosynthesis and leaf area expansion, reducing dry matter production. It also limits root growth, which reduces nutrient uptake. This is important in areas with low rainfall. The period of crop growth is restricted at the start of the season by lack of rainfall and at the end of the season by water deficits and high temperatures. There is therefore little scope in these areas to lengthen the period of crop growth to increase dry matter production and yields. [6]

14.2.2 Waterlogging

Barley is very susceptible to waterlogging. It is less tolerant than wheat or oats. Barley should not be grown on soils where waterlogging is likely to occur for periods of more than 2 weeks, or on irrigation layouts with poor drainage.

Waterlogging occurs when rainfall exceeds the infiltration rate, water-holding capacity, and internal drainage rate of the soil profile. Waterlogging fills the air spaces of the soil with water, reducing the oxygen concentration. This limits root function and survival, resulting in decreased crop growth or plant death. Availability of nitrogen and other nutrients may also be reduced. The lack of nutrients slows the rate of leaf growth and accelerates leaf death. Tiller initiation is also slowed, reducing the growth and survival of tillers. These conditions contribute to yield reductions. The amount of reduction depends on the stage of plant development when the waterlogging occurs, the duration of the waterlogging, and the soil quality. [7]

More information

GRDC Update: A snapshot of wheat and barley agronomy trials in the northern grains region of NSW at http://www.grdc.com.au/Research-and-Development/GRDC-Update-Papers/2013/02/A-snapshot-of-wheat-and-barley-agronomy-trials-in-the-northern-grains-region-of-NSW

Impact of sowing time and varietal tolerance on yield loss to the root-lesion nematode Pratylenchus thornei at http://www.dpi.nsw.gov.au/__data/assets/pdf_file/0007/431287/Nematodes-and-sowing-date-2011.pdf

Northern Grains Region Trial Results, Autumn 2013 at http://www.dpi.nsw.gov.au/agriculture/broadacre/guides/ngrt-results

5 Barley agronomy in southern NSW: https://www.grdc.com.au/Research-and-Development/GRDC-Update-Papers/2015/02/Barley-agronomy-in-southern-NSW

6 Industry & Investment NSW agronomists (2010), Barley growth & development, PROCROP Series, Industry & Investment NSW. http://www.dpi.nsw.gov.au/__data/assets/pdf_file/0003/516180/Procrop-barley-growth-and-development.pdf

7 Industry & Investment NSW agronomists (2010), Barley growth & development, PROCROP Series, Industry & Investment NSW. http://www.dpi.nsw.gov.au/__data/assets/pdf_file/0003/516180/Procrop-barley-growth-and-development.pdf