**Evaluation of the frost tolerance of triticale varieties and other winter cereals at flowering**

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**Abstract**

Frost damage of winter crops during flowering and grain fill costs the Australian grain industry an estimated $100 million per year. Much of the current frost research aims to find sources of tolerance to frost damage to allow breeders to develop plants with increased frost tolerance. The objective of this trial was to determine if there was any difference in frost tolerance between eight triticale varieties, and how triticale compared to three other winter cereals. Individual plants were grown in pots in a glasshouse through to maturity. At flowering (?5 days), plants were exposed to a single overnight frost event outside the glasshouse between June and August 2009, with the temperature of these events varying from 0.2?C to -6.6?C at head height. After plants were grown to maturity, damage was assessed by counting the number of developed grains in the first two florets of each spikelet. Barley showed a higher tolerance to frost than wheat and triticale. Variation in tolerance between individual triticale varieties was also evident, suggesting there is potential for both breeders and farmers to reduce the frost susceptibility of this crop.

**Key Words**

Spring radiation frost, reproductive stage

**Introduction**

Temperature extremes are one of the main abiotic stresses that constrain winter cereal production throughout the world. Low temperatures caused by radiation frosts in spring are of particular importance in the grain growing regions in Australia (Frederiks et al. 2004), the Mediterranean region and South America (Shroyer et al. 1995). Radiation frosts occur when the night temperature falls below zero under conditions of clear skies, calm cold air, dry atmospheric conditions and temperature inversions. Frost is estimated to cause a 10% reduction in long term average yields even under the best management practices (Frederiks et al. 2004), costing around AU$ 50-100 million per year in the northern grain region of Australia (Frederiks et al. 2008). The practice of delaying sowing to reduce frost risk also has costs, with yields being reduced when the crop flowers in the hotter and drier conditions of late spring (Frederiks et al. 2004). Crop yields could be increased if frost damage could be reduced as better yields can be obtained when crops flower earlier with more favourable moisture and temperature regimes (Woodruff and Tonks 1983).

Knowing the relative frost tolerance of different varieties and crops is important for both breeding programs and farmers. However, there have been few varieties identified as having any advantage. Partly, this is because assessment is difficult due to differences in crop phenology, canopy development, experimental methods and genotype x environment interaction. However, even a broader classification of species tolerance is uncertain, with Synder and Melo-Abreu (2005) reporting that frost resistance was in the order of rye > bread wheat > triticale > barley > oats and durum wheat, while Rebbeck et al. (2007) reported that triticale is the most susceptible crop followed by wheat, barley, rye and oats.

The objective of this study was to determine if there were differences in the frost tolerance of a range of triticale varieties during flowering, and to compare the frost tolerance of triticale with wheat and barley.

## Methods

*Plant materials*

Three seeds of each variety to be tested were sown into pots (7.5 x 7.5cm x 20cm deep) containing a grey vertosol, and thinned to one plant after emergence. Twelve pots of each variety were sown weekly over a 5 week period from March 30th, 2009 to generate a wide spread of flowering times. Varieties being tested included 8 lines of triticale (X *Triticosecale* Wittmack *cv.* Bogong, Tahara, H20, H151, H418, H426, JRCT74, and JRCT400), 2 of bread wheats (*Triticum aestivum* L. *cv.* Kite and Ventura), one durum wheat (*Triticum turgidum* L. *cv.* Bellaroi) and one barley (*Hordeum vulgare* L. *cv* Kaputar).

Plants were grown until maturity in a naturally lit glasshouse at the University of New England, Armidale, with temperatures of 20/10?C (day/night). Tillers were tagged when the emergence of the top spikelet on each head was observed, and the number of days to anthesis monitored for each variety. Anthesis generally occurred 14 days after emergence of the top spikelet for triticale, 10 days for wheat, and at emergence for barley.

*Frosting treatments*

Frost treatments were imposed when sufficient plants within ?5 days of anthesis were available, and when temperatures were forecast to fall below 0?C overnight. Selected plants were taken to an open paddock at 5pm and spaced approximately 40cm apart to allow free air flow and avoid the influence of a thick crop canopy. The pots were buried to prevent freezing of the roots, and plants with weak stems loosely tied to bamboo stakes to prevent lodging. Four Thermocron iButton DS1922L temperature loggers recorded temperatures at 60 and 110cm above the ground at 10 minute intervals, with the minimum temperature for the night at 110cm being averaged to determine floret exposure to frost. Plants were returned to the glasshouse at 9am and grown to maturity. Frost damage was then assessed by counting grains set in the lowest two florets of each spikelet. Data was analysed in R using a generalised linear model with quasibinomial distribution.

## Results and Discussion

Plants were exposed to one of six frost events between 24th June and 14th August, with measured temperatures of -6.6, -4.2, -3.5, -1.9, -1.7, and 0.2?C. The minimum temperature measured in the glasshouse controls was 8?C. The -6.6?C frost killed all plant shoots overnight. Analysis of the results found no significant influence of temperature on floret survival for the -1.9?C or warmer frosts (data not presented), so the results presented below compare the effects seen in the -4.2, -3.5?C and control treatments only. The temperature profile during the night for each frost event is shown in Figure 2.

*Frost tolerance of crop types*

Barley was found to be much more tolerant of low temperatures than wheat or triticale (Table 1), with the -4.2?C frost having little effect on barley floret survival while wheat and triticale survival were severely reduced. Analysis found significant effects ($P<0.001$) for temperature, crop type, head height, and ($P<0.05$) crop x temperature interaction. Unfortunately, the difference in head height between the crop types (Table 1) confounds this analysis as the difference in survival may be due to the different temperatures at the different head heights. The temperature at 60cm was 0.4 and 0.1?C cooler than 110cm for the -4.2 and -3.5?C frosts respectively. While this prevents any conclusion being made on the relative frost tolerance of wheat and triticale, it does support published results showing that barley is more tolerant than the other crops (Rebbeck et al. 2007).

**Table 1. Floret survival and height of winter cereals in different frost treatments.**

| Species | Frost | Floret survival | Height |
|---|---|---|---|

| | Temperature (°C) | (%) | (cm) |
|---|---|---|---|
| Wheat | 8.0 | 96.8?2.0 | 74.3?1.6 |
| | -3.5 | 73.1?6.0 | 66.9?2.8 |
| | -4.2 | 0.0?0.0 | 64.3?2.5 |
| Triticale | 8.0 | 95.9?0.4 | 106.7?0.8 |
| | -3.5 | 89.0?1.3 | 107.5?1.8 |
| | -4.2 | 6.1?1.6 | 102.9?1.5 |
| Barley | 8.0 | 95.3?2.0 | 59.5?1.7 |
| | -3.5 | 94.5?3.2 | 59.3?1.7 |
| | -4.2 | 83.6?5.2 | 61.4?1.2 |

*Frost tolerance of triticale varieties*

The analysis of floret survival at each temperature found significant differences between varieties (Figure 1), but no effect of height. This could be because the varieties are similar in height, and possibly because they were all taller than 80cm, which appeared to be where height had no effect on floret survival for Bellaroi in the -3.5?C treatment (data not shown). There was also no obvious trend between floret survival and stage of development within the treatment window (anthesis ?5 day) for any variety.

Variety H20, followed by JRCT400, had the highest floret survival in the -4.2°C treatment, while H418 was the worst with no florets surviving. H20 and JRCT400 were also the best performing varieties in the -3.5?C treatment, supporting the idea that they may be more tolerant than the other triticale varieties. Bogong and H151 were not included in the -3.5?C treatment as no plants were at anthesis during that frost.

These results are encouraging and suggest there may be variation in frost tolerance between different triticale varieties. While these differences are small, they suggest there is potential to increase triticale frost tolerance by screening germplasm within breeding programs. However, this trial needs to be repeated with temperatures around the -3.8 to -4?C level, when floret survival is around the 50% level, to provide a greater ability to discriminate between varieties, and to confirm these results.

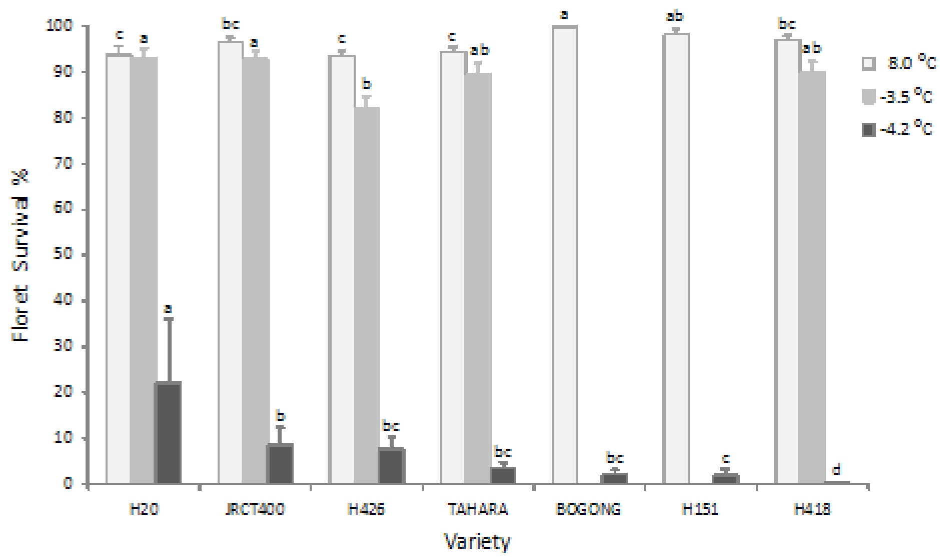


**Figure 1. Floret survival in different varieties of triticale in different frost treatments. Columns with different letters within a frost treatment are significantly different (P<0.05).**

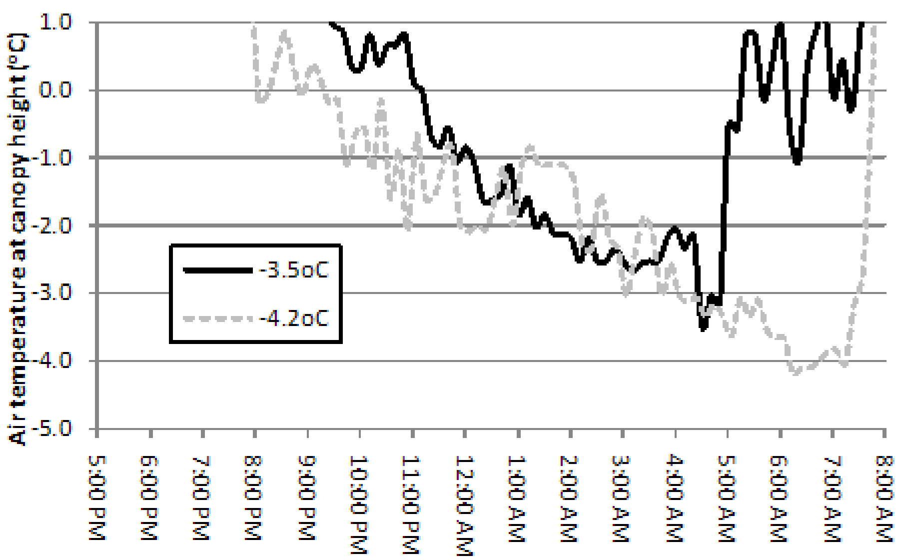


**Figure 2. Measured air temperature during the night for each frost event.**

## Conclusion

This study found differences in the frost tolerance of the triticale varieties tested, and between the different winter cereals, with barley being more tolerant of frost than wheat or triticale. If confirmed, these varietal differences could be useful in breeding programs, and in the selection of varieties by farmers.


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**References**


Frederiks TM, Christopher JT and Borrell AK (2004). Investigation of post head-emergence frost resistance in several CIMMYT synthetic and Queensland wheats. Proceedings of the 4th International Crop Science Congress, Brisbane, Australia. www.cropscience.org.au/icsc2004/poster/3/6/.../1403_frederikstm.htm. Accessed 1 March 2010.

Frederiks TM, Christopher JT and Borrell AK (2008). Low temperature adaption of wheat post head-emergence in northern Australia. The 11th International Wheat Genetics Symposium, Sydney University Press.

Rebbeck M, Knell G and Duffield T (2007). Identifying frost damage in wheat crops. In Managing frost risk: A guide for Southern Australian Grains. Eds D Reuter- Reuter and Associates. pp. 39-45, SARDI and GRDC.

Shroyer JP, Mikesell ME and Paulsen GM (1995) Spring Freeze Injury to Kansas Wheat. Kansas State University.

Single W and Marcellos H (1974). Studies on frost injury to wheat. IV. Freezing of ears after emergence from the leaf sheath. Australian Journal of Agriculture Research 25, 679–686.

Snyder RL and Paulo de Melo-Abreu J (2005). Frost protection: fundamentals, practice, and economics. Rome, Food and Agriculture Organization of the United Nations.

Woodruff DR and Tonks J (1983). Relationship between time of anthesis and grain yield of wheat genotypes with differing developmental patterns. Australian Journal of Agriculture Research 34, 1-11.