NORTHERN
OCTOBER 2016

GRDC™
GROWNOTES™

GRDC™
GRAINS RESEARCH & DEVELOPMENT CORPORATION

DURUM

SECTION 14

ENVIRONMENTAL ISSUES

FROST RESISTANCE IN CEREALS AFTER HEAD EMERGENCE | WATERLOGGING/ FLOODING ISSUES | HEAT STRESS

SECTION 14

Environmental issues

More information

[B Zheng, S Chapman, J Christopher, T Frederiks, K Chenu (2015), Predicting heading date and frost impact in wheat across Australia.]

[K Barlow, B Christy, G O'Leary, J Nuttall (2015), Modelling the impact of frost on wheat production in Australia.]

14.1 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 Wheat can be affected when the canopy air temperature reaches -3.5°C (D Woodruff unpublished data), with damage increasing as the temperature falls further. 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 that heading and grain development occur when warmer temperatures prevail. Unfortunately, this delay increases the likelihood of drought and high temperatures during grain-filling, 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. Optimum flowering time and maximised yields are achieved, in the long term, when a compromise between the effects of frost and drought is reached.

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 and temperature. The crop temperatures experienced and recorded can vary widely due to differences in topography, micro-environment and recording method. 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 crop head height can be several degrees colder than temperatures measured in the Stevenson screen, as reported by the Bureau of Meteorology. For best results, at least two or three field thermometers are required to give representative temperatures throughout a crop. In undulating country, more thermometers should be used at various heights in the landscape (Woodruff *et al.* 1997). [1]

[1] T Frederiks, C Birchall, J Christopher, A Borrell (2011) Frost resistance in cereals after head-emergence. GRDC Update Papers 14 April 2011, http://www.grdc.com.au/Research-and-Development/GRDC-Update-Papers/2011/04/Frost-resistance-in-cereals-after-heademergence

14.1.1 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. Young crops will usually regrow from damage, particularly if good follow-up rain is received [2]. Rarely, very severe frosts (lower than -7°C canopy air temperature) may result in damage to the developing crown of the plant. [3]

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). [4]

Figure 1: Frost damage prior to head-emergence.

[2] M Afanasev 1966. Frost injury in wheat. Plant Disease Reporter 50, 929–930

[3] T Frederiks, C Birchall, J Christopher, A Borrell (2011) Frost resistance in cereals after head-emergence. GRDC Update Papers 14 April 2011, http://www.grdc.com.au/Research-and-Development/GRDC-Update-Papers/2011/04/Frost-resistance-in-cereals-after-heademergence

[4] T Frederiks, C Birchall, J Christopher, A Borrell (2011) Frost resistance in cereals after head-emergence. GRDC Update Papers 14 April 2011, http://www.grdc.com.au/Research-and-Development/GRDC-Update-Papers/2011/04/Frost-resistance-in-cereals-after-heademergence

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. Frost damage after head-emergence often results in severe stem and head damage, and frequently occurs at milder temperatures. 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, later shrivelling, drying out and bleaching. If this happens, connection between the head and the rest of the plant is severed, and the head dies [5] (Figure 2).

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

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 down grading (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. [6]

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

More information

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

5 M Afanasev 1966. Frost injury in wheat. Plant Disease Reporter 50, 929–930

6 T Frederiks, C Birchall, J Christopher, A Borrell (2011) Frost resistance in cereals after head-emergence. GRDC Update Papers 14 April 2011, http://www.grdc.com.au/Research-and-Development/GRDC-Update-Papers/2011/04/Frost-resistance-in-cereals-after-heademergence

14.1.2 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 [7]

Trials by the (former) 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 with 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 line consistently outperforms controls. [8]

In addition to small-scale national trials, diverse wheat and barley types are being screened. Testing in the field is labour-intensive and expensive; however, the reliability of screening in artificial freezing chambers is yet to be demonstrated. A field screening method has been refined and developed over more than 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 key to maximising research effort—a rigorous screening method is required that minimises frost escapes and false positives.
- The method allows lines with different flowering habit (phenology) to be compared following a single frost event, enabling 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. [9]

---

7 T Frederiks, C Birchall, J Christopher, A Borrell (2011) Frost resistance in cereals after head-emergence. GRDC Update Papers 14 April 2011, http://www.grdc.com.au/Research-and-Development/GRDC-Update-Papers/2011/04/Frost-resistance-in-cereals-after-heademergence

8 T Frederiks, C Birchall, J Christopher, A Borrell (2011) Frost resistance in cereals after head-emergence. GRDC Update Papers 14 April 2011, http://www.grdc.com.au/Research-and-Development/GRDC-Update-Papers/2011/04/Frost-resistance-in-cereals-after-heademergence

9 T Frederiks, C Birchall, J Christopher, A Borrell (2011) Frost resistance in cereals after head-emergence. GRDC Update Papers 14 April 2011, http://www.grdc.com.au/Research-and-Development/GRDC-Update-Papers/2011/04/Frost-resistance-in-cereals-after-heademergence

14.1.3 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 improve understanding of 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. Infrared thermal imaging was successfully 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. [10]

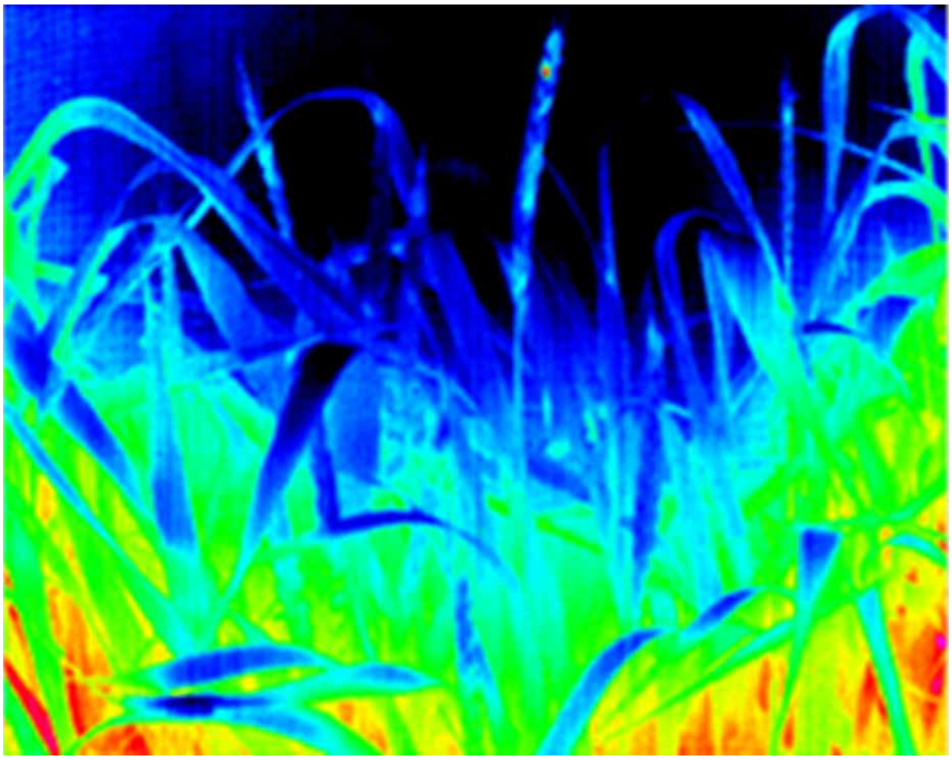

Figure 4: Artificially coloured infrared image (coldest dark blue, through blue, green, yellow, and red for warmest), 16 July 2010, showing an individual wheat floret freezing.

14.2 Waterlogging/flooding issues

14.2.1 Winter cereals pathology

Three drivers influence the incidence of plant disease:

- the host
- the environment
- the pathogen

Aspects of the host promoting disease are the growing of susceptible crop varieties, and widespread and sequential sowings of hosts susceptible to specific pathogens.

[10] T Frederiks, C Birchall, J Christopher, A Borrell (2011) Frost resistance in cereals after head-emergence. GRDC Update Papers 14 April 2011, http://www.grdc.com.au/Research-and-Development/GRDC-Update-Papers/2011/04/Frost-resistance-in-cereals-after-heademergence

The environment influences disease incidence through moisture, both the frequency and duration of events, temperature and wind.

For disease to occur, the pathogen must have virulence to the particular variety, inoculum must be available and easily transported, and favourable conditions are needed for infection and disease development. [11]

Legacy of the floods and rain

The legacy of the floods and rain included transport of inoculum (crown rot, nematodes, leaf spots through movement of infected stubble and soil), development of sexual stages (leaf spots, head blights), survival of volunteers (unharvested material and self-sown plants in double-crop situations) and weather-damaged seed. Cereal diseases that need living plants over-season on volunteer (self-sown) crops; this particularly applies to rusts and mildews. Diseases such as yellow spot, net blotches and head blights survive on stubble. Crown rot and nematodes over-season in soil.

Problems are recognised through inspection of plants. Leaf and stem rusts produce visible pustules on leaves, while stripe rust survives as dormant mycelium with spores not being produced until temperatures favour disease development. Presence of leaf spots is recognised by the presence of fruiting bodies (pseudothecia) on straw and lesions on volunteers. Head blights produce fruiting bodies (perithecia) on straw, whereas crown rot survives mainly as mycelium in straw. Soil-borne nematodes are detected through soil tests.[12]

Management options

Management options for disease control include elimination of volunteers, if possible producing a 4-week period that is totally host-free, crop rotation with non-hosts, growing resistant varieties, reduction of stubble, and fungicides.

Fungicides are far more effective as protectants than as eradicants, so are best applied prior to, or very soon after, infection. Systemic fungicides work within the sprayed leaf, providing 3–5 weeks of protection. Leaves produced after this spraying are not protected. Spray to protect the upper three or four leaves, which are the most important as they contribute to grain-fill. In general, rusts are easier to control than leaf spots. Fungicides do not make yield; they can only protect the existing yield potential.

The application of fungicides is an economic decision, and in many cases, a higher application rate can give a better economic return through greater yield and higher grain quality. Timing and rate of application are more important than product selection. Bear in mind that stripe rust ratings in variety guides are for adult plant response to the pathogen, and may not accurately reflect seedling response. [13]

Strategies

The incidence and severity of disease will depend on the environment, but with known plentiful inoculum present, even in a season with average weather, disease risks will be significant.

Strategies include:

- using the best available seed
- identifying your risks
- formulating management strategies based on perceived risk

11 DAFF (2013) Winter cereals pathology. Department of Agriculture, Fisheries and Forestry Queensland, http://www.daff.qld.gov.au/plants/field-crops-and-pastures/broadacre-field-crops/prepare-for-winter-crops-following-floods/winter-cereals-pathology

12 DAFF (2013) Winter cereals pathology. Department of Agriculture, Fisheries and Forestry Queensland, http://www.daff.qld.gov.au/plants/field-crops-and-pastures/broadacre-field-crops/prepare-for-winter-crops-following-floods/winter-cereals-pathology

13 DAFF (2013) Winter cereals pathology. Department of Agriculture, Fisheries and Forestry Queensland, http://www.daff.qld.gov.au/plants/field-crops-and-pastures/broadacre-field-crops/prepare-for-winter-crops-following-floods/winter-cereals-pathology

- monitoring crops regularly
- timely intervention with fungicides [14]

14.2.2 Nutritional and structural impact of flooding on soil

A temporary loss of soil structure prevents clay particles from aggregating and forming channels for water infiltration, so despite flooding, some soil moisture profiles are not full as might be expected. This reduction in infiltration is also affected by which crop was grown most recently, with persistent roots forming channels in the soil, aiding water entry. Cultivation, either prior to or during planting of the next crop, will help break up surface crusting.

Flooding has also affected nutrient levels. Flooding and long periods of waterlogging have resulted in the depletion of nutrients. Nitrogen (N) levels are very low in many soils tested. Soil testing has shown that N has been lost throughout the entire soil profile in many cases. It appears to have been denitrified and lost from the system. Very little has been leached through the profile and deposited at depth. [15]

Implications for following seasons

The implications for the coming season are that it is not a typical season in which growers could use historical information, cropping history and experience to develop fertiliser programs. Soil testing will be a very important management tool this season to ensure that crop nutritional demands are adequately met. Crops will also need to be monitored through the production period for signs of nutrient stress. [16]

Soil testing

Ideally, soil testing should be performed at the same place each time, and on the dominant soil type of the paddock. In most years, this information, combined with yield and protein levels, will guide N requirements, but the coming year is very different. Placement of N fertiliser is important, with application on alternate rows close to planting time being a good option. [17]

14.2.3 Soil erosion and waterlogging due to flooding

According to satellite images, over 100,000 ha of land was inundated from the Condamine River due to flooding in early 2011. The river was 7 km wide at the widest point. There has been significant damage on riverbanks as a result, but in general perhaps less erosion than might be expected. This is probably due to:

- increased use of no-till and summer cropping
- wet conditions leading up to the major flood event, resulting in green cover
- the protective effects of 'failed', unharvested winter crops

In some cases, contour banks were poorly maintained due to years of drought conditions.[18]

[14] DAFF (2013) Winter cereals pathology. Department of Agriculture, Fisheries and Forestry Queensland, http://www.daff.qld.gov.au/plants/field-crops-and-pastures/broadacre-field-crops/prepare-for-winter-crops-following-floods/winter-cereals-pathology

[15] DAFF (2013) Nutritional and structural impact of flooding on soil. Department of Agriculture, Fisheries and Forestry Queensland, http://www.daff.qld.gov.au/plants/field-crops-and-pastures/broadacre-field-crops/prepare-for-winter-crops-following-floods/nutritional-and-structural-impact-of-flooding-on-soil

[16] DAFF (2013) Nutritional and structural impact of flooding on soil. Department of Agriculture, Fisheries and Forestry Queensland, http://www.daff.qld.gov.au/plants/field-crops-and-pastures/broadacre-field-crops/prepare-for-winter-crops-following-floods/nutritional-and-structural-impact-of-flooding-on-soil

[17] DAFF (2013) Nutritional and structural impact of flooding on soil. Department of Agriculture, Fisheries and Forestry Queensland, http://www.daff.qld.gov.au/plants/field-crops-and-pastures/broadacre-field-crops/prepare-for-winter-crops-following-floods/nutritional-and-structural-impact-of-flooding-on-soil

[18] DAFF (2013) Soil erosion and waterlogging due to flooding. Department of Agriculture, Fisheries and Forestry Queensland, http://www.daff.qld.gov.au/plants/field-crops-and-pastures/broadacre-field-crops/prepare-for-winter-crops-following-floods/soil-erosion-and-waterlogging-due-to-flooding

Preventing future damage

A number of approaches can be used to prevent damage in the future. Contours running down a hill generally spread the flow of water and reduce flow rates, although with the intensity of the flooding this year, that was not always the case. Wheel tracks can be used like raised beds to assist drainage. These wheel tracks need to be maintained and managed for effectiveness. Wide tyres for spraying and tracks for harvesters and tractors are options to reduce compaction.

14.2.4 Weed management following floods

Floodwater affects soil, stubble/trash, weed seed and plant movement. Differences may have been seen between conventional and minimum tillage farming systems due to differences in ground cover, soil type and, ultimately, intensity of floodwater. Because of flooding, growers might expect to see new weed incursions and removal of topsoil.

New weeds could be species not previously seen on a property, or new species in specific fields from other fields or non-cultivated areas. There is also the potential for the introduction and movement of herbicide-resistant weeds. The removal of topsoil could lead to the exposure of previously buried seed and, hence, the resurrection of buried problems. It is hard to predict where weed seeds will settle, but a concentration is likely where water and trash have settled. [19]

Potential problem weeds

A number of specific weed species are likely to be a problem in some areas. Potential problem winter weeds include fleabane and sowthistle, which may have been seeding at the time of the floods and may be establishing now.

Potential problem winter grasses include wild oats and paradoxa grass, which may have set seed prior to floods and may be buried in soil. Winter hard-seeded broadleaf species such as buckwheat that may have previously been buried may now be exposed.

Potential problem summer weeds also include fleabane and sowthistle, which in recent years have become nearly year-round problems.

Problem summer grasses (e.g. awnless barnyard grass and feathertop Rhodes grass) were likely to have been seeding at the time of the floods and existing seed may have moved. Hard-seeded summer broadleaves include bladder ketmia, peachvine and bindweed, and previously buried seed may now be exposed.

Species of weeds in which herbicide resistance has been identified in the northern agricultural region include wild oats, sowthistle, fleabane, barnyard grass and liverseed grass. The problem is not currently widespread. [20]

Implications for the coming season

The implication for the coming season is that integrated weed management principles still apply. These principles include diligent monitoring, targeting small weeds with robust rates of herbicide, rotating herbicides with different modes of action, and preventing seed-set and seed-bank replenishment. This approach will prevent herbicide resistance from becoming a problem.

For cropping, aim for a clean start with effective knockdown control (e.g. using a 'double-knock' strategy). Use residual herbicides to minimise in-crop weed emergences. To control weeds in-crop, grow a competitive crop and use correct application and timing of in-crop herbicides. Stop seed-set on survivors after harvest.

[19] DAFF (2011) Weed management following floods. Department of Agriculture, Fisheries and Forestry Queensland, http://www.daff.qld.gov.au/plants/field-crops-and-pastures/broadacre-field-crops/prepare-for-winter-crops-following-floods/weed-management-following-floods

[20] DAFF (2011) Weed management following floods. Department of Agriculture, Fisheries and Forestry Queensland, http://www.daff.qld.gov.au/plants/field-crops-and-pastures/broadacre-field-crops/prepare-for-winter-crops-following-floods/weed-management-following-floods

More information

Weed management in field crops for information about managing summer grasses, managing fleabane and sowthistle, and herbicide resistance: http://www.daff.qld.gov.au/plants/field-crops-and-pastures/broadacre-field-crops/weed-management-in-field-crops

More information

J Watson, B Zheng, S Chapman, K Chenu (2015), Impact of projected climates on drought occurrence in the Australian wheatbelt.

In fallows, weed seedlings should be effectively controlled with robust herbicide rates and/or a double-knock strategy. An early application of a residual herbicide will minimise subsequent flushes. Be diligent in control of survivors of herbicide applications.

In non-crop areas, seed may have been captured around fence lines and sheds and these may become sources of ongoing infections. Monitor these areas and stop seed set. [21]

14.3 Heat stress

Heat is a key abiotic stress. The effects of heat on grain yield are equally as important as drought and frost. Varieties that are better adapted also generally perform better in heat-stress conditions.

Heat-stress affects crop and cereal production in all regions of the Australian wheatbelt. It can have significant effects on grain yield and productivity, with potential losses equal to, and potentially greater than, other abiotic stress such as drought and frost. Controlled environment studies have established that a 3–5% reduction in grain yield of wheat can occur for every 1°C increase in average temperature above 15°C. Field data suggest that yield losses can be in the order of 190 kg/ha for every 1°C rise in average temperature, in some situations having a more severe effect on yield loss than water availability.

The reproductive stages of growth have greater sensitivity to elevated temperatures, with physiological responses including premature leaf senescence, reduced photosynthetic rate, reduced seed set, reduced duration of grain-fill, and reduced grain size, all ultimately leading to reduced grain yield. Such elevated temperatures are a normal, largely unavoidable occurrence during the reproductive phase of Australian crops in September and October. [22]

[21] DAFF (2011) Weed management following floods. Department of Agriculture, Fisheries and Forestry Queensland, http://www.daff.qld.gov.au/plants/field-crops-and-pastures/broadacre-field-crops/prepare-for-winter-crops-following-floods/weed-management-following-floods

[22] P Telfer, J Edwards, H Kuchel, J Reinheimer, D Bennett (2013) Heat stress tolerance of wheat. GRDC Update Papers 7 February 2013, http://www.grdc.com.au/Research-and-Development/GRDC-Update-Papers/2013/02/Heat-stress-tolerance-of-wheat